MySQL Reference Manual

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1 General Information

The MySQL ® software delivers a very fast, multi-threaded, multi-user, and robust SQL (Structured Query Language) database server. MySQL Server is intended for mission-critical, heavy-load production systems as well as for embedding into mass-deployed software. MySQL is a trademark of MySQL AB.

The MySQL software is Dual Licensed. Users can choose to use the MySQL software as an Open Source/Free Software product under the terms of the GNU General Public License (http://www.gnu.org/licenses/) or can purchase a standard commercial license from MySQL AB. See Section 1.4 [Licensing and Support], page 15.

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

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

- For information about the company behind the MySQL Database Server, see Section 1.3 [MySQL AB Overview], page 11.
- For a discussion about the capabilities of the MySQL Database Server, see Section 1.2.2 [Features], page 5.
- For installation instructions, see Chapter 2 [Installing], page 56.
- For tips on porting the MySQL Database Software to new architectures or operating systems, see Appendix E [Porting], page 1006.
- For information about upgrading from a Version 4.0 release, see Section 2.5.1 [Upgrading-from-4.0], page 110.
- For information about upgrading from a Version 3.23 release, see Section 2.5.2 [Upgrading-from-3.23], page 113.
- For information about upgrading from a Version 3.22 release, see Section 2.5.3 [Upgrading-from-3.22], page 116.
- For a tutorial introduction to the MySQL Database Server, see Chapter 3 [Tutorial], page 157.
- For examples of SQL and benchmarking information, see the benchmarking directory ('sql-bench' in the distribution).
- For a history of new features and bug fixes, see Appendix D [News], page 889.
- For a list of currently known bugs and misfeatures, see Section 1.7.6 [Bugs], page 44.
- For future plans, see Section 1.8 [TODO], page 49.
- For a list of all the contributors to this project, see Appendix C [Credits], page 878.

Important:

Reports of errors (often called bugs), as well as questions and comments, should be sent to the general MySQL mailing list. See Section 1.6.1.1 [Mailing-list], page 25. See Section 1.6.1.3 [Bug reports], page 27.

The mysqlbug script should be used to generate bug reports on Unix. (Windows distributions contain a file 'mysqlbug.txt' in the base directory that can be used as a template for a bug report.)

For source distributions, the `mysqlbug` script can be found in the '`scripts`' directory. For binary distributions, `mysqlbug` can be found in the '`bin`' directory ('`/usr/bin`' for the `MySQL-server` RPM package).

If you have found a sensitive security bug in `MySQL Server`, you should send an e-mail to `security@mysql.com`.

1.1 About This Manual

This is the `MySQL` reference manual; it documents `MySQL` up to Version 4.1.1-alpha. Functional changes are always indicated with reference to the version, so this manual is also suitable if you are using an older version of the `MySQL` software (such as 3.23 or 4.0-production). There are also references for version 5.0 (development).

Being a reference manual, it does not provide general instruction on `SQL` or relational database concepts.

As the `MySQL Database Software` is under constant development, the manual is also updated frequently. The most recent version of this manual is available at `http://www.mysql.com/documentation/` in many different formats, including HTML, PDF, and Windows HLP versions.

The primary document is the Texinfo file. The HTML version is produced automatically using a modified version of `texi2html`. The plain text and Info versions are produced with `makeinfo`. The PostScript version is produced using `texi2dvi` and `dvips`. The PDF version is produced with `pdftex`.

If you have a hard time finding information in the manual, you can try our searchable version at `http://www.mysql.com/doc/`.

If you have any suggestions concerning additions or corrections to this manual, please send them to the documentation team at `docs@mysql.com`.

This manual was initially written by David Axmark and Michael (Monty) Widenius. It is now maintained by the MySQL Documentation Team, consisting of Arjen Lentz, Paul DuBois and Stefan Hinz. For the many other contributors, see Appendix C [Credits], page 878.

The copyright (2003) to this manual is owned by the Swedish company `MySQL AB`. See Section 1.4.2 [Copyright], page 16.

1.1.1 Conventions Used in This Manual

This manual uses certain typographical conventions:

`constant` Constant-width font is used for command names and options; SQL statements; database, table, and column names; C and Perl code; and environment variables. Example: "To see how `mysqladmin` works, invoke it with the `--help` option."

'`filename`'
Constant-width font with surrounding quotes is used for filenames and pathnames. Example: "The distribution is installed under the '`/usr/local/`' directory."

'`c`' Constant-width font with surrounding quotes is also used to indicate character sequences. Example: "To specify a wildcard, use the '`%`' character."

italic Italic font is used for emphasis, *like this*.

boldface Boldface font is used in table headings and to convey **especially strong emphasis**.

When commands are shown that are meant to be executed by a particular program, the program is indicated by a prompt shown before the command. For example, `shell>` indicates a command that you execute from your login shell, and `mysql>` indicates a command that you execute from the `mysql` client program:

```
shell> type a shell command here
mysql> type a mysql command here
```

Shell commands are shown using Bourne shell syntax. If you are using a `csh`-style shell, you may need to issue commands slightly differently. For example, the sequence to set an environment variable and run a command looks like this in Bourne shell syntax:

```
shell> VARNAME=value some_command
```

For `csh`, you would execute the sequence like this:

```
shell> setenv VARNAME value
shell> some_command
```

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

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

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

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

SQL keywords are not case-sensitive and may be written in uppercase or lowercase. This manual uses uppercase.

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

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

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

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

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

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

1.2 Overview of the MySQL Database Management System

MySQL, the most popular Open Source SQL database management system, is developed, distributed, and supported by MySQL AB. MySQL AB is a commercial company, founded by the MySQL developers, that builds its business providing services around the MySQL database management system. See Section 1.3 [MySQL AB Overview], page 11.

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

MySQL is a database management system.

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

MySQL is a relational database management system.

A relational database stores data in separate tables rather than putting all the data in one big storeroom. This adds speed and flexibility. The SQL part of "MySQL" stands for "Structured Query Language". SQL is the most common standardised language used to access databases and is defined by the ANSI/ISO SQL Standard.(The SQL standard has been evolving since 1986 and several versions exist. In this manual, "SQL-92" refers to the standard released in 1992, "SQL-99" refers to the standard released in 1999, and "SQL:2003" refers to the version of the standard that is expected to be released in mid-2003.We use the term "the SQL standard" to mean the current version of the SQL Standard at any time.)

MySQL software is Open Source.

Open Source means that it is possible for anyone to use and modify the software. Anybody can download the MySQL software from the Internet and use it without paying anything. If you wish, you may study the source code and change it to suit your needs. The MySQL software uses the GPL (GNU General Public License), http://www.gnu.org/licenses/, to define what you may and may not do with the software in different situations. If you feel uncomfortable with the GPL or need to embed MySQL code into a commercial application you can buy a commercially licensed version from us. See Section 1.4.3 [MySQL licenses], page 17.

Why use the MySQL Database Server?

The MySQL Database Server is very fast, reliable, and easy to use. If that is what you are looking for, you should give it a try. MySQL Server also has a practical set of features developed in close cooperation with our users. You can find a performance comparison of MySQL Server with other database managers on our benchmark page. See Section 5.1.4 [MySQL Benchmarks], page 397.

MySQL Server was originally developed to handle large databases much faster than existing solutions and has been successfully used in highly demanding pro-

duction environments for several years. Though under constant development, MySQL Server today offers a rich and useful set of functions. Its connectivity, speed, and security make MySQL Server highly suited for accessing databases on the Internet.

The technical features of MySQL Server

For advanced technical information, see Chapter 6 [Reference], page 441. The MySQL Database Software is a client/server system that consists of a multi-threaded SQL server that supports different backends, several different client programs and libraries, administrative tools, and a wide range of programming interfaces (APIs).

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

There is a large amount of contributed MySQL software available.

It is very likely that you will find that your favorite application or language already supports the MySQL Database Server.

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

1.2.1 History of MySQL

We started out with the intention of using mSQL to connect to our tables using our own fast low-level (ISAM) routines. However, after some testing we came to the conclusion that mSQL was not fast enough nor flexible enough for our needs. This resulted in a new SQL interface to our database but with almost the same API interface as mSQL. This API was chosen to ease porting of third-party code.

The derivation of the name MySQL is not clear. Our base directory and a large number of our libraries and tools have had the prefix "my" for well over 10 years. However, co-founder Monty Widenius's daughter (some years younger) is also named My. Which of the two gave its name to MySQL is still a mystery, even for us.

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

1.2.2 The Main Features of MySQL

The following list describes some of the important characteristics of the MySQL Database Software. See Section 1.5.1 [MySQL 4.0 Nutshell], page 20.

Internals and Portability

- Written in C and C++. Tested with a broad range of different compilers.
- Works on many different platforms. See Section 2.2.3 [Which OS], page 73.
- Uses GNU Automake, Autoconf, and Libtool for portability.

- APIs for C, C++, Eiffel, Java, Perl, PHP, Python, Ruby, and Tcl. See Chapter 11 [Clients], page 716.
- Fully multi-threaded using kernel threads. This means it can easily use multiple CPUs if available.
- Transactional and non-transactional storage engines.
- Very fast B-tree disk tables (MyISAM) with index compression.
- Relatively easy to add another storage engine. This is useful if you want to add an SQL interface to an in-house database.
- A very fast thread-based memory allocation system.
- Very fast joins using an optimised one-sweep multi-join.
- In-memory hash tables which are used as temporary tables.
- SQL functions are implemented through a highly optimised class library and should be as fast as possible. Usually there isn't any memory allocation at all after query initialisation.
- The `MySQL` code gets tested with Purify (a commercial memory leakage detector) as well as with Valgrind, a `GPL` tool (`http://developer.kde.org/~sewardj/`).
- Available as client/server or embedded (linked) version.

Column Types

- Many column types: signed/unsigned integers 1, 2, 3, 4, and 8 bytes long, `FLOAT`, `DOUBLE`, `CHAR`, `VARCHAR`, `TEXT`, `BLOB`, `DATE`, `TIME`, `DATETIME`, `TIMESTAMP`, `YEAR`, `SET`, and `ENUM` types. See Section 6.2 [Column types], page 453.
- Fixed-length and variable-length records.

Commands and Functions

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

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

- Full support for SQL `GROUP BY` and `ORDER BY` clauses. Support for group functions (`COUNT()`, `COUNT(DISTINCT ...)`, `AVG()`, `STD()`, `SUM()`, `MAX()`, `MIN()`, and `GROUP_CONCAT()`).
- Support for `LEFT OUTER JOIN` and `RIGHT OUTER JOIN` with both standard SQL and ODBC syntax.
- Support for aliases on tables and columns as required by SQL-92.
- `DELETE`, `INSERT`, `REPLACE`, and `UPDATE` return the number of rows that were changed (affected). It is possible to return the number of rows matched instead by setting a flag when connecting to the server.
- The `MySQL`-specific `SHOW` command can be used to retrieve information about databases, tables, and indexes. The `EXPLAIN` command can be used to determine how the optimiser resolves a query.

- Function names do not clash with table or column names. For example, `ABS` is a valid column name. The only restriction is that for a function call, no spaces are allowed between the function name and the '`(`' that follows it. See Section 6.1.7 [Reserved words], page 451.
- You can mix tables from different databases in the same query (as of Version 3.22).

Security

- A privilege and password system that is very flexible and secure, and allows host-based verification. Passwords are secure because all password traffic is encrypted when you connect to a server.

Scalability and Limits

- Handles large databases. We use `MySQL Server` with databases that contain 50 million records. We also know of users that use `MySQL Server` with 60,000 tables and about 5,000,000,000 rows.
- Up to 32 indexes per table are allowed. Each index may consist of 1 to 16 columns or parts of columns. The maximum index width is 500 bytes (this may be changed when compiling `MySQL Server`). An index may use a prefix of a `CHAR` or `VARCHAR` field.

Connectivity

- Clients may connect to the `MySQL` server using TCP/IP Sockets, Unix Sockets (Unix), or Named Pipes (NT).
- ODBC (Open-DataBase-Connectivity) support for Win32 (with source). All ODBC 2.5 functions are supported, as are many others. For example, you can use MS Access to connect to your `MySQL` server. See Section 11.2 [ODBC], page 806.

Localisation

- The server can provide error messages to clients in many languages. See Section 4.7.2 [Languages], page 307.
- Full support for several different character sets, including ISO-8859-1 (Latin1), german, big5, ujis, and more. For example, the Scandinavian characters '`å`', '`ä`' and '`ö`' are allowed in table and column names.
- All data is saved in the chosen character set. All comparisons for normal string columns are case-insensitive.
- Sorting is done according to the chosen character set (the Swedish way by default). It is possible to change this when the `MySQL` server is started. To see an example of very advanced sorting, look at the Czech sorting code. `MySQL Server` supports many different character sets that can be specified at compile and runtime.

Clients and Tools

- Includes `myisamchk`, a very fast utility for table checking, optimisation, and repair. All of the functionality of `myisamchk` is also available through the SQL interface. See Chapter 4 [MySQL Database Administration], page 195.

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

1.2.3 Stability of MySQL

This section addresses the questions "*How stable is MySQL Server?*" and "*Can I depend on MySQL Server in this project?*" We will try to clarify these issues and answer some important questions that concern many potential users. The information in this section is based on data gathered from the mailing list, which is very active in identifying problems as well as reporting types of use.

Original code stems back from the early '80s, providing a stable code base, and the ISAM table format remains backward-compatible. At TcX, the predecessor of MySQL AB, MySQL code has worked in projects since mid-1996, without any problems. When the MySQL Database Software was released to a wider public, our new users quickly found some pieces of "untested code". Each new release since then has had fewer portability problems (even though each new release has also had many new features).

Each release of the MySQL Server has been usable. Problems have occurred only when users try code from the "gray zones." Naturally, new users don't know what the gray zones are; this section therefore attempts to document those areas that are currently known. The descriptions mostly deal with Version 3.23 and 4.0 of MySQL Server. All known and reported bugs are fixed in the latest version, with the exception of those listed in the bugs section, which are things that are design-related. See Section 1.7.6 [Bugs], page 44.

The MySQL Server design is multi-layered with independent modules. Some of the newer modules are listed here with an indication of how well-tested each of them is:

Replication — Gamma
: Large server clusters using replication are in production use, with good results. Work on enhanced replication features is continuing in MySQL 4.x.

InnoDB **tables — Stable (in 3.23 from 3.23.49)**
: The InnoDB transactional storage engine has been declared stable in the MySQL 3.23 tree, starting from version 3.23.49. InnoDB is being used in large, heavy-load production systems.

BDB **tables — Gamma**
: The Berkeley DB code is very stable, but we are still improving the BDB transactional storage engine interface in MySQL Server, so it will take some time before this is as well tested as the other table types.

FULLTEXT — **Beta**
: Full-text search works but is not yet widely used. Important enhancements have been implemented in MySQL 4.0.

MyODBC 3.51 **(uses ODBC SDK 3.51) — Stable**
: In wide production use. Some issues brought up appear to be application-related and independent of the ODBC driver or underlying database server.

Automatic recovery of `MyISAM` tables — Gamma
This status applies only to the new code in the `MyISAM` storage engine that checks if the table was closed properly on open and executes an automatic check/repair of the table if it wasn't.

Bulk-insert — Alpha
New feature in `MyISAM` tables in `MySQL` 4.0 for faster insert of many rows.

Locking — Gamma
This is very system-dependent. On some systems there are big problems using standard OS locking (`fcntl()`). In these cases, you should run `mysqld` with the `--skip-external-locking` flag. Problems are known to occur on some Linux systems, and on SunOS when using NFS-mounted filesystems.

`MySQL AB` provides high-quality support for paying customers, and the `MySQL` mailing list usually provides answers to common questions. Bugs are usually fixed right away with a patch; for serious bugs, there is almost always a new release.

1.2.4 How Big MySQL Tables Can Be

`MySQL` Version 3.22 had a 4 GB (4 gigabyte) limit on table size. With the `MyISAM` table type in `MySQL` Version 3.23, the maximum table size was pushed up to 8 million terabytes (2 ^ 63 bytes).

In effect, then, the table size for `MySQL` databases is normally limited by the operating system.

Note, however, that operating systems have their own file-size limits. Here are some examples:

Operating System	File-Size Limit
Linux-Intel 32 bit	2 GB, much more when using LFS
Linux-Alpha	8 TB (?)
Solaris 2.5.1	2 GB (possible 4GB with patch)
Solaris 2.6	4 GB (can be changed with flag)
Solaris 2.7 Intel	4 GB
Solaris 2.7 UltraSPARC	512 GB

On Linux 2.2 you can get tables larger than 2 GB in size by using the LFS patch for the ext2 filesystem. On Linux 2.4 patches also exist for ReiserFS to get support for big files. Most current distributions are based on kernel 2.4 and already include all the required Large File Support (LFS) patches. However, the maximum available file size still depends on several factors, one of them being the file system used to store MySQL tables.

For a very detailed overview about LFS in Linux, have a look at Andreas Jaeger's "Large File Support in Linux" page at `http://www.suse.de/~aj/linux_lfs.html`.

By default, `MySQL` tables have a maximum size of about 4 GB. You can check the maximum table size for a table with the `SHOW TABLE STATUS` command or with the `myisamchk -dv table_name`. See Section 4.6.8 [SHOW], page 284.

If you need a table that will be larger than 4 GB in size (and your operating system supports it), set the `AVG_ROW_LENGTH` and `MAX_ROWS` parameters accordingly when you create your

table. See Section 6.5.3 [CREATE TABLE], page 564. You can also set these parameters later, with `ALTER TABLE`. See Section 6.5.4 [ALTER TABLE], page 573.

If your big table is a read-only table, you could use `myisampack` to merge and compress many tables into one. `myisampack` usually compresses a table by at least 50%, so you can have, in effect, much bigger tables. See Section 4.8.4 [`myisampack`], page 317.

You can get around the operating system file limit for `MyISAM` datafiles using the `RAID` option. See Section 6.5.3 [CREATE TABLE], page 564.

Another solution can be the included `MERGE` library, which allows you to handle a collection of identical tables as one. See Section 7.2 [`MERGE` tables], page 601.

1.2.5 Year 2000 Compliance

The `MySQL Server` itself has no problems with Year 2000 (Y2K) compliance:

- `MySQL Server` uses Unix time functions and has no problems with dates until `2069`. All 2-digit years are considered to be in the range `1970` to `2069`, which means that if you store `01` in a `YEAR` column, `MySQL Server` treats it as `2001`.
- All `MySQL` date functions are stored in one file, '`sql/time.cc`', and are coded very carefully to be year 2000-safe.
- In `MySQL` Version 3.22 and later, the `YEAR` column type can store years `0` and `1901` to `2155` in one byte and display them using two or four digits.

You may run into problems with applications that use `MySQL Server` in a way that is not Y2K-safe. For example, many old applications store or manipulate years using 2-digit values (which are ambiguous) rather than 4-digit values. This problem may be compounded by applications that use values such as `00` or `99` as "missing" value indicators.

Unfortunately, these problems may be difficult to fix because different applications may be written by different programmers, each of whom may use a different set of conventions and date-handling functions.

Here is a simple demonstration illustrating that `MySQL Server` doesn't have any problems with dates until the year 2030:

```
mysql> DROP TABLE IF EXISTS y2k;
Query OK, 0 rows affected (0.01 sec)

mysql> CREATE TABLE y2k (date DATE,
    ->                   date_time DATETIME,
    ->                   time_stamp TIMESTAMP);
Query OK, 0 rows affected (0.00 sec)

mysql> INSERT INTO y2k VALUES
    -> ("1998-12-31","1998-12-31 23:59:59",19981231235959),
    -> ("1999-01-01","1999-01-01 00:00:00",19990101000000),
    -> ("1999-09-09","1999-09-09 23:59:59",19990909235959),
    -> ("2000-01-01","2000-01-01 00:00:00",20000101000000),
    -> ("2000-02-28","2000-02-28 00:00:00",20000228000000),
    -> ("2000-02-29","2000-02-29 00:00:00",20000229000000),
```

```
    -> ("2000-03-01","2000-03-01 00:00:00",20000301000000),
    -> ("2000-12-31","2000-12-31 23:59:59",20001231235959),
    -> ("2001-01-01","2001-01-01 00:00:00",20010101000000),
    -> ("2004-12-31","2004-12-31 23:59:59",20041231235959),
    -> ("2005-01-01","2005-01-01 00:00:00",20050101000000),
    -> ("2030-01-01","2030-01-01 00:00:00",20300101000000),
    -> ("2050-01-01","2050-01-01 00:00:00",20500101000000);
Query OK, 13 rows affected (0.01 sec)
Records: 13  Duplicates: 0  Warnings: 0

mysql> SELECT * FROM y2k;
+------------+---------------------+----------------+
| date       | date_time           | time_stamp     |
+------------+---------------------+----------------+
| 1998-12-31 | 1998-12-31 23:59:59 | 19981231235959 |
| 1999-01-01 | 1999-01-01 00:00:00 | 19990101000000 |
| 1999-09-09 | 1999-09-09 23:59:59 | 19990909235959 |
| 2000-01-01 | 2000-01-01 00:00:00 | 20000101000000 |
| 2000-02-28 | 2000-02-28 00:00:00 | 20000228000000 |
| 2000-02-29 | 2000-02-29 00:00:00 | 20000229000000 |
| 2000-03-01 | 2000-03-01 00:00:00 | 20000301000000 |
| 2000-12-31 | 2000-12-31 23:59:59 | 20001231235959 |
| 2001-01-01 | 2001-01-01 00:00:00 | 20010101000000 |
| 2004-12-31 | 2004-12-31 23:59:59 | 20041231235959 |
| 2005-01-01 | 2005-01-01 00:00:00 | 20050101000000 |
| 2030-01-01 | 2030-01-01 00:00:00 | 20300101000000 |
| 2050-01-01 | 2050-01-01 00:00:00 | 00000000000000 |
+------------+---------------------+----------------+
13 rows in set (0.00 sec)
```

This example shows that the `DATE` and `DATETIME` datatypes will not give any problems with future dates (they handle dates until the year 9999).

The `TIMESTAMP` datatype, which is used to store the current time, supports values that range from `19700101000000` to `20300101000000` on 32-bit machines (signed value). On 64-bit machines, `TIMESTAMP` handles values up to `2106` (unsigned value).

Even though `MySQL Server` is Y2K-compliant, it is your responsibility to provide unambiguous input. See Section 6.2.2.1 [Y2K issues], page 461 for `MySQL Server`'s rules for dealing with ambiguous date input data (data containing 2-digit year values).

1.3 Overview of MySQL AB

`MySQL AB` is the company of the `MySQL` founders and main developers. `MySQL AB` was originally established in Sweden by David Axmark, Allan Larsson, and Michael `Monty` Widenius.

The developers of the `MySQL` server are all employed by the company. We are a virtual organisation with people in a dozen countries around the world. We communicate extensively over the Net every day with one another and with our users, supporters, and partners.

We are dedicated to developing the MySQL software and spreading our database to new users. MySQL AB owns the copyright to the MySQL source code, the MySQL logo and trademark, and this manual. See Section 1.2 [MySQL DBMS Overview], page 4.

The MySQL core values show our dedication to MySQL and Open Source.

We want the MySQL Database Software to be:

- The best and the most widely used database in the world.
- Available to, and affordable by all.
- Easy to use.
- Continuously improving while remaining fast and safe.
- Fun to use and improve.
- Free from bugs.

MySQL AB and the people at MySQL AB:

- Promote Open Source philosophy and support the Open Source community.
- Aim to be good citizens.
- Prefer partners that share our values and mind-set.
- Answer e-mail and provide support.
- Are a virtual company, networking with others.
- Work against software patents.

The MySQL web site (http://www.mysql.com/) provides the latest information about MySQL and MySQL AB.

By the way, the "AB" part of the company name is the acronym for the Swedish "aktiebolag", or "stock company." It translates to "MySQL, Inc." In fact, MySQL Inc. and MySQL GmbH are examples of MySQL AB subsidiaries. They are located in the US and Germany, respectively.

1.3.1 The Business Model and Services of MySQL AB

One of the most common questions we encounter is: "*How can you make a living from something you give away for free?*" This is how.

MySQL AB makes money on support, services, commercial licenses, and royalties. We use these revenues to fund product development and to expand the MySQL business.

The company has been profitable since its inception. In October 2001, we accepted venture financing from leading Scandinavian investors and a handful of business angels. This investment is used to solidify our business model and build a basis for sustainable growth.

1.3.1.1 Support

MySQL AB is run and owned by the founders and main developers of the MySQL database. The developers are committed to giving support to customers and other users in order to stay in touch with their needs and problems. All our support is given by qualified developers. Really tricky questions are answered by Michael Monty Widenius, principal author of the MySQL Server. See Section 1.4.1 [Support], page 16.

For more information and ordering support at various levels, see http://www.mysql.com/support/ or contact our sales staff at sales@mysql.com.

1.3.1.2 Training and Certification

MySQL AB delivers MySQL and related training worldwide. We offer both open courses and in-house courses tailored to the specific needs of your company. MySQL Training is also available through our partners, the Authorised MySQL Training Centers.

Our training material uses the same example databases used in our documentation and our sample applications, and is always updated to reflect the latest MySQL version. Our trainers are backed by the development team to guarantee the quality of the training and the continuous development of the course material. This also ensures that no questions raised during the courses remain unanswered.

Attending our training courses will enable you to achieve your MySQL application goals. You will also:

- Save time.
- Improve the performance of your application(s).
- Reduce or eliminate the need for additional hardware, decreasing cost.
- Enhance security.
- Increase customers' and co-workers' satisfaction.
- Prepare yourself for MySQL Certification.

If you are interested in our training as a potential participant or as a training partner, please visit the training section at http://www.mysql.com/training/ or contact us at: training@mysql.com.

For details about the MySQL Certification Program, please see http://www.mysql.com/certification/.

1.3.1.3 Consulting

MySQL AB and its Authorised Partners offer consulting services to users of MySQL Server and to those who embed MySQL Server in their own software, all over the world.

Our consultants can help you design and tune your databases, construct efficient queries, tune your platform for optimal performance, resolve migration issues, set up replication, build robust transactional applications, and more. We also help customers embed MySQL Server in their products and applications for large-scale deployment.

Our consultants work in close collaboration with our development team, which ensures the technical quality of our professional services. Consulting assignments range from 2-day power-start sessions to projects that span weeks and months. Our expertise not only covers MySQL Server—it also extends into programming and scripting languages such as PHP, Perl, and more.

If you are interested in our consulting services or want to become a consulting partner, please visit the consulting section of our web site at http://www.mysql.com/consulting/ or contact our consulting staff at consulting@mysql.com.

1.3.1.4 Commercial Licenses

The MySQL database is released under the GNU General Public License (GPL). This means that the MySQL software can be used free of charge under the GPL. If you do not want to be bound by the GPL terms (such as the requirement that your application must also be GPL, you may purchase a commercial license for the same product from MySQL AB; see http://www.mysql.com/products/pricing.html. Since MySQL AB owns the copyright to the MySQL source code, we are able to employ Dual Licensing, which means that the same product is available under GPL and under a commercial license. This does not in any way affect the Open Source commitment of MySQL AB. For details about when a commercial license is required, please see Section 1.4.3 [MySQL licenses], page 17.

We also sell commercial licenses of third-party Open Source GPL software that adds value to MySQL Server. A good example is the InnoDB transactional storage engine that offers ACID support, row-level locking, crash recovery, multi-versioning, foreign key support, and more. See Section 7.5 [InnoDB], page 606.

1.3.1.5 Partnering

MySQL AB has a worldwide partner programme that covers training courses, consulting and support, publications, plus reselling and distributing MySQL and related products. MySQL AB Partners get visibility on the http://www.mysql.com/ web site and the right to use special versions of the MySQL trademarks to identify their products and promote their business.

If you are interested in becoming a MySQL AB Partner, please e-mail partner@mysql.com.

The word MySQL and the MySQL dolphin logo are trademarks of MySQL AB. See Section 1.4.4 [MySQL AB Logos and Trademarks], page 18. These trademarks represent a significant value that the MySQL founders have built over the years.

The MySQL web site (http://www.mysql.com/) is popular among developers and users. In October 2001, we served 10 million page views. Our visitors represent a group that makes purchase decisions and recommendations for both software and hardware. Twelve percent of our visitors authorise purchase decisions, and only nine percent are not involved in purchase decisions at all. More than 65% have made one or more online business purchases within the last half-year, and 70% plan to make one in the next few months.

1.3.2 Contact Information

The MySQL web site (http://www.mysql.com/) provides the latest information about MySQL and MySQL AB.

For press services and inquiries not covered in our News releases (http://www.mysql.com/news/), please send an e-mail to press@mysql.com.

If you have a valid support contract with MySQL AB, you will get timely, precise answers to your technical questions about the MySQL software. For more information, see Section 1.4.1 [Support], page 16. On our web site, see http://www.mysql.com/support/, or send an e-mail to sales@mysql.com.

For information about MySQL training, please visit the training section at http://www.mysql.com/training/. If you have restricted access to the Internet, please

contact the MySQL AB training staff via e-mail at training@mysql.com. See Section 1.3.1.2 [Business Services Training], page 13.

For information on the MySQL Certification Program, please see http://www.mysql.com/certification/. See Section 1.3.1.2 [Business Services Training], page 13.

If you're interested in consulting, please visit the consulting section of our web site at http://www.mysql.com/consulting/. If you have restricted access to the Internet, please contact the MySQL AB consulting staff via e-mail at consulting@mysql.com. See Section 1.3.1.3 [Business Services Consulting], page 13.

Commercial licenses may be purchased online at https://order.mysql.com/. There you will also find information on how to fax your purchase order to MySQL AB. More information about licensing can be found at http://www.mysql.com/products/pricing.html. If you have questions regarding licensing or you want a quote for a high-volume license deal, please fill in the contact form on our web site (http://www.mysql.com/) or send an e-mail message to licensing@mysql.com (for licensing questions) or to sales@mysql.com (for sales inquiries). See Section 1.4.3 [MySQL licenses], page 17.

If you represent a business that is interested in partnering with MySQL AB, please send an e-mail to partner@mysql.com. See Section 1.3.1.5 [Business Services Partnering], page 14.

For more information on the MySQL trademark policy, refer to http://www.mysql.com/company/trademark.html or send an e-mail to trademark@mysql.com. See Section 1.4.4 [MySQL AB Logos and Trademarks], page 18.

If you are interested in any of the MySQL AB jobs listed in our jobs section (http://www.mysql.com/company/jobs/), please send an e-mail to jobs@mysql.com. Please do not send your CV as an attachment, but rather as plain text at the end of your e-mail message.

For general discussion among our many users, please direct your attention to the appropriate mailing list. See Section 1.6.1 [Questions], page 24.

Reports of errors (often called bugs), as well as questions and comments, should be sent to the general MySQL mailing list. See Section 1.6.1.1 [Mailing-list], page 25. If you have found a sensitive security bug in the MySQL Server, please send an e-mail to security@mysql.com. See Section 1.6.1.3 [Bug reports], page 27.

If you have benchmark results that we can publish, please contact us via e-mail at benchmarks@mysql.com.

If you have suggestions concerning additions or corrections to this manual, please send them to the manual team via e-mail at docs@mysql.com.

For questions or comments about the workings or content of the MySQL web site (http://www.mysql.com/), please send an e-mail to webmaster@mysql.com.

MySQL AB has a privacy policy, which can be read at http://www.mysql.com/company/privacy.html. For any queries regarding this policy, please send an e-mail to privacy@mysql.com.

For all other inquires, please send an e-mail to info@mysql.com.

1.4 MySQL Support and Licensing

This section describes MySQL support and licensing arrangements.

1.4.1 Support Offered by MySQL AB

Technical support from MySQL AB means individualised answers to your unique problems direct from the software engineers who code the MySQL database engine.

We try to take a broad and inclusive view of technical support. Almost any problem involving MySQL software is important to us if it's important to you. Typically customers seek help on how to get different commands and utilities to work, remove performance bottlenecks, restore crashed systems, understand operating system or networking impacts on MySQL, set up best practices for backup and recovery, utilise APIs, and so on. Our support covers only the MySQL server and our own utilities, not third-party products that access the MySQL server, though we try to help with these where we can.

Detailed information about our various support options is given at http://www.mysql.com/support/, where support contracts can also be ordered online. If you have restricted access to the Internet, please contact our sales staff via e-mail at sales@mysql.com.

Technical support is like life insurance. You can live happily without it for years, but when your hour arrives it becomes critically important, yet it's too late to buy it. If you use MySQL Server for important applications and encounter sudden difficulties, it may be too time consuming to figure out all the answers yourself. You may need immediate access to the most experienced MySQL troubleshooters available, those employed by MySQL AB.

1.4.2 Copyrights and Licenses Used by MySQL

MySQL AB owns the copyright to the MySQL source code, the MySQL logos and trademarks and this manual. See Section 1.3 [MySQL AB Overview], page 11. Several different licenses are relevant to the MySQL distribution:

1. All the MySQL-specific source in the server, the mysqlclient library and the client, as well as the GNU readline library is covered by the GNU General Public License. See Appendix H [GPL license], page 1023. The text of this license can be found as the file 'COPYING' in the distribution.
2. The GNU getopt library is covered by the GNU Lesser General Public License. See Appendix I [LGPL license], page 1029.
3. Some parts of the source (the regexp library) are covered by a Berkeley-style copyright.
4. Older versions of MySQL (3.22 and earlier) are subject to a stricter license (http://www.mysql.com/products/mypl.html). See the documentation of the specific version for information.
5. The MySQL reference manual is currently **not** distributed under a GPL-style license. Use of the manual is subject to the following terms:
   - Conversion to other formats is allowed, but the actual content may not be altered or edited in any way.
   - You may create a printed copy for your own personal use.
   - For all other uses, such as selling printed copies or using (parts of) the manual in another publication, prior written agreement from MySQL AB is required.

   Please send an e-mail to docs@mysql.com for more information or if you are interested in doing a translation.

For information about how the MySQL licenses work in practice, please refer to Section 1.4.3 [MySQL licenses], page 17. Also see Section 1.4.4 [MySQL AB Logos and Trademarks], page 18.

1.4.3 MySQL Licenses

The MySQL software is released under the GNU General Public License (GPL), which is probably the best known Open Source license. The formal terms of the GPL license can be found at http://www.gnu.org/licenses/. See also http://www.gnu.org/licenses/gpl-faq.html and http://www.gnu.org/philosophy/enforcing-gpl.html

Since the MySQL software is released under the GPL, it may often be used for free, but for certain uses you may want or need to buy commercial licenses from MySQL AB at https://order.mysql.com/. See http://www.mysql.com/products/licensing.html for more information.

Older versions of MySQL (3.22 and earlier) are subject to a stricter license (http://www.mysql.com/products/mypl.html). See the documentation of the specific version for information.

Please note that the use of the MySQL software under commercial license, GPL, or the old MySQL license does not automatically give you the right to use MySQL AB trademarks. See Section 1.4.4 [MySQL AB Logos and Trademarks], page 18.

1.4.3.1 Using the MySQL Software Under a Commercial License

The GPL license is contagious in the sense that when a program is linked to a GPL program all the source code for all the parts of the resulting product must also be released under the GPL. If you do not follow this GPL requirement, you break the license terms and forfeit your right to use the GPL program altogether. You also risk damages.

You need a commercial license:

- When you link a program with any GPL code from the MySQL software and don't want the resulting product to be licensed under GPL, perhaps because you want to build a commercial product or keep the added non-GPL code closed source for other reasons. When purchasing commercial licenses, you are not using the MySQL software under GPL even though it's the same code.
- When you distribute a non-GPL application that **only** works with the MySQL software and ship it with the MySQL software. This type of solution is considered to be linking even if it's done over a network.
- When you distribute copies of the MySQL software without providing the source code as required under the GPL license.
- When you want to support the further development of the MySQL database even if you don't formally need a commercial license. Purchasing support directly from MySQL AB is another good way of contributing to the development of the MySQL software, with immediate advantages for you. See Section 1.4.1 [Support], page 16.

If you require a license, you will need one for each installation of the MySQL software. This covers any number of CPUs on a machine, and there is no artificial limit on the number of clients that connect to the server in any way.

For commercial licenses, please visit our website at http://www.mysql.com/products/licensing.html. For support contracts, see http://www.mysql.com/support/. If you have special needs or you have restricted access to the Internet, please contact our sales staff via e-mail at sales@mysql.com.

1.4.3.2 Using the MySQL Software for Free Under GPL

You can use the MySQL software for free under the GPL if you adhere to the conditions of the GPL. For additional details, including answers to common questions about the GPL, see the generic FAQ from the Free Software Foundation at http://www.gnu.org/licenses/gpl-faq.html. Common uses of the GPL include:

- When you distribute both your own application and the MySQL source code under the GPL with your product.
- When you distribute the MySQL source code bundled with other programs that are not linked to or dependent on the MySQL system for their functionality even if you sell the distribution commercially. This is called mere aggregation in the GPL license.
- When you are not distributing **any** part of the MySQL system, you can use it for free.
- When you are an Internet Service Provider (ISP), offering web hosting with MySQL servers for your customers. We encourage people to use ISPs that have MySQL support, as this will give them the confidence that their ISP will, in fact, have the resources to solve any problems they may experience with the MySQL installation. Even if an ISP does not have a commercial license for MySQL Server, their customers should at least be given read access to the source of the MySQL installation so that the customers can verify that it is correctly patched.
- When you use the MySQL database software in conjunction with a web server, you do not need a commercial license (so long as it is not a product you distribute). This is true even if you run a commercial web server that uses MySQL Server, because you are not distributing any part of the MySQL system. However, in this case we would like you to purchase MySQL support because the MySQL software is helping your enterprise.

If your use of MySQL database software does not require a commercial license, we encourage you to purchase support from MySQL AB anyway. This way you contribute toward MySQL development and also gain immediate advantages for yourself. See Section 1.4.1 [Support], page 16.

If you use the MySQL database software in a commercial context such that you profit by its use, we ask that you further the development of the MySQL software by purchasing some level of support. We feel that if the MySQL database helps your business, it is reasonable to ask that you help MySQL AB. (Otherwise, if you ask us support questions, you are not only using for free something into which we've put a lot a work, you're asking us to provide free support, too.)

1.4.4 MySQL AB Logos and Trademarks

Many users of the MySQL database want to display the MySQL AB dolphin logo on their web sites, books, or boxed products. We welcome and encourage this, although it should be noted that the word MySQL and the MySQL dolphin logo are

trademarks of MySQL AB and may only be used as stated in our trademark policy at http://www.mysql.com/company/trademark.html.

1.4.4.1 The Original MySQL Logo

The MySQL dolphin logo was designed by the Finnish advertising agency Priority in 2001. The dolphin was chosen as a suitable symbol for the MySQL database since it is a smart, fast, and lean animal, effortlessly navigating oceans of data. We also happen to like dolphins.

The original MySQL logo may only be used by representatives of MySQL AB and by those having a written agreement allowing them to do so.

1.4.4.2 MySQL Logos that may be Used Without Written Permission

We have designed a set of special *Conditional Use* logos that may be downloaded from our web site at http://www.mysql.com/press/logos.html and used on third-party web sites without written permission from MySQL AB. The use of these logos is not entirely unrestricted but, as the name implies, subject to our trademark policy that is also available on our web site. You should read through the trademark policy if you plan to use them. The requirements are basically as follows:

- Use the logo you need as displayed on the http://www.mysql.com/ site. You may scale it to fit your needs, but may not change colours or design, or alter the graphics in any way.
- Make it evident that you, and not MySQL AB, are the creator and owner of the site that displays the MySQL trademark.
- Don't use the trademark in a way that is detrimental to MySQL AB or to the value of MySQL AB trademarks. We reserve the right to revoke the right to use the MySQL AB trademark.
- If you use the trademark on a web site, make it clickable, leading directly to http://www.mysql.com/.
- If you are use the MySQL database under GPL in an application, your application must be Open Source and must be able to connect to a MySQL server.

Contact us via e-mail at trademark@mysql.com to inquire about special arrangements to fit your needs.

1.4.4.3 When You Need Written Permission to Use MySQL Logos

You need written permission from MySQL AB before using MySQL logos in the following cases:

- When displaying any MySQL AB logo anywhere except on your web site.
- When displaying any MySQL AB logo except the *Conditional Use* logos mentioned previously on web sites or elsewhere.

Due to legal and commercial reasons we monitor the use of MySQL trademarks on products, books, and other items. We usually require a fee for displaying MySQL AB logos on commercial products, since we think it is reasonable that some of the revenue is returned to fund further development of the MySQL database.

1.4.4.4 MySQL AB Partnership Logos

MySQL partnership logos may be used only by companies and persons having a written partnership agreement with MySQL AB. Partnerships include certification as a MySQL trainer or consultant. For more information, please see Section 1.3.1.5 [Partnering], page 14.

1.4.4.5 Using the word MySQL in Printed Text or Presentations

MySQL AB welcomes references to the MySQL database, but it should be noted that the word MySQL is a trademark of MySQL AB. Because of this, you must append the trademark symbol (TM) to the first or most prominent use of the word MySQL in a text and, where appropriate, state that MySQL is a trademark of MySQL AB. For more information, please refer to our trademark policy at http://www.mysql.com/company/trademark.html.

1.4.4.6 Using the word MySQL in Company and Product Names

Use of the word MySQL in product or company names or in Internet domain names is not allowed without written permission from MySQL AB.

1.5 MySQL Development Roadmap

This section provides a snapshot of the MySQL development roadmap, including major features implemented or planned for MySQL 4.0, 4.1, 5.0, and 5.1 The following sections provide information for each release. Plans for some of the most requested features are summarized in the following table.

Feature	MySQL version
Unions	4.0
Subqueries	4.1
R-trees	4.1 (for MyISAM tables)
Stored procedures	5.0
Views	5.0 or 5.1
Cursors	5.0
Foreign keys	5.1 (3.23 with InnoDB)
Triggers	5.1
Full outer join	5.1
Constraints	5.1

1.5.1 MySQL 4.0 in a Nutshell

Long promised by MySQL AB and long awaited by our users, MySQL Server 4.0 is now available in production version.

MySQL 4.0 is available for download from http://www.mysql.com/ and from our mirrors. MySQL 4.0 has been tested by a large number of users and is in production use at many large sites.

The major new features of MySQL Server 4.0 are geared toward our existing business and community users, enhancing the MySQL database software as the solution for mission-critical, heavy-load database systems. Other new features target the users of embedded databases.

MySQL Version 4.0.12 was declared stable for production use in March 2003. This means that, in future, only bug fixes will be done for the 4.0 release series and only critical bug fixes will be done for the older 3.23 series. See Section 2.5.2 [Upgrading-from-3.23], page 113.

New features to the `MySQL` software are being added to MySQL 4.1 which is now also available (alpha version). See Section 1.5.2 [MySQL 4.1 Nutshell], page 22.

1.5.1.1 Features Available in MySQL 4.0

Speed enhancements

- MySQL 4.0 has a query cache that can give a huge speed boost to applications with repetitive queries. See Section 6.9 [Query Cache], page 589.
- Version 4.0 further increases the speed of MySQL Server in a number of areas, such as bulk `INSERT`s, searching on packed indexes, creation of `FULLTEXT` indexes, and `COUNT(DISTINCT)`.

Embedded MySQL Server introduced

- The new Embedded Server library (instead of client/server) can easily be used in standalone and embedded applications. See Section 1.5.1.2 [Nutshell Embedded MySQL], page 22.

InnoDB storage engine as standard

- The `InnoDB` storage engine is now offered as a standard feature of the `MySQL` server. This means full support for ACID *transactions*, *foreign keys* with cascading UPDATE/DELETE, and *row-level locking* are now standard features. See Section 7.5 [InnoDB], page 606.

New functionality

- The enhanced `FULLTEXT` search properties of MySQL Server 4.0 enables `FULLTEXT` indexing of large text masses with both binary and natural-language searching logic. You can customise minimal word length and define your own stop word lists in any human language, enabling a new set of applications to be built on MySQL Server. See Section 6.8 [Fulltext Search], page 584.

Standards compliance, portability, and migration

- Features to simplify migration from other database systems to MySQL Server include `TRUNCATE TABLE` (as in Oracle).
- Many users will also be happy to learn that MySQL Server now supports the `UNION` statement, a long-awaited standard SQL feature.
- MySQL can now run natively on the Novell NetWare 6.0 platform. See Section 2.6.8 [Novell NetWare], page 152.

Internationalisation

- Our German, Austrian, and Swiss users will note that `MySQL` now supports a new character set, `latin1_de`, which ensures that the *German sorting*

order sorts words with umlauts in the same order as do German telephone books.

Usability enhancements

In the process of building features for new users, we have not forgotten requests from our community of loyal users.

- Most `mysqld` parameters (startup options) can now be set without taking down the servers. This is a convenient feature for Database Administrators (DBAs). See Section 5.5.6 [SET OPTION], page 432.
- Multi-table `DELETE` and `UPDATE` statements have been added..
- Support has been added for `symbolic linking` to `MyISAM` at the table level (and not just the database level as before) and for enabling symlink handling by default on Windows.
- `SQL_CALC_FOUND_ROWS` and `FOUND_ROWS()` are new functions that make it possible to find out the number of rows a `SELECT` query that includes a `LIMIT` clause would have returned without that clause.

The news section of this manual includes a more in-depth list of features. See Section D.3 [News-4.0.x], page 896.

1.5.1.2 Embedded MySQL Server

`libmysqld` makes MySQL Server suitable for a vastly expanded realm of applications. Using the embedded MySQL server library, one can embed MySQL Server into various applications and electronics devices, where the end user has no knowledge of there actually being an underlying database. Embedded MySQL Server is ideal for use behind the scenes in Internet appliances, public kiosks, turnkey hardware/software combination units, high performance Internet servers, self-contained databases distributed on CD-ROM, and so on.

Many users of `libmysqld` will benefit from the MySQL *Dual Licensing*. For those not wishing to be bound by the `GPL`, the software is also made available under a commercial license. The embedded MySQL library uses the same interface as the normal client library, so it is convenient and easy to use. See Section 11.1.15 [libmysqld], page 800.

1.5.2 MySQL 4.1 in a Nutshell

MySQL Server 4.0 laid the foundation for new features such as *subqueries* and *Unicode* (implemented in version 4.1) and for the work on SQL-99 *stored procedures* being done for version 5.0. These features come at the top of the wish list of many of our customers.

With these additions, critics of the MySQL Database Server have to be more imaginative than ever in pointing out deficiencies in the MySQL Database Management System. Already well-known for its stability, speed, and ease of use, MySQL Server will be able to fulfill the requirement checklists of very demanding buyers.

1.5.2.1 Features Available in MySQL 4.1

The features listed in this section are implemented in MySQL 4.1. A few other features are still planned for MySQL 4.1. See Section 1.8.1 [TODO MySQL 4.1], page 49.

Most new features being coded, such as *stored procedures*, will be available in MySQL 5.0. See Section 1.8.2 [TODO MySQL 5.0], page 49.

Support for subqueries and derived tables

- A subquery is a `SELECT` statement nested within another statement. A derived table (unnamed view) is a subquery in the `FROM` clause of another statement. See Section 6.4.2 [Subqueries], page 537.

Speed enhancements

- Faster binary protocol with prepared statements and parameter binding. See Section 11.1.4 [C API Prepared statements], page 765.
- `BTREE` indexing is now supported for `HEAP` tables, significantly improving response time for non-exact searches.

New functionality

- `CREATE TABLE table LIKE table` allows you to create a new table with the exact structure of an existing table, using a single command.
- Support for OpenGIS spatial types (geographical data). See Chapter 10 [Spatial extensions in MySQL], page 687.
- Replication can be done over SSL connections.

Standards compliance, portability, and migration

- The new client/server protocol adds the ability to pass multiple warnings to the client, rather than only a single result. This makes jobs such as bulk loading of data much easier to track. `SHOW WARNINGS` shows warnings for the last command. See Section 4.6.8.9 [SHOW WARNINGS], page 303.

Internationalisation

- To support our ever expanding user base using local languages in applications, the MySQL software now offers extensive Unicode (UTF8) support.
- Character sets can now be defined per column, table, and database. This allows for a high degree of flexibility in application design, particularly for multi-language web sites.
- For documentation for this improved character set support, see Chapter 9 [Charset], page 665.

Usability enhancements

- In response to popular demand, we have added a server-based `HELP command` that can be used in the `mysql` command line client (and other clients) to get help for SQL commands. The advantage of having this information on the server side is that the information is always applicable for that particular server version.
- In the new client/server protocol, multi-line queries can now be enabled. This allows you to issue several queries in a single call and then read all the results in one go. See Section 11.1.8 [C API multiple queries], page 792.
- A new `INSERT ... ON DUPLICATE KEY UPDATE ...` syntax has been implemented. This allows you to `UPDATE` an existing row if the `INSERT` would have caused a duplicate in a `PRIMARY` or `UNIQUE` key (index). See Section 6.4.3 [INSERT], page 546.

- We have designed a new aggregate function `GROUP_CONCAT()`, adding the extremely useful capability of concatenating columns from grouped rows into a single result string. See Section 6.3.7 [Group by functions and modifiers], page 524.
- The new client/server protocol supports multiple result sets.

The news section in this manual includes a more in-depth list of features. See Section D.2 [News-4.1.x], page 889.

1.5.2.2 Stepwise Rollout

New features are being added to MySQL 4.1, which is already available for download (alpha version). See Section 1.5.2.3 [Nutshell Ready for Immediate Use], page 24.

The set of features that are being added to version 4.1 is mostly fixed. Additional development is already ongoing for version 5.0. MySQL 4.1 will go through the steps of *Alpha* (during which time new features might still be added/changed), *Beta* (when we have feature freeze and only bug corrections will be done), and *Gamma* (indicating that a production release is just weeks ahead). At the end of this process, MySQL 4.1 will become the new production release.

1.5.2.3 Ready for Immediate Development Use

MySQL 4.1 is currently in the alpha stage, and binaries are available for download at `http://www.mysql.com/downloads/mysql-4.1.html`. All binary releases pass our extensive test suite without any errors on the platforms on which we test. See Section D.2 [News-4.1.x], page 889.

For those wishing to use the most recent development source for MySQL 4.1, we have made our 4.1 BitKeeper repository publicly available. See Section 2.3.4 [Installing source tree], page 94.

1.5.3 MySQL 5.0, The Next Development Release

New development for MySQL is focused on the 5.0 release, featuring Stored Procedures and other new features. See Section 1.8.2 [TODO MySQL 5.0], page 49.

For those wishing to take a look at the bleeding edge of MySQL development, we have made our BitKeeper repository for MySQL version 5.0 publicly available. See Section 2.3.4 [Installing source tree], page 94.

1.6 MySQL Information Sources

1.6.1 MySQL Mailing Lists

This section introduces you to the MySQL mailing lists and gives some guidelines as to how the lists should be used. When you subscribe to a mailing list, you will receive, as e-mail messages, all postings to the list. You will also be able to send your own questions and answers to the list.

1.6.1.1 The MySQL Mailing Lists

To subscribe to or unsubscribe from any of the mailing lists described in this section, visit `http://lists.mysql.com/`. Please **do not** send messages about subscribing or unsubscribing to any of the mailing lists, because such messages are distributed automatically to thousands of other users.

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

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

The MySQL mailing lists are as follows:

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

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

`mysql-digest`
This is the `mysql` list in digest form. Subscribing to this list means you will get all list messages, sent as one large mail message once a day.

`bugs` This list will be of interest to you if you want to stay informed about issues reported since the last release of `MySQL` or if you want to be actively involved in the process of bug hunting and fixing. See Section 1.6.1.3 [Bug reports], page 27.

`bugs-digest`
This is the `bugs` list in digest form.

`internals`
This list is for people who work on the MySQL code. This is also the forum for discussions on MySQL development and post patches.

`internals-digest`
This is the `internals` list in digest form.

`mysqldoc` This list is for people who work on the MySQL documentation: people from MySQL AB, translators, and other community members.

`mysqldoc-digest`
This is the `mysqldoc` list in digest form.

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

`benchmarks-digest`
: This is the `benchmarks` list in digest form.

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

`packagers-digest`
: This is the `packagers` list in digest form.

`java`
: This list is for discussions about the MySQL server and Java.It is mostly used to discuss JDBC drivers, including MySQL Connector/J.

`java-digest`
: This is the `java` list in digest form.

`win32`
: This list is for all things concerning the MySQL software on Microsoft operating systems, such as Windows 9x/Me/NT/2000/XP.

`win32-digest`
: This is the `win32` list in digest form.

`myodbc`
: This list is for all things concerning connecting to the MySQL server with ODBC.

`myodbc-digest`
: This is the `myodbc` list in digest form.

`mysqlcc`
: This list is for all things concerning the `MySQL Control Center` graphical client.

`mysqlcc-digest`
: This is the `mysqlcc` list in digest form.

`plusplus`
: This list is for all things concerning programming with the C++ API to MySQL.

`plusplus-digest`
: This is the `plusplus` list in digest form.

`msql-mysql-modules`
: This list is for all things concerning the Perl support for MySQL with `msql-mysql-modules`, which is now named `DBD-mysql`.

`msql-mysql-modules-digest`
: This is the `msql-mysql-modules` list in digest form.

If you're unable to get an answer to your question(s) from a `MySQL` mailing list, one option is to pay for support from MySQL AB. This will put you in direct contact with MySQL developers. See Section 1.4.1 [Support], page 16.

The following table shows some MySQL mailing lists in languages other than English. These lists are not operated by MySQL AB, so we can't guarantee their quality.

`mysql-france-subscribe@yahoogroups.com A French mailing list`
`list@tinc.net A Korean mailing list`
: E-mail `subscribe mysql your@e-mail.address` to this list.

`mysql-de-request@lists.4t2.com` A German mailing list
: E-mail `subscribe mysql-de your@e-mail.address` to this list. You can find information about this mailing list at `http://www.4t2.com/mysql/`.

`mysql-br-request@listas.linkway.com.br` A Portuguese mailing list
: E-mail `subscribe mysql-br your@e-mail.address` to this list.

`mysql-alta@elistas.net` A Spanish mailing list
: E-mail `subscribe mysql your@e-mail.address` to this list.

1.6.1.2 Asking Questions or Reporting Bugs

Before posting a bug report or question, please do the following:

- Start by searching the MySQL online manual at:
  `http://www.mysql.com/doc/`
  We try to keep the manual up to date by updating it frequently with solutions to newly found problems. The change history appendix (`http://www.mysql.com/doc/en/News.html`) can be particularly useful since it is quite possible that a newer version already contains a solution to your problem.
- Search in the bugs database at `http://bugs.mysql.com/` to see whether the bug has already been reported/solved.
- Search the MySQL mailing list archives:
  `http://lists.mysql.com/`
- You can also use `http://www.mysql.com/search/` to search all the web pages (including the manual) that are located at `http://www.mysql.com/`.

If you can't find an answer in the manual or the archives, check with your local MySQL expert. If you still can't find an answer to your question, please follow the guidelines on sending mail to a MySQL mailing list, outlined in the next section, before contacting us.

1.6.1.3 How to Report Bugs or Problems

Our bugs database is public, and can be browsed and searched by anyone at `http://bugs.mysql.com/`. If you log into the system, you will also be able to enter new reports.

Writing a good bug report takes patience, but doing it right the first time saves time both for us and for yourself. A good bug report, containing a full test case for the bug, makes it very likely that we will fix the bug in the next release. This section will help you write your report correctly so that you don't waste your time doing things that may not help us much or at all.

We encourage everyone to use the `mysqlbug` script to generate a bug report (or a report about any problem). `mysqlbug` can be found in the '`scripts`' directory (source distribution) and in the '`bin`' directory under your MySQL installation directory (binary distribution). If you are unable to use `mysqlbug` (for instance, if you are running on Windows), it is still vital that you include all the necessary information noted in this section (most importantly a description of the operating system and the MySQL version).

The `mysqlbug` script helps you generate a report by determining much of the following information automatically, but if something important is missing, please include it with your message. Please read this section carefully and make sure that all the information described here is included in your report.

Preferably, you should test the problem using the latest production or development version of MySQL Server before posting. Anyone should be able to repeat the bug by just using '`mysql test < script`' on the included test case or run the shell or Perl script that is included in the bug report.

All bugs posted in the bugs database at `http://bugs.mysql.com/` will be corrected or documented in the next MySQL release. If only minor code changes are needed to correct a problem, we will also post a patch that fixes the problem.

The normal place to report bugs is `http://bugs.mysql.com/`.

If you have found a sensitive security bug in MySQL, please send an e-mail to `security@mysql.com`.

If you have a repeatable bug report, please report this into the bugs database at `http://bugs.mysql.com/`. Note that even in this case it's good to run the `mysqlbug` script first to find information about your system. Any bug that we are able to repeat has a high chance of being fixed in the next MySQL release.

To report other problems, you can use one of the MySQL mailing lists.

Remember that it is possible for us to respond to a message containing too much information, but not to one containing too little. People often omit facts because they think they know the cause of a problem and assume that some details don't matter. A good principle is: if you are in doubt about stating something, state it. It is a thousand times faster and less troublesome to write a couple of lines more in your report than to be forced to ask again and wait for the answer because you didn't include enough information the first time.

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

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

It is most helpful when a good description of the problem is included in the bug report. That is, give a good example of all the things you did that led to the problem and describe, in exact detail, the problem itself. The best reports are those that include a full example showing how to reproduce the bug or problem. See Section E.1.6 [Reproduceable test case], page 1012.

If a program produces an error message, it is very important to include the message in your report. If we try to search for something from the archives using programs, it is better that the error message reported exactly matches the one that the program produces. (Even the case should be observed.) You should never try to remember what the error message was; instead, copy and paste the entire message into your report.

If you have a problem with MyODBC, please try to generate a MyODBC trace file and send it with your report. See Section 11.2.7 [MyODBC bug report], page 815.

Please remember that many of the people who will read your report will do so using an 80-column display. When generating reports or examples using the `mysql` command-line tool, you should therefore use the `--vertical` option (or the `\G` statement terminator) for output that would exceed the available width for such a display (for example, with the `EXPLAIN SELECT` statement; see the example later in this section).

Please include the following information in your report:

- The version number of the MySQL distribution you are using (for example, MySQL Version 4.0.12). You can find out which version you are running by executing `mysqladmin version`. `mysqladmin` can be found in the '`bin`' directory under your MySQL installation directory.
- The manufacturer and model of the machine on which you experience the problem.
- The operating system name and version. For most operating systems, you can get this information by executing the Unix command `uname -a`. If you work with Windows, you can usually get the name and version number by double-clicking your "My Computer" icon and pulling down the "Help/About Windows" menu.
- Sometimes the amount of memory (real and virtual) is relevant. If in doubt, include these values.
- If you are using a source distribution of the MySQL software, the name and version number of the compiler used is needed. If you have a binary distribution, the distribution name is needed.
- If the problem occurs during compilation, include the exact error message(s) and also a few lines of context around the offending code in the file where the error occurrs.
- If `mysqld` died, you should also report the query that crashed `mysqld`. You can usually find this out by running `mysqld` with logging enabled. See Section E.1.5 [Using log files], page 1011.
- If a database table is related to the problem, include the output from `mysqldump --no-data db_name tbl_name1 tbl_name2 ...`. This is very easy to do and is a powerful way to get information about any table in a database. The information will help us create a situation matching the one you have.
- For speed-related bugs or problems with `SELECT` statements, you should always include the output of `EXPLAIN SELECT ...`, and at least the number of rows that the `SELECT` statement produces. You should also include the output from `SHOW CREATE TABLE tbl_name` for each involved table. The more information you give about your situation, the more likely it is that someone can help you. The following is an example of a very good bug report (it should of course be posted with the `mysqlbug` script).

  Example run using the `mysql` command-line tool (note the use of the `\G` statement terminator for statements whose output width would otherwise exceed that of an 80-column display device):

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

- If a bug or problem occurs while running `mysqld`, try to provide an input script that will reproduce the anomaly. This script should include any necessary source files. The more closely the script can reproduce your situation, the better. If you can make a reproducible test case, you should post it on `http://bugs.mysql.com/` for high-priority treatment.

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

- If you can't produce a test case with only a few rows, or if the test table is too big to be mailed to the mailing list (more than 10 rows), you should dump your tables using `mysqldump` and create a '`README`' file that describes your problem.

  Create a compressed archive of your files using `tar` and `gzip` or `zip`, and use `ftp` to transfer the archive to `ftp://support.mysql.com/pub/mysql/secret/`. Then enter the problem into our bugs database at `http://bugs.mysql.com/`.

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

- When giving an example of the problem, it's better to use the variable names, table names, etc., that exist in your actual situation than to come up with new names. The problem could be related to the name of a variable or table. These cases are rare, perhaps, but it is better to be safe than sorry. After all, it should be easier for you to provide an example that uses your actual situation, and it is by all means better for us. In case you have data you don't want to show to others, you can use `ftp` to transfer it to `ftp://support.mysql.com/pub/mysql/secret/`. If the data is really top secret and you don't want to show it even to us, then go ahead and provide an example using other names, but please regard this as the last choice.

- Include all the options given to the relevant programs, if possible. For example, indicate the options that you use when you start the `mysqld` daemon as well as the options that you use to run any MySQL client programs. The options to programs like `mysqld` and `mysql`, and to the `configure` script, are often keys to answers and are very relevant. It is never a bad idea to include them. If you use any modules, such as Perl or PHP, please include the version number(s) of those as well.

- If your question is related to the privilege system, please include the output of `mysqlaccess`, the output of `mysqladmin reload`, and all the error messages you

get when trying to connect. When you test your privileges, you should first run `mysqlaccess`. After this, execute `mysqladmin reload version` and try to connect with the program that gives you trouble. `mysqlaccess` can be found in the '`bin`' directory under your MySQL installation directory.

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

  If we can't verify exactly what the patch is meant for, we won't use it. Test cases will help us here. Show that the patch will handle all the situations that may occur. If we find a borderline case (even a rare one) where the patch won't work, it may be useless.
- Guesses about what the bug is, why it occurs, or what it depends on are usually wrong. Even the MySQL team can't guess such things without first using a debugger to determine the real cause of a bug.
- Indicate in your bug report that you have checked the reference manual and mail archive so that others know you have tried to solve the problem yourself.
- If you get a `parse error`, please check your syntax closely. If you can't find something wrong with it, it's extremely likely that your current version of MySQL Server doesn't support the syntax you are using. If you are using the current version and the manual at `http://www.mysql.com/doc/` doesn't cover the syntax you are using, MySQL Server doesn't support your query. In this case, your only options are to implement the syntax yourself or e-mail `licensing@mysql.com` and ask for an offer to implement it.

  If the manual covers the syntax you are using, but you have an older version of MySQL Server, you should check the MySQL change history to see when the syntax was implemented. In this case, you have the option of upgrading to a newer version of MySQL Server. See Appendix D [News], page 889.
- If your problem is that your data appears corrupt or you get errors when you access a particular table, you should first check and then try repairing your tables with `myisamchk` or `CHECK TABLE` and `REPAIR TABLE`. See Chapter 4 [MySQL Database Administration], page 195.
- If you often get corrupted tables you should try to find out when and why this happens. In this case, the '`mysql-data-directory/'hostname'.err`' file may contain some information about what happened. See Section 4.10.1 [Error log], page 350. Please include any relevant information from this file in your bug report. Normally `mysqld` should **never** crash a table if nothing killed it in the middle of an update. If you can find the cause of `mysqld` dying, it's much easier for us to provide you with a fix for the problem. See Section A.1 [What is crashing], page 846.
- If possible, download and install the most recent version of MySQL Server and check whether it solves your problem. All versions of the MySQL software are thoroughly tested and should work without problems. We believe in making everything as backward-compatible as possible, and you should be able to switch MySQL versions without difficulty. See Section 2.2.4 [Which version], page 75.

If you are a support customer, please cross-post the bug report to `mysql-support@mysql.com` for higher-priority treatment, as well as to the appropriate mailing list to see if someone else has experienced (and perhaps solved) the problem.

For information on reporting bugs in `MyODBC`, see Section 11.2.4 [ODBC Problems], page 809.

For solutions to some common problems, see Appendix A [Problems], page 846.

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

1.6.1.4 Guidelines for Answering Questions on the Mailing List

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

Try to summarise the essential part of the question in your reply; don't feel obliged to quote the entire original message.

Please don't post mail messages from your browser with HTML mode turned on. Many users don't read mail with a browser.

1.6.2 MySQL Community Support on IRC (Internet Relay Chat)

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

- **freenode** (see `http://www.freenode.net/` for servers)
  - `#mysql` Primarily MySQL questions but other database and SQL questions welcome.
  - `#mysqlphp` Questions about MySQL+PHP, a popular combination.
  - `#mysqlperl` Questions about MySQL+Perl, another popular combination.
- **EFnet** (see `http://www.efnet.org/` for servers)
  - `#mysql` MySQL questions.

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

1.7 MySQL Standards Compliance

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

Our goal is to not, without a very good reason, restrict MySQL Server usability for any usage. Even if we don't have the resources to do development for every possible use, we are always willing to help and offer suggestions to people who are trying to use MySQL Server in new territories.

One of our main goals with the product is to continue to work toward compliance with the SQL-99 standard, but without sacrificing speed or reliability. We are not afraid to add extensions to SQL or support for non-SQL features if this greatly increases the usability of MySQL Server for a big part of our users. (The new `HANDLER` interface in MySQL Server 4.0 is an example of this strategy. See Section 6.4.9 [`HANDLER`], page 562.)

We will continue to support transactional and non-transactional databases to satisfy both heavy web/logging usage and mission-critical 24/7 usage.

MySQL Server was designed from the start to work with medium size databases (10-100 million rows, or about 100 MB per table) on small computer systems. We will continue to extend MySQL Server to work even better with terabyte-size databases, as well as to make it possible to compile a reduced MySQL version that is more suitable for hand-held devices and embedded usage. The compact design of the MySQL server makes both of these directions possible without any conflicts in the source tree.

We are currently not targeting realtime support or clustered databases (even if you can already do a lot of things with our replication services).

We are looking at providing XML support in the database server.

1.7.1 What Standards MySQL Follows

Entry-level SQL-92. ODBC levels 0-3.51.

We are aiming toward supporting the full SQL-99 standard, but without concessions to speed and quality of the code.

1.7.2 Running MySQL in ANSI Mode

If you start `mysqld` with the `--ansi` or `--sql-mode=ANSI` option, the following behaviours of MySQL Server change:

- `||` is a string concatenation operator rather than a synonym for `OR`.
- '`"`' is treated as an identifier quote character (like the MySQL Server '`` ` ``' quote character) and not as a string quote character. You can still use '`` ` ``' to quote identifers in ANSI mode. An implication of this is that you cannot use double quotes to quote a literal string, because it will be intepreted as an identifier.
- You can have any number of spaces between a function name and the '`(`' character. This forces all function names to be treated as reserved words. As a result, if you want to access any database, table, or column name that is a reserved word, you must quote it. For example, because there is a `USER()` function, the name of the `user` table in the `mysql` database and the `User` column in that table become reserved, so you must quote them:

```
SELECT "User" FROM mysql."user";
```

- `REAL` is a synonym for `FLOAT` instead of a synonym for `DOUBLE`.
- The default transaction isolation level is `SERIALIZABLE`. See Section 6.7.6 [`SET TRANSACTION`], page 583.
- You can use a field/expression in `GROUP BY` that is not in the field list.

Running the server in ANSI mode is the same as starting it with these options:

```
--sql-mode=REAL_AS_FLOAT,PIPES_AS_CONCAT,ANSI_QUOTES,IGNORE_SPACE,ONLY_FULL_GROUP_BY
--transaction-isolation=SERIALIZABLE
```

In MySQL 4.1, you can achieve the same effect with these two statements:

```
SET GLOBAL TRANSACTION ISOLATION LEVEL SERIALIZABLE;
SET GLOBAL sql_mode =
  "REAL_AS_FLOAT,PIPES_AS_CONCAT,ANSI_QUOTES,IGNORE_SPACE,ONLY_FULL_GROUP_BY";
```

In MySQL 4.1.1, the `sql_mode` options shown can be also be set with:

```
SET GLOBAL sql_mode="ansi";
```

In this case, the value of the `sql_mode` variable will be set to all options that are relevant for ANSI mode. You can check the result by doing:

```
mysql> SET GLOBAL sql_mode="ansi";
mysql> SELECT @@GLOBAL.sql_mode;
         -> "REAL_AS_FLOAT,PIPES_AS_CONCAT,ANSI_QUOTES,IGNORE_SPACE,ONLY_FULL_GROUP_BY
```

1.7.3 MySQL Extensions to the SQL-92 Standard

MySQL Server includes some extensions that you probably will not find in other SQL databases. Be warned that if you use them, your code will not be portable to other SQL servers. In some cases, you can write code that includes MySQL extensions, but is still portable, by using comments of the form `/*! ... */`. In this case, MySQL Server will parse and execute the code within the comment as it would any other MySQL statement, but other SQL servers will ignore the extensions. For example:

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

If you add a version number after the `'!'`, the syntax will be executed only if the MySQL version is equal to or newer than the used version number:

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

This means that if you have Version 3.23.02 or newer, MySQL Server will use the `TEMPORARY` keyword.

The following is a list of MySQL extensions:

- The field types `MEDIUMINT`, `SET`, `ENUM`, and the different `BLOB` and `TEXT` types.
- The field attributes `AUTO_INCREMENT`, `BINARY`, `NULL`, `UNSIGNED`, and `ZEROFILL`.
- All string comparisons are case-insensitive by default, with sort ordering determined by the current character set (ISO-8859-1 Latin1 by default). If you don't like this, you should declare your columns with the `BINARY` attribute or use the `BINARY` cast, which causes comparisons to be done according to the ASCII order used on the MySQL server host.
- MySQL Server maps each database to a directory under the MySQL data directory, and tables within a database to filenames in the database directory.

  This has a few implications:

  – Database names and table names are case-sensitive in MySQL Server on operating systems that have case-sensitive filenames (like most Unix systems). See Section 6.1.3 [Name case sensitivity], page 445.

  - Database, table, index, column, or alias names may begin with a digit (but may not consist solely of digits).
  - You can use standard system commands to back up, rename, move, delete, and copy tables. For example, to rename a table, rename the '`.MYD`', '`.MYI`', and '`.frm`' files to which the table corresponds.
- In SQL statements, you can access tables from different databases with the `db_name.tbl_name` syntax. Some SQL servers provide the same functionality but call this `User space`. MySQL Server doesn't support tablespaces as in: `create table ralph.my_table...IN my_tablespace`.
- `LIKE` is allowed on numeric columns.
- Use of `INTO OUTFILE` and `STRAIGHT_JOIN` in a `SELECT` statement. See Section 6.4.1 [`SELECT`], page 530.
- The `SQL_SMALL_RESULT` option in a `SELECT` statement.
- `EXPLAIN SELECT` to get a description of how tables are joined.
- Use of index names, indexes on a prefix of a field, and use of `INDEX` or `KEY` in a `CREATE TABLE` statement. See Section 6.5.3 [`CREATE TABLE`], page 564.
- Use of `TEMPORARY` or `IF NOT EXISTS` with `CREATE TABLE`.
- Use of `COUNT(DISTINCT list)` where `list` has more than one element.
- Use of `CHANGE col_name`, `DROP col_name`, or `DROP INDEX`, `IGNORE` or `RENAME` in an `ALTER TABLE` statement. See Section 6.5.4 [`ALTER TABLE`], page 573.
- Use of `RENAME TABLE`. See Section 6.5.5 [`RENAME TABLE`], page 577.
- Use of multiple `ADD`, `ALTER`, `DROP`, or `CHANGE` clauses in an `ALTER TABLE` statement.
- Use of `DROP TABLE` with the keywords `IF EXISTS`.
- You can drop multiple tables with a single `DROP TABLE` statement.
- The `ORDER BY` and `LIMIT` clauses of the `UPDATE` and `DELETE` statements.
- `INSERT INTO ... SET col_name = ...` syntax.
- The `DELAYED` clause of the `INSERT` and `REPLACE` statements.
- The `LOW_PRIORITY` clause of the `INSERT`, `REPLACE`, `DELETE`, and `UPDATE` statements.
- Use of `LOAD DATA INFILE`. In many cases, this syntax is compatible with Oracle's `LOAD DATA INFILE`. See Section 6.4.8 [`LOAD DATA`], page 555.
- The `ANALYZE TABLE`, `CHECK TABLE`, `OPTIMIZE TABLE`, and `REPAIR TABLE` statements.
- The `SHOW` statement. See Section 4.6.8 [`SHOW`], page 284.
- Strings may be enclosed by either '`"`' or '`'`', not just by '`'`'.
- Use of the escape '`\`' character.
- The `SET` statement. See Section 5.5.6 [`SET`], page 432.
- You don't need to name all selected columns in the `GROUP BY` part. This gives better performance for some very specific, but quite normal queries. See Section 6.3.7 [Group by functions and modifiers], page 524.
- One can specify `ASC` and `DESC` with `GROUP BY`.
- To make it easier for users who come from other SQL environments, MySQL Server supports aliases for many functions. For example, all string functions support both standard SQL syntax and ODBC syntax.

- MySQL Server understands the `||` and `&&` operators to mean logical OR and AND, as in the C programming language. In MySQL Server, `||` and `OR` are synonyms, as are `&&` and `AND`. Because of this nice syntax, MySQL Server doesn't support the standard SQL-99 `||` operator for string concatenation; use `CONCAT()` instead. Because `CONCAT()` takes any number of arguments, it's easy to convert use of the `||` operator to MySQL Server.
- `CREATE DATABASE` or `DROP DATABASE`. See Section 6.5.1 [`CREATE DATABASE`], page 563.
- The `%` operator is a synonym for `MOD()`. That is, `N % M` is equivalent to `MOD(N,M)`. `%` is supported for C programmers and for compatibility with PostgreSQL.
- The `=`, `<>`, `<=` ,`<`, `>=`,`>`, `<<`, `>>`, `<=>`, `AND`, `OR`, or `LIKE` operators may be used in column comparisons to the left of the `FROM` in `SELECT` statements. For example:

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

- The `LAST_INSERT_ID()` function. See Section 11.1.3.31 [`mysql_insert_id()`], page 743.
- The `REGEXP` and `NOT REGEXP` extended regular expression operators.
- `CONCAT()` or `CHAR()` with one argument or more than two arguments. (In MySQL Server, these functions can take any number of arguments.)
- The `BIT_COUNT()`, `CASE`, `ELT()`, `FROM_DAYS()`, `FORMAT()`, `IF()`, `PASSWORD()`, `ENCRYPT()`, `MD5()`, `ENCODE()`, `DECODE()`, `PERIOD_ADD()`, `PERIOD_DIFF()`, `TO_DAYS()`, or `WEEKDAY()` functions.
- Use of `TRIM()` to trim substrings. SQL-99 supports removal of single characters only.
- The `GROUP BY` functions `STD()`, `BIT_OR()`, `BIT_AND()`, `BIT_XOR()`, and `GROUP_CONCAT()`. See Section 6.3.7 [Group by functions and modifiers], page 524.
- Use of `REPLACE` instead of `DELETE + INSERT`. See Section 6.4.7 [`REPLACE`], page 554.
- The `FLUSH`, `RESET` and `DO` statements.
- The ability to set variables in a statement with `:=`:

```
SELECT @a:=SUM(total),@b=COUNT(*),@a/@b AS avg FROM test_table;
SELECT @t1:=(@t2:=1)+@t3:=4,@t1,@t2,@t3;
```

1.7.4 MySQL Differences Compared to SQL-92

We try to make MySQL Server follow the ANSI SQL standard (SQL-92/SQL-99) and the ODBC SQL standard, but in some cases MySQL Server does things differently:

- For `VARCHAR` columns, trailing spaces are removed when the value is stored. See Section 1.7.6 [Bugs], page 44.
- In some cases, `CHAR` columns are silently changed to `VARCHAR` columns. See Section 6.5.3.1 [Silent column changes], page 573.
- Privileges for a table are not automatically revoked when you delete a table. You must explicitly issue a `REVOKE` to revoke privileges for a table. See Section 4.4.1 [`GRANT`], page 239.

For a prioritised list indicating when new extensions will be added to MySQL Server, you should consult the online MySQL TODO list at `http://www.mysql.com/doc/en/TODO.html`. That is the latest version of the TODO list in this manual. See Section 1.8 [TODO], page 49.

1.7.4.1 Subqueries

MySQL Version 4.1 supports subqueries and derived tables (unnamed views). See Section 6.4.2 [Subqueries], page 537.

For MySQL versions prior to 4.1, most subqueries can be successfully rewritten using joins and and other methods. See Section 6.4.2.11 [Rewriting subqueries], page 545.

1.7.4.2 SELECT INTO TABLE

MySQL Server doesn't yet support the Oracle SQL extension: `SELECT ... INTO TABLE ...`. Instead, MySQL Server supports the SQL-99 syntax `INSERT INTO ... SELECT ...`, which is basically the same thing. See Section 6.4.3.1 [INSERT SELECT], page 549.

```
INSERT INTO tblTemp2 (fldID)
       SELECT tblTemp1.fldOrder_ID
       FROM tblTemp1 WHERE tblTemp1.fldOrder_ID > 100;
```

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

1.7.4.3 Transactions and Atomic Operations

MySQL Server (version 3.23-max and all versions 4.0 and above) supports transactions with the `InnoDB` and `BDB Transactional storage engines`. `InnoDB` provides *full* `ACID` compliance. See Chapter 7 [Table types], page 594.

The other non-transactional table types (such as `MyISAM`) in MySQL Server follow a different paradigm for data integrity called "`Atomic Operations`." In transactional terms, `MyISAM` tables effectively always operate in `AUTOCOMMIT=1` mode. Atomic operations often offer comparable integrity with higher performance.

With MySQL Server supporting both paradigms, the user is able to decide if he needs the speed of atomic operations or if he needs to use transactional features in his applications. This choice can be made on a per-table basis.

As noted, the trade off for transactional vs. non-transactional table types lies mostly in performance. Transactional tables have significantly higher memory and diskspace requirements, and more CPU overhead. That said, transactional table types such as `InnoDB` do of course offer many unique features. MySQL Server's modular design allows the concurrent use of all these different storage engines to suit different requirements and deliver optimum performance in all situations.

But how does one use the features of MySQL Server to maintain rigorous integrity even with the non-transactional `MyISAM` tables, and how do these features compare with the transactional table types?

1. In the transactional paradigm, if your applications are written in a way that is dependent on the calling of `ROLLBACK` instead of `COMMIT` in critical situations, transactions are more convenient. Transactions also ensure that unfinished updates or corrupting activities are not committed to the database; the server is given the opportunity to do an automatic rollback and your database is saved.

   MySQL Server, in almost all cases, allows you to resolve potential problems by including simple checks before updates and by running simple scripts that check the databases

for inconsistencies and automatically repair or warn if such an inconsistency occurs. Note that just by using the MySQL log or even adding one extra log, one can normally fix tables perfectly with no data integrity loss.

2. More often than not, critical transactional updates can be rewritten to be atomic. Generally speaking, all integrity problems that transactions solve can be done with `LOCK TABLES` or atomic updates, ensuring that you never will get an automatic abort from the server, which is a common problem with transactional database systems.
3. Even a transactional system can lose data if the server goes down. The difference between different systems lies in just how small the time-lap is where they could lose data. No system is 100% secure, only "secure enough." Even Oracle, reputed to be the safest of transactional database systems, is reported to sometimes lose data in such situations.

   To be safe with MySQL Server, whether using transactional tables or not, you only need to have backups and have the binary logging turned on. With this you can recover from any situation that you could with any other transactional database system. It is, of course, always good to have backups, independent of which database system you use.

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

In situations where integrity is of highest importance, MySQL Server offers transaction-level reliability and integrity even for non-transactional tables. If you lock tables with `LOCK TABLES`, all updates will stall until any integrity checks are made. If you only obtain a read lock (as opposed to a write lock), reads and inserts are still allowed to happen. The new inserted records will not be seen by any of the clients that have a read lock until they release their read locks. With `INSERT DELAYED` you can queue inserts into a local queue, until the locks are released, without having the client wait for the insert to complete. See Section 6.4.3.2 [INSERT DELAYED], page 550.

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

Following are some techniques for working with non-transactional tables:

- Loops that need transactions normally can be coded with the help of `LOCK TABLES`, and you don't need cursors to update records on the fly.
- To avoid using `ROLLBACK`, you can use the following strategy:
  1. Use `LOCK TABLES ...` to lock all the tables you want to access.
  2. Test conditions.
  3. Update if everything is okay.
  4. Use `UNLOCK TABLES` to release your locks.

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

- You can also use functions to update records in a single operation. You can get a very efficient application by using the following techniques:
  - Modify fields relative to their current value.
  - Update only those fields that actually have changed.

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

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

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

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

  As you can see, this is very efficient and works even if another client has changed the values in the pay_back or money_he_owes_us columns.

- In many cases, users have wanted ROLLBACK and/or LOCK TABLES for the purpose of managing unique identifiers for some tables. This can be handled much more efficiently by using an AUTO_INCREMENT column and either the SQL function LAST_INSERT_ID() or the C API function mysql_insert_id(). See Section 11.1.3.31 [mysql_insert_id()], page 743.

  You can generally code around row-level locking. Some situations really need it, and InnoDB tables support row-level locking. With MyISAM, you can use a flag column in the table and do something like the following:

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

  MySQL returns 1 for the number of affected rows if the row was found and row_flag wasn't already 1 in the original row.

  You can think of it as though MySQL Server changed the preceding query to:

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

1.7.4.4 Stored Procedures and Triggers

Stored procedures are being implemented in our version 5.0 development tree. See Section 2.3.4 [Installing source tree], page 94.

This effort is based on SQL-99, which has a basic syntax similar (but not identical) to Oracle PL/SQL. In addition to this, we are implementing the SQL-99 framework to hook in external languages.

A stored procedure is a set of SQL commands that can be compiled and stored in the server. Once this has been done, clients don't need to keep re-issuing the entire query but can refer to the stored procedure. This provides better overall performance because the query has to be parsed only once, and less information needs to be sent between the server and the client. You can also raise the conceptual level by having libraries of functions in the server. However, stored procedures of course do increase the load on the database server system, as more of the work is done on the server side and less on the client (application) side.

Triggers are scheduled for implementation in MySQL version 5.1. A trigger is effectively a type of stored procedure, one that is invoked when a particular event occurs. For example, you could set up a stored procedure that is triggered each time a record is deleted from a transactional table and that stored procedure automatically deletes the corresponding customer from a customer table when all their transactions are deleted.

1.7.4.5 Foreign Keys

In MySQL Server 3.23.44 and up, `InnoDB` tables support checking of foreign key constraints, including `CASCADE`, `ON DELETE`, and `ON UPDATE`. See Section 7.5.5.2 [InnoDB foreign key constraints], page 615.

For other table types, MySQL Server currently only parses the `FOREIGN KEY` syntax in `CREATE TABLE` commands, but does not use/store this info. In the near future this implementation will be extended so that the information is stored in the table specification file and may be retrieved by `mysqldump` and ODBC. At a later stage, foreign key constraints will be implemented for `MyISAM` tables as well.

Note that foreign keys in SQL are not used to join tables, but are used for checking and enforcing referential integrity (foreign key constraints). If you want to get results from multiple tables from a `SELECT` statement, you do this by joining tables:

```
SELECT * FROM table1,table2 WHERE table1.id = table2.id;
```

See Section 6.4.1.1 [JOIN], page 535. See Section 3.6.6 [example-Foreign keys], page 186.

When used as a constraint, `FOREIGN KEY`s don't need to be used if the application inserts rows into `MyISAM` tables in the proper order.

For `MyISAM` tables, you can work around the lack of `ON DELETE` by adding the appropriate `DELETE` statement to an application when you delete records from a table that has a foreign key. In practice this is as quick (in some cases quicker) and much more portable than using foreign keys.

In MySQL Server 4.0 you can use multi-table delete to delete rows from many tables with one command. See Section 6.4.5 [DELETE], page 552.

The `FOREIGN KEY` syntax without `ON DELETE ...` is often used by ODBC applications to produce automatic `WHERE` clauses.

Do keep in mind that foreign keys are often misused, which can cause severe problems. Even when used properly, it is not a magic solution for the referential integrity problem, although it can make things easier.

Some advantages of foreign key enforcement:

- Assuming proper design of the relations, foreign key constraints will make it more difficult for a programmer to introduce an inconsistency into the database.
- Using cascading updates and deletes can simplify the client code.
- Properly designed foreign key rules aid in documenting relations between tables.

Disadvantages:

- Mistakes, which are easy to make in designing key relations, can cause severe problems—for example, circular rules, or the wrong combination of cascading deletes.
- Additional checking on the database level affects performance, for this reason some major commercial applications have coded this logic on the application level.
- It is not uncommon for a DBA to make such a complex topology of relations that it becomes very difficult, and in some cases impossible, to back up or restore individual tables.

1.7.4.6 Views

Views are currently being implemented, and will appear in the 5.0 or 5.1 version of MySQL Server.

Historically, MySQL Server has been most used in applications and on web systems where the application writer has full control over database usage. Of course, usage has shifted over time, and so we find that an increasing number of users now regard views as an important aspect.

Unnamed views (*derived tables*, a subquery in the `FROM` clause of a `SELECT`) are already implemented in version 4.1.

Views are useful for allowing users to access a set of relations (tables) as if it were a single table, and limiting their access to just that. Views can also be used to restrict access to rows (a subset of a particular table). One does not require views to restrict access to columns, as MySQL Server has a sophisticated privilege system. See Section 4.3 [Privilege system], page 213.

Many DBMS don't allow updates to a view, instead you have to perform the updates on the individual tables. In designing our implementation of views, we aim toward (as fully as possible within the confines of SQL) compliance with "**Codd's Rule #6**" for relational database systems: all views that are theoretically updatable, should in practice also be updatable.

1.7.4.7 '--' as the Start of a Comment

Some other SQL databases use '`--`' to start comments. MySQL Server has '`#`' as the start comment character. You can also use the C comment style `/* this is a comment */` with MySQL Server. See Section 6.1.6 [Comments], page 450.

MySQL Server Version 3.23.3 and above support the '`--`' comment style, provided the comment is followed by a space (or by a control character such as a newline). This is because this comment style has caused many problems with automatically generated SQL queries that have used something like the following code, where we automatically insert the value of the payment for `!payment!`:

```
UPDATE tbl_name SET credit=credit-!payment!
```

Think about what happens if the value of `payment` is negative. Because `1--1` is legal in SQL, the consequences of allowing comments to start with '`--`' are terrible.

Using our implementation of this method of commenting in MySQL Server Version 3.23.3 and up, `1-- This is a comment` is actually safe.

Another safe feature is that the `mysql` command-line client removes all lines that start with '`--`'.

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

If you have an SQL program in a text file that contains '`--`' comments you should use:

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

instead of the usual:

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

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

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

Change them back with this command:

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

1.7.5 How MySQL deals with constraints

As MySQL allows you to work with both transactional and non-transactional tables (which don't allow rollback), constraint handling is a bit different in MySQL than in other databases.

We have to handle the case when you have updated a lot of rows with a non-transactional table which can't rollback on errors.

The basic philosophy is to try to give an error for anything that we can detect on compile time but try to recover from any errors we get run time. We do this in most cases, but not yet for all. See Section 1.8.4 [TODO future], page 51.

The basic options MySQL has is to stop the statement in the middle or do its best to recover from the problem and continue.

Here follows what happens with the different types of constraints.

1.7.5.1 Constraint PRIMARY KEY / UNIQUE

Normally you will get an error when you try to `INSERT` / `UPDATE` a row that causes a primary key, unique key or foreign key violation. If you are using a transactional storage engine, like InnoDB, MySQL will automatically roll back the transaction. If you are using a non-transactional storage engine MySQL will stop at the wrong row and leave the rest of the rows unprocessed.

To make life easier MySQL has added support for the `IGNORE` directive to most commands that can cause a key violation (like `INSERT IGNORE ...`). In this case MySQL will ignore any key violation and continue with processing the next row. You can get information of what MySQL did with the `mysql_info()` API function and in later MySQL 4.1 version with the `SHOW WARNINGS` command. See Section 11.1.3.29 [mysql_info], page 741. See Section 4.6.8.9 [SHOW WARNINGS], page 303.

Note that for the moment only `InnoDB` tables support foreign keys. See Section 7.5.5.2 [InnoDB foreign key constraints], page 615. Foreign key support in `MyISAM` tables is scheduled for inclusion in the MySQL 5.0 source tree.

1.7.5.2 Constraint `NOT NULL` and `DEFAULT` values

To be able to support easy handling of non-transactional tables all fields in MySQL have default values.

If you insert a 'wrong' value in a column like a `NULL` in a `NOT NULL` column or a too big numerical value in a numerical column, MySQL will instead of giving an error instead set the column to the 'best possible value'. For numerical values this is 0, the smallest possible values or the largest possible value. For strings this is either the empty string or the longest possible string that can be in the column.

This means that if you try to store `NULL` into a column that doesn't take `NULL` values, MySQL Server will store 0 or `''` (empty string) in it instead. This last behaviour can, for single row inserts, be changed with the `-DDONT_USE_DEFAULT_FIELDS` compile option.) See Section 2.3.3 [configure options], page 91. This causes `INSERT` statements to generate an error unless you explicitly specify values for all columns that require a non-`NULL` value.

The reason for the above rules is that we can't check these conditions before the query starts to execute. If we encounter a problem after updating a few rows, we can't just rollback as the table type may not support this. The option to stop is not that good as in this case the update would be 'half done' which is probably the worst possible scenario. In this case it's better to 'do the best you can' and then continue as if nothing happened. In MySQL 5.0 we plan to improve this by providing warnings for automatic field conversions, plus an option to let you roll back statements that only use transactional tables in case one such statement does a field assignment that is not allowed.

The above means that one should generally not use MySQL to check field content, but instead handle this in the application.

1.7.5.3 Constraint ENUM and SET

In MySQL 4.x ENUM is not a real constrain but a more efficient way to store fields that can only contain a given set of values. This is because of the same reasons NOT NULL is not honoured. See Section 1.7.5.2 [constraint NOT NULL], page 43.

If you insert an wrong value in an ENUM field, it will be set to the reserved enum number 0, which will be displayed as an empty string in string context. See Section 6.2.3.3 [ENUM], page 469.

If you insert an wrong option in a SET field, the wrong value will be ignored. See Section 6.2.3.4 [SET], page 470.

1.7.6 Known Errors and Design Deficiencies in MySQL

1.7.6.1 Errors in 3.23 Fixed in a Later MySQL Version

The following known errors/bugs are not fixed in MySQL 3.23 because fixing them would involves changing a lot of code which could introduce other even worse bugs. The bugs are also classified as 'not fatal' or 'bearable'.

- One can get a deadlock when doing LOCK TABLE on multiple tables and then in the same connection doing a DROP TABLE on one of them while another thread is trying to lock the table. One can however do a KILL on any of the involved threads to resolve this. Fixed in 4.0.12.
- SELECT MAX(key_column) FROM t1,t2,t3... where one of the tables are empty doesn't return NULL but instead the maximum value for the column. Fixed in 4.0.11.
- DELETE FROM heap_table without a WHERE doesn't work on a locked HEAP table.

1.7.6.2 Open Bugs / Design Deficiencies in MySQL

The following problems are known and fixing them is a high priority:

- FLUSH TABLES WITH READ LOCK does not block CREATE TABLE or COMMIT, which make cause a problem with the binary log position when doing a full backup of tables and the binary log.
- ANALYZE TABLE on a BDB table may in some cases make the table unusable until one has restarted mysqld. When this happens you will see errors like the following in the MySQL error file:

```
001207 22:07:56  bdb:  log_flush: LSN past current end-of-log
```

- MySQL accepts parentheses in the FROM part, but silently ignores them. The reason for not giving an error is that many clients that automatically generate queries add parentheses in the FROM part even where they are not needed.
- Concatenating many RIGHT JOINS or combining LEFT and RIGHT join in the same query may not give a correct answer as MySQL only generates NULL rows for the table preceding a LEFT or before a RIGHT join. This will be fixed in 5.0 at the same time we add support for parentheses in the FROM part.

- Don't execute `ALTER TABLE` on a `BDB` table on which you are running multi-statement transactions until all those transactions complete. (The transaction will probably be ignored.)
- `ANALYZE TABLE`, `OPTIMIZE TABLE`, and `REPAIR TABLE` may cause problems on tables for which you are using `INSERT DELAYED`.
- Doing a `LOCK TABLE ...` and `FLUSH TABLES ...` doesn't guarantee that there isn't a half-finished transaction in progress on the table.
- BDB tables are a bit slow to open. If you have many BDB tables in a database, it will take a long time to use the `mysql` client on the database if you are not using the `-A` option or if you are using `rehash`. This is especially notable when you have a big table cache.
- Replication uses query-level logging: the master writes the executed queries to the binary log. This is a very fast, compact, and efficient logging method that works perfectly in most cases. Though we have never heard of it actually occurring, it is theoretically possible for the data on the master and slave to become different if a query is designed in such a way that the data modification is non-deterministic, that is, left to the will of the query optimiser (which generally is not a good practice, even outside of replication!). For example:
  - `CREATE ... SELECT` or `INSERT ... SELECT` which feeds zeros or `NULL`s into an `auto_increment` column.
  - `DELETE` if you are deleting rows from a table which has foreign keys with `ON DELETE CASCADE` properties.
  - `REPLACE ... SELECT`, `INSERT IGNORE ... SELECT` if you have duplicate key values in the inserted data.

  IF and only if all these queries have NO `ORDER BY` clause guaranteeing a deterministic order.

  Indeed, for example for `INSERT ... SELECT` with no `ORDER BY`, the `SELECT` may return rows in a different order (which will result in a row having different ranks, hence getting a different number in the `auto_increment` column), depending on the choices made by the optimisers on the master and slave. A query will be optimised differently on the master and slave only if:
  - The files used by the two queries are not exactly the same; for example `OPTIMIZE TABLE` was run on the master tables and not on the slave tables (to fix this, since MySQL 4.1.1, `OPTIMIZE`, `ANALYZE` and `REPAIR` are written to the binary log).
  - The table is stored in a different storage engine on the master than on the slave (one can run with different storage engines on the slave and master: for example InnoDB on the master and MyISAM on the slave, if the slave has less available disk space).
  - The MySQL buffers' sizes (`key_buffer_size` etc) are different on the master and slave.
  - The master and slave run different MySQL versions, and the optimiser code is different between these versions.

  This problem may also affect database restoration using `mysqlbinlog|mysql`.

The easiest way to avoid this problem in all cases is add an `ORDER BY` clause to such non-deterministic queries to ensure that the rows are always stored/modified in the same order. In future MySQL versions we will automatically add an `ORDER BY` clause when needed.

The following problems are known and will be fixed in due time:

- `LIKE` is not `multi-byte character` safe. Comparison is done character by character.
- When using `RPAD` function, or any other string function that ends up adding blanks to the right, in a query that has to use temporary table to be resolved, then all resulting strings will be RTRIM'ed. This is an example of the query:

  ```
  SELECT RPAD(t1.field1, 50, ' ') AS f2, RPAD(t2.field2, 50, ' ') AS f1
  FROM table1 as t1 LEFT JOIN table2 AS t2 ON t1.record=t2.joinID ORDER BY
  t2.record;
  ```

  Final result of this bug is that use will not be able to get blanks on the right side of the resulting field.

  The above behaviour exists in all versions of MySQL.

  The reason for this is due to the fact that HEAP tables, which are used first for temporary tables, are not capable of handling VARCHAR columns.

  This behaviour will be fixed in one of the 4.1 series releases.
- Because of how table definitions files are stored one can't use character 255 (`CHAR(255)`) in table names, column names or enums. This is scheduled to be fixed in version 5.1 when we have new table definition format files.
- When using `SET CHARACTER SET`, one can't use translated characters in database, table, and column names.
- One can't use `_` or `%` with `ESCAPE` in `LIKE ... ESCAPE`.
- If you have a `DECIMAL` column with a number stored in different formats (+01.00, 1.00, 01.00), `GROUP BY` may regard each value as a different value.
- `DELETE FROM merge_table` used without a `WHERE` will only clear the mapping for the table, not delete everything in the mapped tables.
- You cannot build the server in another directory when using MIT-pthreads. Because this requires changes to MIT-pthreads, we are not likely to fix this. See Section 2.3.6 [MIT-pthreads], page 99.
- `BLOB` values can't "reliably" be used in `GROUP BY` or `ORDER BY` or `DISTINCT`. Only the first `max_sort_length` bytes (default 1024) are used when comparing `BLOB`s in these cases. This can be changed with the `-O max_sort_length` option to `mysqld`. A workaround for most cases is to use a substring: `SELECT DISTINCT LEFT(blob,2048) FROM tbl_name`.
- Calculation is done with `BIGINT` or `DOUBLE` (both are normally 64 bits long). It depends on the function which precision one gets. The general rule is that bit functions are done with `BIGINT` precision, `IF`, and `ELT()` with `BIGINT` or `DOUBLE` precision and the rest with `DOUBLE` precision. One should try to avoid using unsigned long long values if they resolve to be bigger than 63 bits (9223372036854775807) for anything else than bit fields. MySQL Server 4.0 has better `BIGINT` handling than 3.23.

- All string columns, except `BLOB` and `TEXT` columns, automatically have all trailing spaces removed when retrieved. For `CHAR` types this is okay, and may be regarded as a feature according to SQL-92. The bug is that in MySQL Server, `VARCHAR` columns are treated the same way.
- You can only have up to 255 `ENUM` and `SET` columns in one table.
- In `MIN()`, `MAX()` and other aggregate functions, MySQL currently compares `ENUM` and `SET` columns by their string value rather than by the string's relative position in the set.
- `mysqld_safe` redirects all messages from `mysqld` to the `mysqld` log. One problem with this is that if you execute `mysqladmin refresh` to close and reopen the log, `stdout` and `stderr` are still redirected to the old log. If you use `--log` extensively, you should edit `mysqld_safe` to log to '`''hostname''.err`' instead of '`''hostname''.log`' so you can easily reclaim the space for the old log by deleting the old one and executing `mysqladmin refresh`.
- In the `UPDATE` statement, columns are updated from left to right. If you refer to an updated column, you will get the updated value instead of the original value. For example:

  ```
  mysql> UPDATE tbl_name SET KEY=KEY+1,KEY=KEY+1;
  ```

  This will update `KEY` with `2` instead of with `1`.
- You can refer to multiple temporary tables in the same query, but you cannot refer to any given temporary table more than once. For example, the following doesn't work:

  ```
  mysql> SELECT * FROM temporary_table, temporary_table AS t2;
  ```
- `RENAME` doesn't work with `TEMPORARY` tables or tables used in a `MERGE` table.
- The optimiser may handle `DISTINCT` differently if you are using 'hidden' columns in a join or not. In a join, hidden columns are counted as part of the result (even if they are not shown) while in normal queries hidden columns don't participate in the `DISTINCT` comparison. We will probably change this in the future to never compare the hidden columns when executing `DISTINCT`.

  An example of this is:

  ```
  SELECT DISTINCT mp3id FROM band_downloads
         WHERE userid = 9 ORDER BY id DESC;
  ```

  and

  ```
  SELECT DISTINCT band_downloads.mp3id
         FROM band_downloads,band_mp3
         WHERE band_downloads.userid = 9
         AND band_mp3.id = band_downloads.mp3id
         ORDER BY band_downloads.id DESC;
  ```

  In the second case you may in MySQL Server 3.23.x get two identical rows in the result set (because the hidden `id` column may differ).

  Note that this happens only for queries where you don't have the ORDER BY columns in the result, something that you are not allowed to do in SQL-92.
- Because MySQL Server allows you to work with table types that don't support transactions, and thus can't `rollback` data, some things behave a little differently in MySQL

Server than in other SQL servers. This is just to ensure that MySQL Server never needs to do a rollback for an SQL command. This may be a little awkward at times as column values must be checked in the application, but this will actually give you a nice speed increase as it allows MySQL Server to do some optimisations that otherwise would be very hard to do.

If you set a column to an incorrect value, MySQL Server will, instead of doing a rollback, store the `best possible value` in the column:

- If you try to store a value outside the range in a numerical column, MySQL Server will instead store the smallest or biggest possible value in the column.
- If you try to store a string that doesn't start with a number into a numerical column, MySQL Server will store 0 into it.
- If you try to store `NULL` into a column that doesn't take `NULL` values, MySQL Server will store 0 or `''` (empty string) in it instead. (This behaviour can, however, be changed with the -DDONT_USE_DEFAULT_FIELDS compile option.)
- MySQL allows you to store some wrong date values into `DATE` and `DATETIME` columns (like 2000-02-31 or 2000-02-00). The idea is that it's not the SQL server job to validate date. If MySQL can store a date and retrieve exactly the same date, then MySQL will store the date. If the date is totally wrong (outside the server's ability to store it), then the special date value 0000-00-00 will be stored in the column.
- If you set an `ENUM` column to an unsupported value, it will be set to the error value `empty string`, with numeric value 0.
- If you set a `SET` column to an unsupported value, the value will be ignored.

- If you execute a `PROCEDURE` on a query that returns an empty set, in some cases the `PROCEDURE` will not transform the columns.
- Creation of a table of type `MERGE` doesn't check if the underlying tables are of compatible types.
- MySQL Server can't yet handle `NaN`, `-Inf`, and `Inf` values in double. Using these will cause problems when trying to export and import data. We should as an intermediate solution change `NaN` to `NULL` (if possible) and `-Inf` and `Inf` to the minimum respective maximum possible `double` value.
- `LIMIT` on negative numbers are treated as big positive numbers.
- If you use `ALTER TABLE` to first add a `UNIQUE` index to a table used in a `MERGE` table and then use `ALTER TABLE` to add a normal index on the `MERGE` table, the key order will be different for the tables if there was an old key that was not unique in the table. This is because `ALTER TABLE` puts `UNIQUE` keys before normal keys to be able to detect duplicate keys as early as possible.

The following are known bugs in earlier versions of MySQL:

- You can get a hung thread if you do a `DROP TABLE` on a table that is one among many tables that is locked with `LOCK TABLES`.
- In the following case you can get a core dump:
  - Delayed insert handler has pending inserts to a table.
  - `LOCK table` with `WRITE`.

  - `FLUSH TABLES`.
- Before MySQL Server Version 3.23.2 an `UPDATE` that updated a key with a `WHERE` on the same key may have failed because the key was used to search for records and the same row may have been found multiple times:

  ```
  UPDATE tbl_name SET KEY=KEY+1 WHERE KEY > 100;
  ```

  A workaround is to use:

  ```
  mysql> UPDATE tbl_name SET KEY=KEY+1 WHERE KEY+0 > 100;
  ```

  This will work because MySQL Server will not use an index on expressions in the `WHERE` clause.
- Before MySQL Server Version 3.23, all numeric types were treated as fixed-point fields. That means you had to specify how many decimals a floating-point field shall have. All results were returned with the correct number of decimals.

For platform-specific bugs, see the sections about compiling and porting.

1.8 MySQL and the Future (The TODO)

This section summarises the features that we plan to implement in `MySQL Server`. The lists are broken up per version, and the items are approximately in the order they will be done.

Note: If you are an enterprise level user with an urgent need for a particular feature, please contact `sales@mysql.com` to discuss sponsoring options. Targeted financing by one or more companies allows us to allocate additional resources for that specific purpose. One example of a feature sponsored in the past is replication.

1.8.1 New Features Planned For 4.1

The features below are not yet implemented in MySQL 4.1, but are planned for implementation before MySQL 4.1 moves into its beta phase. For a list what is already done in MySQL 4.1, see Section 1.5.2.1 [Nutshell 4.1 features], page 22.

- Stable OpenSSL support (MySQL 4.0 supports rudimentary, not 100% tested, support for OpenSSL).
- Character set casts and syntax for handling multiple character sets.
- More testing of prepared statements and multiple characters sets for one table.

Development of other things has already shifted to the 5.0 tree.

1.8.2 New Features Planned For 5.0

The following features are planned for inclusion into MySQL 5.0. Note that because we have many developers that are working on different projects, there will also be many additional features. There is also a small chance that some of these features will be added to MySQL 4.1. For a list what is already done in MySQL 4.1, see Section 1.5.2.1 [Nutshell 4.1 features], page 22.

For those wishing to take a look at the bleeding edge of MySQL development, we have made our BitKeeper repository for MySQL version 5.0 publicly available. See Section 2.3.4 [Installing source tree], page 94.

Stored Procedures

- Stored procedures are currently being implemented. This effort is based on SQL-99, which has a basic syntax similar (but not identical) to Oracle PL/SQL. We will also implement the SQL-99 framework to hook in external languages, and (where possible) compatibility with, for example, PL/SQL and T-SQL.

New functionality

- Elementary cursor support.
- Visible `RTREE` index for MyISAM tables. In 4.1 RTREE indexes are used internally for geometrical data, but not directly usable.
- Dynamic length rows for HEAP tables.

Standards compliance, portability and migration

- Add true `VARCHAR` support (there is already support for this in `MyISAM`).

Speed enhancements

- `SHOW COLUMNS FROM table_name` (used by `mysql` client to allow expansions of column names) should not open the table, only the definition file. This will require less memory and be much faster.
- Allow `DELETE` on `MyISAM` tables to use the record cache. To do this, we need to update the threads record cache when we update the '`.MYD`' file.
- Better in-memory (`HEAP`) tables:
  - Dynamic size rows.
  - Faster row handling (less copying).

Internationalisation

- When using `SET CHARACTER SET` we should translate the whole query at once and not only strings. This will enable users to use the translated characters in database, table, and column names.

Usability enhancements

- Resolving the issue of `RENAME TABLE` on a table used in an active `MERGE` table possibly corrupting the table.

1.8.3 New Features Planned For 5.1

New functionality

- `FOREIGN KEY` support for all table types.
- Column-level constraints.
- Fail-safe replication.
- Online backup with very low performance penalty. The online backup will make it easy to add a new replication slave without taking down the master.

Speed enhancements

- New text based table definition file format ('`.frm`' files) and a table cache for table definitions. This will enable us to do faster queries of table structures and do more efficient foreign key support.

- Optimise `BIT` type to take 1 bit (now `BIT` takes 1 char).

Usability enhancements

- Add options to the client/server protocol to get progress notes for long running commands.
- Implement `RENAME DATABASE`. To make this safe for all storage engines, it should work as follows:
  - Create the new database.
  - For every table do a rename of the table to another database, as we do with the `RENAME` command.
  - Drop the old database.
- New internal file interface change. This will make all file handling much more general and make it easier to add extensions like RAID. (The current implementation is a hack.)

1.8.4 New Features Planned for the Near Future

New functionality

- Oracle-like `CONNECT BY PRIOR ...` to search tree-like (hierarchical) structures.
- Add all missing SQL-92 and ODBC 3.0 types.
- Add `SUM(DISTINCT)`.
- `INSERT SQL_CONCURRENT` and `mysqld --concurrent-insert` to do a concurrent insert at the end of the file if the file is read-locked.
- Allow update of variables in `UPDATE` statements. For example: `UPDATE TABLE foo SET @a=a+b,a=@a, b=@a+c`.
- Change when user variables are updated so that one can use them with `GROUP BY`, as in the following example: `SELECT id, @a:=COUNT(*), SUM(sum_col)/@a FROM table_name GROUP BY id`.
- Add an `IMAGE` option to `LOAD DATA INFILE` to not update `TIMESTAMP` and `AUTO_INCREMENT` fields.
- Added `LOAD DATA INFILE ... UPDATE` syntax.
  - For tables with primary keys, if the data contains the primary key, entries matching that primary key are updated from the remainder of the columns. However, columns **missing** from the incoming data feed are not touched.
  - For tables with primary keys that are missing some part of the key in the incoming data stream, or that have no primary key, the feed is treated as a `LOAD DATA INFILE ... REPLACE INTO` now.
- Make `LOAD DATA INFILE` understand syntax like:

```
LOAD DATA INFILE 'file_name.txt' INTO TABLE tbl_name
     TEXT_FIELDS (text_field1, text_field2, text_field3)
     SET table_field1=CONCAT(text_field1, text_field2),
         table_field3=23
```

```
IGNORE text_field3
```

This can be used to skip over extra columns in the text file, or update columns based on expressions of the read data.

- New functions for working with `SET` type columns:
  - `ADD_TO_SET(value,set)`
  - `REMOVE_FROM_SET(value,set)`
- If you abort `mysql` in the middle of a query, you should open another connection and kill the old running query. Alternatively, an attempt should be made to detect this in the server.
- Add a storage engine interface for table information so that you can use it as a system table. This would be a bit slow if you requested information about all tables, but very flexible. `SHOW INFO FROM tbl_name` for basic table information should be implemented.
- Allow `SELECT a FROM crash_me LEFT JOIN crash_me2 USING (a)`; in this case `a` is assumed to come from the `crash_me` table.
- `DELETE` and `REPLACE` options to the `UPDATE` statement (this will delete rows when one gets a duplicate key error while updating).
- Change the format of `DATETIME` to store fractions of seconds.
- Make it possible to use the new GNU regexp library instead of the current one (the GNU library should be much faster than the old one).

Standards compliance, portability and migration

- Don't add automatic `DEFAULT` values to columns. Give an error when using an `INSERT` that doesn't contain a column that doesn't have a `DEFAULT`.
- Add `ANY()`, `EVERY()`, and `SOME()` group functions. In standard SQL these work only on boolean columns, but we can extend these to work on any columns/expressions by applying: value == 0 -> FALSE and value <> 0 -> TRUE.
- Fix that the type for `MAX(column)` is the same as the column type:

```
mysql> CREATE TABLE t1 (a DATE);
mysql> INSERT INTO t1 VALUES (NOW());
mysql> CREATE TABLE t2 SELECT MAX(a) FROM t1;
mysql> SHOW COLUMNS FROM t2;
```

Speed enhancements

- Don't allow more than a defined number of threads to run MyISAM recover at the same time.
- Change `INSERT ... SELECT` to optionally use concurrent inserts.
- Add an option to periodically flush key pages for tables with delayed keys if they haven't been used in a while.
- Allow join on key parts (optimisation issue).
- Add simulation of `pread()`/`pwrite()` on Windows to enable concurrent inserts.

- A logfile analyser that could parse out information about which tables are hit most often, how often multi-table joins are executed, etc. It should help users identify areas or table design that could be optimised to execute much more efficient queries.

Internationalisation

Usability enhancements

- Return the original field types() when doing `SELECT MIN(column) ... GROUP BY`.
- Make it possible to specify `long_query_time` with a granularity in microseconds.
- Link the `myisampack` code into the server, enabling a PACK or COMPRESS command on the server.
- Add a temporary key buffer cache during `INSERT/DELETE/UPDATE` so that we can gracefully recover if the index file gets full.
- If you perform an `ALTER TABLE` on a table that is symlinked to another disk, create temporary tables on this disk.
- Implement a `DATE/DATETIME` type that handles time zone information properly so that dealing with dates in different time zones is easier.
- Fix configure so that one can compile all libraries (like `MyISAM`) without threads.
- Allow SQL variables in `LIMIT`, like in `LIMIT @a,@b`.
- Automatic output from `mysql` to a web browser.
- `LOCK DATABASES` (with various options).
- Many more variables for `SHOW STATUS`. Records reads and updates. Selects on 1 table and selects with joins. Mean number of tables in select. Number of `ORDER BY` and `GROUP BY` queries.
- `mysqladmin copy database new-database`; requires `COPY` command to be added to `mysqld`.
- Processlist should show number of queries/threads.
- `SHOW HOSTS` for printing information about the hostname cache.
- Change table names from empty strings to `NULL` for calculated columns.
- Don't use `Item_copy_string` on numerical values to avoid number->string->number conversion in case of: `SELECT COUNT(*)*(id+0) FROM table_name GROUP BY id`
- Change so that `ALTER TABLE` doesn't abort clients that execute `INSERT DELAYED`.
- Fix so that when columns are referenced in an `UPDATE` clause, they contain the old values from before the update started.

New operating systems

- Port of the MySQL clients to LynxOS.

1.8.5 New Features Planned for the Mid-Term Future

- Implement function: `get_changed_tables(timeout,table1,table2,...)`.
- Change reading through tables to use memmap when possible. Now only compressed tables use memmap.
- Make the automatic timestamp code nicer. Add timestamps to the update log with `SET TIMESTAMP=#;`.
- Use read/write mutex in some places to get more speed.
- Simple views (stepwise implementation up to full functionality). See Section 1.7.4.6 [ANSI diff Views], page 41.
- Automatically close some tables if a table, temporary table, or temporary files gets error 23 (not enough open files).
- When one finds a field=#, change all occurrences of field to #. Now this is only done for some simple cases.
- Change all const expressions with calculated expressions if possible.
- Optimise key = expression. At the moment only key = field or key = constant are optimised.
- Join some of the copy functions for nicer code.
- Change '`sql_yacc.yy`' to an inline parser to reduce its size and get better error messages (5 days).
- Change the parser to use only one rule per different number of arguments in function.
- Use of full calculation names in the order part (for ACCESS97).
- `MINUS`, `INTERSECT`, and `FULL OUTER JOIN`. (Currently `UNION` [in 4.0] and `LEFT|RIGHT OUTER JOIN` are supported.)
- `SQL_OPTION MAX_SELECT_TIME=#` to put a time limit on a query.
- Make the update log write to a database.
- Enhance `LIMIT` to allow retrieval of data from the end of a result set.
- Alarm around client connect/read/write functions.
- Please note the changes to `mysqld_safe`: according to FSSTND (which Debian tries to follow) PID files should go into '`/var/run/<progname>.pid`' and log files into '`/var/log`'. It would be nice if you could put the "DATADIR" in the first declaration of "pidfile" and "log", so the placement of these files can be changed with a single statement.
- Allow a client to request logging.
- Add use of `zlib()` for `gzip`-ed files to `LOAD DATA INFILE`.
- Fix sorting and grouping of `BLOB` columns (partly solved now).
- Change to use semaphores when counting threads. One should first implement a semaphore library to MIT-pthreads.
- Don't assign a new `AUTO_INCREMENT` value when one sets a column to 0. Use `NULL` instead.
- Add full support for `JOIN` with parentheses.

- As an alternative for one thread/connection manage a pool of threads to handle the queries.
- Allow one to get more than one lock with `GET_LOCK`. When doing this, one must also handle the possible deadlocks this change will introduce.

Time is given according to amount of work, not real time.

1.8.6 New Features We Don't Plan to Do

- Nothing; we aim toward full compliance with SQL-92/SQL-99.

2 Installing MySQL

This chapter describes how to obtain and install MySQL:

- For a list of sites from which you can obtain MySQL, see Section 2.2.1 [Getting MySQL], page 70.
- To see which platforms are supported, see Section 2.2.3 [Which OS], page 73. Please note that not all supported systems are equally good for running MySQL on them. On some it is much more robust and efficient than others—see Section 2.2.3 [Which OS], page 73 for details.
- Several versions of MySQL are available in both binary and source distributions. We also provide public access to our current source tree for those who want to see our most recent developments and help us test new code. To determine which version and type of distribution you should use, see Section 2.2.4 [Which version], page 75. When in doubt, use a binary distribution.
- Installation instructions for binary and source distributions are described in Section 2.2.9 [Installing binary], page 85, and Section 2.3 [Installing source], page 88. Each set of instructions includes a section on system-specific problems you may run into.
- For post-installation procedures, see Section 2.4 [Post-installation], page 101. These procedures apply whether you install MySQL using a binary or source distribution.

2.1 Quick Standard MySQL Installation

This chapter covers the installation of MySQL on platforms where we offer packages using the native packaging format of the respective platform. However, binary distributions of MySQL are available for many other platforms as well, see Section 2.2.9 [Installing binary], page 85 for generic installation instructions for these packages that apply to all platforms.

See Section 2.2 [General Installation Issues], page 70 for more information on what other binary distributions are available and how to obtain them.

2.1.1 Installing MySQL on Windows

The installation process for MySQL on Windows has the following steps:

1. Install the distribution.
2. Set up an option file if necessary.
3. Select the server you want to use.
4. Start the server.

MySQL for Windows is available in two distribution formats:

- The binary distribution contains a setup program that installs everything you need so that you can start the server immediately.
- The source distribution contains all the code and support files for building the executables using the VC++ 6.0 compiler. See Section 2.3.7 [Windows source build], page 100.

Generally speaking, you should use the binary distribution. It's simpler, and you need no additional tools to get MySQL up and running.

2.1.1.1 Windows System Requirements

To run MySQL on Windows, you will need the following:

- A 32-bit Windows operating system such as 9x, Me, NT, 2000, or XP. The NT family (Windows NT, 2000, and XP) permits you to run the MySQL server as a service. See Section 2.1.1.7 [NT start], page 61.
- TCP/IP protocol support.
- A copy of the MySQL binary distribution for Windows, which can be downloaded from `http://www.mysql.com/downloads/`.

  Note: The distribution files are supplied with a zipped format and we recommend the use of an adequate FTP client with resume feature to avoid corruption of files during the download process.
- A `ZIP` program to unpack the distribution file.
- Enough space on the hard drive to unpack, install, and create the databases in accordance with your requirements.
- If you plan to connect to the MySQL server via ODBC, you will also need the `MyODBC` driver. See Section 11.2 [ODBC], page 806.
- If you need tables with a size larger than 4 GB, install MySQL on an NTFS or newer filesystem. Don't forget to use `MAX_ROWS` and `AVG_ROW_LENGTH` when you create tables. See Section 6.5.3 [`CREATE TABLE`], page 564.

2.1.1.2 Installing a Windows Binary Distribution

To install MySQL on Windows using a binary distribution, follow this procedure:

1. If you are working on a Windows NT, 2000, or XP machine, make sure you have logged in as a user with administrator privileges.
2. If you are doing an upgrade of an earlier MySQL installation, it is necessary to stop the current server. On Windows NT, 2000, or XP machines, if you are running the server as a Windows service, stop it as follows from the command prompt:

   ```
   C:\> NET STOP MySQL
   ```

   If you plan to use a different server after the upgrade (for example, if you want to run `mysqld-max` rather than `mysqld`), remove the existing service:

   ```
   C:\mysql\bin> mysqld --remove
   ```

   You can reinstall the service to use the proper server after upgrading.

   If you are not running the MySQL server as a service, stop it like this:

   ```
   C:\mysql\bin> mysqladmin -u root shutdown
   ```
3. Exit the `WinMySQLAdmin` program if it is running.
4. Unzip the distribution file to a temporary directory.
5. Run the `setup.exe` program to begin the installation process. If you want to install MySQL into a location other than the default directory ('`C:\mysql`'), use the `Browse` button to specify your preferred directory. If you do not install MySQL into the default location, you will need to specify the location whenever you start the server. The easiest

way to do this is to use an option file, as described in Section 2.1.1.3 [Windows prepare environment], page 58.

6. Finish the install process.

2.1.1.3 Preparing the Windows MySQL Environment

If you need to specify startup options when you run the server, you can indicate them on the command line or place them in an option file. For options that will be used every time the server starts, you will find it most convenient to use an option file to specify your MySQL configuration. This is true particularly under the following circumstances:

- The installation or data directory locations are different from the default locations ('`C:\mysql`' and '`C:\mysql\data`').
- You need to tune the server settings. For example, to use the `InnoDB` transactional tables in MySQL version 3.23, you must manually create two new directories to hold the `InnoDB` data and log files—such as, '`C:\ibdata`' and '`C:\iblogs`'. You will also need to add some extra lines to the option file, as described in Section 7.5.3 [`InnoDB` start], page 607. (As of MySQL 4.0, InnoDB creates its datafiles and log files in the data directory by default. This means you need not configure InnoDB explicitly. You may still do so if you wish, and an option file will be useful in this case, too.)

On Windows, the MySQL installer places the data directory directly under the directory where you install MySQL. If you would like to use a data directory in a different location, you should copy the entire contents of the '`data`' directory to the new location. For example, by default, the installer places MySQL in '`C:\mysql`' and the data directory in '`C:\mysql\data`'. If you want to use a data directory of '`E:\mydata`', you must do two things:

- Move the data directory from '`C:\mysql\data`' to '`E:\mydata`'.
- Use a `--datadir` option to specify the new data directory location each time you start the server.

When the MySQL server starts on Windows, it looks for options in two files: The '`my.ini`' file in the Windows directory, and the '`C:\my.cnf`' file. The Windows directory typically is named something like '`C:\WINDOWS`' or '`C:\WinNT`'. You can determine its exact location from the value of the `WINDIR` environment variable using the following command:

```
C:\> echo %WINDIR%
```

MySQL looks for options first in the '`my.ini`' file, then in the '`my.cnf`' file. However, to avoid confusion, it's best if you use only one file. If your PC uses a boot loader where the `C:` drive isn't the boot drive, your only option is to use the '`my.ini`' file. Whichever one you use, it must be a plain text file.

An option file can be created and modified with any text editor, such as the `Notepad` program. For example, if MySQL is installed at '`D:\mysql`' and the data directory is located as '`D:\mydata\data`', you can create the option file and set up a `[mysqld]` section to specify values for the `basedir` and `datadir` parameters:

```
[mysqld]
# set basedir to your installation path
basedir=D:/mysql
```

```
# set datadir to the location of your data directory
datadir=D:/mydata/data
```

Note that Windows pathnames are specified in option files using forward slashes rather than backslashes. If you do use backslashes, you must double them.

Another way to manage an option file is to use the the `WinMySQLAdmin` tool. You can find `WinMySQLAdmin` in the '`bin`' directory of your MySQL installation, as well as a help file containing instructions for using it. `WinMySQLAdmin` has the capability of editing your option file, but note these points:

- `WinMySQLAdmin` uses only the '`my.ini`' file.
- If `WinMySQLAdmin` finds a '`C:\my.cnf`' file, it will in fact rename it to '`C:\my_cnf.bak`' to disable it.

Now you are ready to test starting the server.

2.1.1.4 Selecting a Windows Server

Starting with MySQL 3.23.38, the Windows distribution includes both the normal and the MySQL-Max server binaries. Here is a list of the different MySQL servers from which you can choose:

Binary	Description
`mysqld`	Compiled with full debugging and automatic memory allocation checking, symbolic links, and `InnoDB` and `BDB` tables.
`mysqld-opt`	Optimised binary. From version 4.0 on, `InnoDB` is enabled. Before 4.0, this server includes no transactional table support.
`mysqld-nt`	Optimised binary for NT/2000/XP with support for named pipes.
`mysqld-max`	Optimised binary with support for symbolic links, and `InnoDB` and `BDB` tables.
`mysqld-max-nt`	Like `mysqld-max`, but compiled with support for named pipes.

All of the preceding binaries are optimised for modern Intel processors but should work on any Intel i386-class or higher processor.

The `mysqld-nt` or `mysqld-max-nt` server support named pipe connections. If you use either of these servers, named pipe use is subject to these conditions:

- The server must be run on a version of Windows that supports named pipes (NT, 2000, XP).
- Starting from 3.23.50, named pipes are enabled only if you start the server with the `--enable-named-pipe` option.
- These servers can be run on Windows 98 or Me, but only if TCP/IP is installed; named pipe connections cannot be used.
- On Windows 95, these servers cannot be used.

2.1.1.5 Starting the Server for the First Time

On Windows 95, 98, or Me, MySQL clients always connect to the server using TCP/IP. On NT-based systems such as Windows NT, 2000, or XP, clients have two options. They can use TCP/IP, or they can use a named pipe if the server supports named pipe connections.

For information about which server binary to run, see Section 2.1.1.3 [Windows prepare environment], page 58.

This section gives a general overview of starting the MySQL server. The following sections provide more specific information for particular versions of Windows.

The examples in these sections assume that MySQL is installed under the default location of '`C:\mysql`'. Adjust the pathnames shown in the examples if you have MySQL installed in a different location.

Testing is best done from a command prompt in a console window (a "DOS window"). This way you can have the server display status messages in the window where they are easy to see. If something is wrong with your configuration, these messages will make it easier for you to identify and fix any problems.

Make sure you are in the directory where the server is located, then enter this command:

```
shell> mysqld --console
```

For servers that include `InnoDB` support, you should see the following messages as the server starts up:

```
InnoDB: The first specified datafile c:\ibdata\ibdata1 did not exist:
InnoDB: a new database to be created!
InnoDB: Setting file c:\ibdata\ibdata1 size to 209715200
InnoDB: Database physically writes the file full: wait...
InnoDB: Log file c:\iblogs\ib_logfile0 did not exist: new to be created
InnoDB: Setting log file c:\iblogs\ib_logfile0 size to 31457280
InnoDB: Log file c:\iblogs\ib_logfile1 did not exist: new to be created
InnoDB: Setting log file c:\iblogs\ib_logfile1 size to 31457280
InnoDB: Log file c:\iblogs\ib_logfile2 did not exist: new to be created
InnoDB: Setting log file c:\iblogs\ib_logfile2 size to 31457280
InnoDB: Doublewrite buffer not found: creating new
InnoDB: Doublewrite buffer created
InnoDB: creating foreign key constraint system tables
InnoDB: foreign key constraint system tables created
011024 10:58:25  InnoDB: Started
```

When the server finishes its startup sequence, you should see something like this, which indicates that the server is ready to service client connections::

```
mysqld: ready for connections
Version: '4.0.14-log'  socket: ''  port: 3306
```

The server will continue to write to the console any further diagnostic output it produces. You can open a new console window in which to run client programs.

If you omit the `--console` option, the server writes diagnostic output to the error log in the data directory. The error log is the file with the '`.err`' extension.

2.1.1.6 Starting MySQL on Windows 95, 98, or Me

On Windows 95, 98, or Me, MySQL uses TCP/IP to connect a client to a server. (This will allow any machine on your network to connect to your MySQL server.) Because of this, you

must make sure that TCP/IP support is installed on your machine before starting MySQL. You can find TCP/IP on your Windows CD-ROM.

Note that if you are using an old Windows 95 release (for example, OSR2), it's likely that you have an old Winsock package; MySQL requires Winsock 2! You can get the newest Winsock from `http://www.microsoft.com/`. Windows 98 has the new Winsock 2 library, so it is unnecessary to update the library.

To start the `mysqld` server, you should start a console window (a "DOS" window) and enter this command:

```
shell> C:\mysql\bin\mysqld
```

This will start `mysqld` in the background. That is, after the server starts up, you should see another command prompt. (Note that if you start the server this way on Windows NT, 2000, or XP, the server will run in the foreground and no command prompt will appear until the server exits. Because of this, you should open another console window to run client programs while the server is running.

You can stop the MySQL server by executing this command:

```
shell> C:\mysql\bin\mysqladmin -u root shutdown
```

This invokes the MySQL administrative utility `mysqladmin` to connect to the server and tell it to shut down. The command connects as `root`, which is the default administrative account in the MySQL grant system. Please note that users in the MySQL grant system are wholly independent from any login users under Windows.

If `mysqld` doesn't start, check the error log to see if the server wrote any messages there to indicate the cause of the problem. The error log is located in the '`C:\mysql\data`' directory. It is the file with a suffix of '`.err`'. You can also try to start the server as `mysqld --console`; in this case, you may get some useful information on the screen that may help solve the problem.

The last option is to start `mysqld` with `--standalone --debug`. In this case `mysqld` will write a log file '`C:\mysqld.trace`' that should contain the reason why `mysqld` doesn't start. See Section E.1.2 [Making trace files], page 1008.

Use `mysqld --help` to display all the options that `mysqld` understands!

2.1.1.7 Starting MySQL on Windows NT, 2000, or XP

On the NT family (Windows NT, 2000, or XP), the recommended way to run MySQL is to install it as a Windows service. Then Windows starts and stops the MySQL server automatically when Windows starts and stops. A server installed as a service can also be controlled from the command line using `NET` commands, or with the graphical `Services` utility.

The `Services` utility (the Windows `Service Control Manager`) can be found in the Windows `Control Panel` (under `Administrative Tools` on Windows 2000). It is advisable to close the `Services` utility while performing server installation or removal operations from this command line. This prevents some odd errors.

To get MySQL to work with TCP/IP on Windows NT 4, you must install service pack 3 (or newer)!

Before installing MySQL as a Windows service, you should first stop the current server if it is running by using the following command:

```
shell> C:\mysql\bin\mysqladmin -u root shutdown
```

This invokes the MySQL administrative utility `mysqladmin` to connect to the server and tell it to shut down. The command connects as `root`, which is the default administrative account in the MySQL grant system. Please note that users in the MySQL grant system are wholly independent from any login users under Windows.

Now install the server as a service:

```
shell> mysqld --install
```

If you have problems installing `mysqld` as a service using just the server name, try installing it using its full pathname:

```
shell> C:\mysql\bin\mysqld --install
```

As of MySQL 4.0.2, you can specify a specific service name after the `--install` option. As of MySQL 4.0.3, you can in addition specify a `--defaults-file` option after the service name to indicate where the server should obtain options when it starts up. The rules that determine the service name and option files the server uses are as follows:

- If you specify no service name, the server uses the default service name of `MySQL` and the server reads options from the `[mysqld]` group in the standard option files.
- If you specify a service name after the `--install` option, the server ignores the `[mysqld]` option group and instead reads options from the group that has the same name as the service. The server reads options from the standard option files.
- If you specify a `--defaults-file` option after the service name, the server ignores the standard option files and reads options only from the `[mysqld]` group of the named file.

In the usual case that you install the server with `--install` but no service name, the server is installed with a service name of `MySQL`.

As a more complex example, consider the following command:

```
shell> C:\mysql\bin\mysqld --install mysql --defaults-file=C:\my-opts.cnf
```

Here, a service name is given after the `--install` option. If no `--defaults-file` option had been given, this command would have the effect of causing the server to read the `[mysql]` group from the standard option files. (This would be a bad idea, because that option group is for use by the `mysql` client program.) However, because the `--defaults-file` option is present, the server reads options only from the named file, and only from the `[mysqld]` option group.

You can also specify options as "`Start parameters`" in the Windows `Services` utility before you start the MySQL service.

Once a MySQL server is installed as a service, Windows will start the service automatically whenever Windows starts. The service also can be started immediately from the `Services` utility, or by using the command `NET START MYSQL`. The `NET` command is not case sensitive.

Please note that when run as a service, `mysqld` has no access to a console window, so no messages can be seen there. If `mysqld` doesn't start, check the error log to see if the server wrote any messages there to indicate the cause of the problem. The error log is located in the '`C:\mysql\data`' directory. It is the file with a suffix of '`.err`'.

When `mysqld` is running as a service, it can be stopped by using the `Services` utility, the command `NET STOP MYSQL`, or the command `mysqladmin shutdown`. If the service is running when Windows shuts down, Windows will stop the server automatically.

From MySQL version 3.23.44, you have the choice of installing the server as a `Manual` service if you don't wish the service to be started automatically during the boot process. To do this, use the `--install-manual` option rather than the `--install` option:

```
shell> C:\mysql\bin\mysqld --install-manual
```

To remove a server that is installed as a service, first stop it if it is running. Then use the `--remove` option to remove it:

```
shell> mysqld --remove
```

One problem with automatic MySQL service shutdown is that, for MySQL versions older than 3.23.49, Windows waited only for a few seconds for the shutdown to complete, then killed the database server process if the time limit was exceeded. This had the potential to cause problems. (For example, the `InnoDB` storage engine had to perform crash recovery at the next startup.) Starting from MySQL version 3.23.49, Windows waits longer for the MySQL server shutdown to complete. If you notice this still is not enough for your installation, it is safest not to run the MySQL server as a service. Instead, start it from the command-line prompt, and stop it with `mysqladmin shutdown`.

The change to tell Windows to wait longer when stopping the MySQL server works for Windows 2000 and XP, but not for Windows NT. On NT, Windows waits only 20 seconds for a service to shut down, and after that kills the service process. You can increase this default by opening the Registry Editor '`\winnt\system32\regedt32.exe`' and editing the value of `WaitToKillServiceTimeout` at `HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Control` in the Registry tree. Specify the new larger value in milliseconds (for example, the value 120000 tells Windows NT to wait up to 120 seconds).

If you don't want to start `mysqld` as a service, you can start it from the command line the same way as for versions of Windows that are not based on NT. For instructions, see Section 2.1.1.6 [Win95 start], page 60.

2.1.1.8 Running MySQL on Windows

MySQL supports TCP/IP on all Windows platforms. The `mysqld-nt` and `mysql-max-nt` servers support named pipes on NT, 2000, and XP. However, the default is to use TCP/IP regardless of the platform:

- Named pipes are actually slower than TCP/IP in many Windows configurations.
- Some users have experienced problems shutting down the MySQL server when named pipes are used.

Starting from 3.23.50, named pipes are enabled for `mysqld-nt` and `mysql-max-nt` only if they are started with the `--enable-named-pipe` option.

You can force a MySQL client to use named pipes by specifying the `--pipe` option or by specifying `.` (period) as the host name. Use the `--socket` option to specify the name of the pipe. In MySQL 4.1, you should use the `--protocol=PIPE` option.

You can test whether the MySQL server is working by executing any of the following commands:

```
C:\> C:\mysql\bin\mysqlshow
C:\> C:\mysql\bin\mysqlshow -u root mysql
C:\> C:\mysql\bin\mysqladmin version status proc
C:\> C:\mysql\bin\mysql test
```

If `mysqld` is slow to answer to connections on Windows 9x/Me, there is probably a problem with your DNS. In this case, start `mysqld` with the `--skip-name-resolve` option and use only `localhost` and IP numbers in the `Host` column of the MySQL grant tables.

There are two versions of the MySQL command-line tool:

Binary	Description
`mysql`	Compiled on native Windows, offering limited text editing capabilities.
`mysqlc`	Compiled with the Cygnus GNU compiler and libraries, which offers `readline` editing.

If you want to use `mysqlc`, you must have a copy of the '`cygwinb19.dll`' library installed somewhere that `mysqlc` can find it. Current distributions of MySQL include this library in the same directory as `mysqlc` (the '`bin`' directory under the base directory of your MySQL installation). If your distribution does not have the `cygwinb19.dll` library in the '`bin`' directory, look for it in the `lib` directory and copy it to your Windows system directory ('`\Windows\system`' or similar place).

The default privileges on Windows give all local users full privileges to all databases without specifying a password. To make MySQL more secure, you should set a password for all users and remove the row in the `mysql.user` table that has `Host='localhost'` and `User=''`.

You should also add a password for the `root` user. The following example starts by removing the anonymous user that has all privileges, then sets a `root` user password:

```
C:\> C:\mysql\bin\mysql mysql
mysql> DELETE FROM user WHERE Host='localhost' AND User='';
mysql> FLUSH PRIVILEGES;
mysql> QUIT
C:\> C:\mysql\bin\mysqladmin -u root password your_password
```

After you've set the password, if you want to shut down the `mysqld` server, you can do so using this command:

```
C:\> mysqladmin --user=root --password=your_password shutdown
```

If you are using a server from an old Windows shareware distribution of MySQL Version 3.21, the `mysqladmin` command to set the password will fail with an error: `parse error near 'SET password'`. The solution to this problem is to upgrade to a newer version of MySQL.

With the current MySQL versions you can easily add new users and change privileges with `GRANT` and `REVOKE` commands. See Section 4.4.1 [GRANT], page 239.

2.1.2 Installing MySQL on Linux

The recommended way to install MySQL on Linux is by using the RPM packages. The MySQL RPMs are currently built on a SuSE Linux 7.3 system but should work on most versions of Linux that support `rpm` and use `glibc`.

If you have problems with an RPM file (for example, if you receive the error "`Sorry, the host 'xxxx' could not be looked up`"), see Section 2.6.2.1 [Binary notes-Linux], page 130.

In most cases, you only need to install the `MySQL-server` and `MySQL-client` packages to get a functional MySQL installation. The other packages are not required for a standard installation. If you want to run a MySQL Max server that has additional capabilities, you should install the `MySQL-Max` RPM after installing the `MySQL-server` RPM. See Section 4.8.5 [`mysqld-max`], page 323.

If you get a dependency failure when trying to install the MySQL 4.0 packages (for example, "`error: removing these packages would break dependencies: libmysqlclient.so.10 is needed by ...`"), you should also install the package `MySQL-shared-compat`, which includes both the shared libraries for backward compatibility (`libmysqlclient.so.12` for MySQL 4.0 and `libmysqlclient.so.10` for MySQL 3.23).

Many Linux distributions still ship with MySQL 3.23 and they usually link applications dynamically to save disk space. If these shared libraries are in a separate package (for example, `MySQL-shared`), it is sufficient to simply leave this package installed and just upgrade the MySQL server and client packages (which are statically linked and do not depend on the shared libraries). For distributions that include the shared libraries in the same package as the MySQL server (for example, Red Hat Linux), you could either install our 3.23 `MySQL-shared` RPM, or use the `MySQL-shared-compat` package instead.

The following RPM packages are available:

- `MySQL-server-VERSION.i386.rpm`

  The MySQL server. You will need this unless you only want to connect to a MySQL server running on another machine. Please note that this package was called `MySQL-VERSION.i386.rpm` before MySQL 4.0.10.

- `MySQL-Max-VERSION.i386.rpm`

  The MySQL Max server. This server has additional capabilities that the one in the `MySQL-server` RPM does not. You must install the `MySQL-server` RPM first, because the `MySQL-Max` RPM depends on it.

- `MySQL-client-VERSION.i386.rpm`

  The standard MySQL client programs. You probably always want to install this package.

- `MySQL-bench-VERSION.i386.rpm`

  Tests and benchmarks. Requires Perl and the `DBD-mysql` module.

- `MySQL-devel-VERSION.i386.rpm`

  The libraries and include files that are needed if you want to compile other MySQL clients, such as the Perl modules.

- `MySQL-shared-VERSION.i386.rpm`

  This package contains the shared libraries (`libmysqlclient.so*`) that certain languages and applications need to dynamically load and use MySQL.

- `MySQL-shared-compat-VERSION.i386.rpm`

  This package includes the shared libraries for both MySQL 3.23 and MySQL 4.0. Install this package instead of `MySQL-shared`, if you have applications installed that are dynamically linked against MySQL 3.23 but you want to upgrade to MySQL 4.0 without breaking the library dependencies. This package is available since MySQL 4.0.13.

- `MySQL-embedded-VERSION.i386.rpm`

  The embedded MySQL server library (from MySQL 4.0).

- `MySQL-VERSION.src.rpm`

  This contains the source code for all of the previous packages. It can also be used to rebuild the RPMs on other architectures (for example, Alpha or SPARC).

To see all files in an RPM package (for example, a `MySQL-server` RPM), run:

```
shell> rpm -qpl MySQL-server-VERSION.i386.rpm
```

To perform a standard minimal installation, run:

```
shell> rpm -i MySQL-server-VERSION.i386.rpm MySQL-client-VERSION.i386.rpm
```

To install just the client package, run:

```
shell> rpm -i MySQL-client-VERSION.i386.rpm
```

RPM provides a feature to verify the integrity and authenticity of packages before installing them. If you would like to learn more about this feature please see Section 2.2.2 [Verifying Package Integrity], page 70.

The server RPM places data under the '`/var/lib/mysql`' directory. The RPM also creates the appropriate entries in '`/etc/init.d/`' to start the server automatically at boot time. (This means that if you have performed a previous installation and have made changes to its startup script, you may want to make a copy of the script so you don't lose it when you install a newer RPM.) See Section 2.4.3 [Automatic start], page 108 for more information on how MySQL can be started automatically on system startup.

If you want to install the MySQL RPM on older Linux distributions that do not support initialisation scripts in '`/etc/init.d`' (directly or via a symlink), you should create a symbolic link that points to the location where your initialisation scripts actually are installed. For example, if that location is '`/etc/rc.d/init.d`', use these commands before installing the RPM to create '`/etc/init.d`' as a symbolic link that points there:

```
shell> cd /etc; ln -s rc.d/init.d .
```

However, all current major Linux distributions should already support the new directory layout that uses '`/etc/init.d`', because it is required for LSB (Linux Standard Base) compliance.

If the RPM files that you install include `MySQL-server`, the `mysqld` daemon should be up and running after installation. You should now be able to start using MySQL. See Section 2.4 [Post-installation], page 101.

If something goes wrong, you can find more information in the binary installation chapter. See Section 2.2.9 [Installing binary], page 85.

2.1.3 Installing MySQL on Mac OS X

Beginning with MySQL 4.0.11, you can install MySQL on Mac OS X 10.2 ("Jaguar") using a Mac OS X `PKG` binary package instead of the binary tarball distribution. Please note that older versions of Mac OS X (for example, 10.1.x) are not supported by this package.

The package is located inside a disk image (`.dmg`) file, that you first need to mount by double-clicking its icon in the Finder. It should then mount the image and display its contents.

NOTE: Before proceeding with the installation, be sure to shut down all running MySQL server instances by either using the MySQL Manager Application (on Mac OS X Server) or via `mysqladmin shutdown` on the command line.

To actually install the MySQL PKG, double click on the package icon. This launches the Mac OS Package Installer, which will guide you through the installation of MySQL.

The Mac OS X PKG of MySQL will install itself into '`/usr/local/mysql-<version>`' and will also install a symbolic link '`/usr/local/mysql`', pointing to the new location. If a directory named '`/usr/local/mysql`' already exists, it will be renamed to '`/usr/local/mysql.bak`' first. Additionally, it will install the grant tables in the `mysql` database by executing `mysql_install_db` after the installation.

The installation layout is similar to the one of the binary distribution; all MySQL binaries are located in the directory '`/usr/local/mysql/bin`'. The MySQL socket file is created as '`/tmp/mysql.sock`' by default. See Section 2.2.5 [Installation layouts], page 77.

MySQL installation requires a Mac OS X user account named `mysql` (a user account with this name should exist by default on Mac OS X 10.2 and up).

If you are running Mac OS X Server, you already have a version of MySQL installed:

- Mac OS X Server 10.2-10.2.2 come with MySQL 3.23.51 installed
- Mac OS X Server 10.2.3-10.2.6 ship with MySQL 3.23.53
- Mac OS X Server 10.3 ships with MySQL 4.0.14

This manual section covers the installation of the official MySQL Mac OS X PKG only. Make sure to read Apple's help about installing MySQL (Run the "Help View" application, select "Mac OS X Server" help, and do a search for "MySQL" and read the item entitled "Installing MySQL").

Especially note that the pre-installed version of MySQL on Mac OS X Server is started with the command `safe_mysqld` instead of `mysqld_safe`.

If you previously used Marc Liyanage's MySQL packages for Mac OS X from `http://www.entropy.ch`, you can simply follow the update instructions for packages using the binary installation layout as given on his pages.

If you are upgrading from Marc's 3.23.xx versions or from the Mac OS X Server version of MySQL to the official MySQL PKG, you also need to convert the existing MySQL privilege tables to the current format, because some new security privileges have been added. See Section 2.5.6 [Upgrading-grant-tables], page 119.

If you would like to automatically start up MySQL during system bootup, you also need to install the MySQL Startup Item. Starting with MySQL 4.0.15, it is part of the Mac OS X installation disk images as a separate installation package. Simply double-click the `MySQLStartupItem.pkg` icon and follow the instructions to install it.

Note that this only has to be done once! There is no need to install the Startup Item every time you upgrade the MySQL package.

The Startup Item will be installed into '`/Library/StartupItems/MySQL`'. It adds a variable `MYSQLCOM=-YES-` to the system configuration file '`/etc/hostconfig`'. If you would like to disable the automatic startup of MySQL, simply change this variable to `MYSQLCOM=-NO-`.

On Mac OS X Server, the Startup Item installation script will automatically disable the startup of the default MySQL installation by changing the variable `MYSQL` in

'`/etc/hostconfig`' to `MYSQL=-NO-`. This is to avoid conflicts on bootup. However, it does not shut down an already running MySQL server.

After the installation, you can start up MySQL by running the following commands in a terminal window. Please note that you need to have administrator privileges to perform this task.

If you have installed the Startup Item:

```
shell> sudo /Library/StartupItems/MySQL/MySQL start
(Enter your password, if necessary)
(Press Control-D or enter "exit" to exit the shell)
```

If you don't use the Startup Item, enter the following command sequence:

```
shell> cd /usr/local/mysql
shell> sudo ./bin/mysqld_safe
(Enter your password, if necessary)
(Press Control-Z)
shell> bg
(Press Control-D or enter "exit" to exit the shell)
```

You should now be able to connect to the MySQL server, for example, by running '`/usr/local/mysql/bin/mysql`'.

If you installed MySQL for the first time, **please remember to set a password for the MySQL `root` user!**

This is done with the following two commands:

```
/usr/local/mysql/bin/mysqladmin -u root password <password>
/usr/local/mysql/bin/mysqladmin -u root -h `hostname` password <password>
```

Please make sure that the `hostname` command in the second line is enclosed by **backticks** (`), so the shell can replace it with the output of this command (the host name of this system)!

You might want to also add aliases to your shell's resource file to access `mysql` and `mysqladmin` from the command line:

```
alias mysql '/usr/local/mysql/bin/mysql'
alias mysqladmin '/usr/local/mysql/bin/mysqladmin'
```

Alternatively, you could simply add `/usr/local/mysql/bin` to your `PATH` environment variable, for example, by adding the following to '`$HOME/.tcshrc`':

```
setenv PATH ${PATH}:/usr/local/mysql/bin
```

Please note that installing a new MySQL PKG does not remove the directory of an older installation. Unfortunately, the Mac OS X Installer does not yet offer the functionality required to properly upgrade previously installed packages.

After you have copied over the MySQL database files from the previous version and have successfully started the new version, you should consider removing the old installation files to save disk space. Additionally, you should also remove older versions of the Package Receipt directories located in '`/Library/Receipts/mysql-<version>.pkg`'.

2.1.4 Installing MySQL on NetWare

As of version 4.0.11, the MySQL server is available for Novell NetWare in binary package form. In order to host MySQL, the NetWare server must meet these requirements:

- NetWare version 6.5, or NetWare 6.0 with Support Pack 3 installed (You can obtain this at `http://support.novell.com/filefinder/13659/index.html`). The system must meet Novell's minimum requirements to run the respective version of NetWare.
- MySQL data, as well as the binaries themselves, must be installed on an NSS volume; traditional volumes are not supported.

The binary package for NetWare can be obtained at `http://www.mysql.com/downloads/`.

If you are running MySQL on NetWare 6.0, we strongly suggest that you use the `--skip-external-locking` option on the command line. It will also be neccesary to use `CHECK TABLE` and `REPAIR TABLE` instead of `myisamchk`, because `myisamchk` makes use of external locking. External locking is known to have problems on NetWare 6.0; the problem has been eliminated in NetWare 6.5.

2.1.4.1 Installing the MySQL for NetWare Binaries

1. If you are upgrading from a prior installation, stop the MySQL server. This is done from the server console, using:

   ```
   SERVER:  mysqladmin -u root shutdown
   ```

2. Log on to the target server from a client machine with access to the location where you will install MySQL.
3. Extract the binary package zip file onto the server. Be sure to allow the paths in the zip file to be used. It is safe to simply extract the file to '`SYS:\`'.

   If you are upgrading from a prior installation, you may need to copy the data directory (for example, '`SYS:MYSQL\DATA`') now, as well as '`my.cnf`' if you have customised it. You can then delete the old copy of MySQL.
4. You may wish to rename the directory to something more consistent and easy to use. We recommend using '`SYS:MYSQL`'; examples in the manual will use this to refer to the installation directory in general.
5. At the server console, add a search path for the directory containing the MySQL NLMs. For example:

   ```
   SERVER:  SEARCH ADD SYS:MYSQL\BIN
   ```

6. Install the initial database, if needed, by executing `mysql_install_db` at the server console.
7. Start the MySQL server using `mysqld_safe` at the server console.
8. To finish the installation, you should also add the following commands to `autoexec.ncf`. For example, if your MySQL installation is in '`SYS:MYSQL`' and you want MySQL to start automatically, you could add these lines:

   ```
   #Starts the MySQL 4.0.x database server
   SEARCH ADD SYS:MYSQL\BIN
   MYSQLD_SAFE
   ```

   If you are using NetWare 6.0, you should add the `--skip-external-locking` flag:

```
#Starts the MySQL 4.0.x database server
SEARCH ADD SYS:MYSQL\BIN
MYSQLD_SAFE --skip-external-locking
```

If there was an existing installation of MySQL on the server, be sure to check for existing MySQL startup commands in `autoexec.ncf`, and edit or delete them as necessary.

2.2 General Installation Issues

2.2.1 How to Get MySQL

Check the MySQL homepage (`http://www.mysql.com/`) for information about the current version and for downloading instructions.

Our main mirror is located at `http://mirrors.sunsite.dk/mysql/`.

For a complete up-to-date list of MySQL web/download mirrors, see `http://www.mysql.com/downloads/mirro`
There you will also find information about becoming a MySQL mirror site and how to report a bad or out-of-date mirror.

2.2.2 Verifying Package Integrity Using `MD5 Checksums` or `GnuPG`

After you have downloaded the MySQL package that suits your needs and before you attempt to install it, you should make sure it is intact and has not been tampered with.

MySQL AB offers two means of integrity checking: `MD5 checksums` and cryptographic signatures using `GnuPG`, the `GNU Privacy Guard`.

Verifying the `MD5 Checksum`

After you have downloaded the package, you should check, if the MD5 checksum matches the one provided on the MySQL download pages. Each package has an individual checksum, that you can verify with the following command:

```
shell> md5sum <package>
```

Note, that not all operating systems support the `md5sum` command - on some it is simply called `md5`, others do not ship it at all. On Linux, it is part of the `GNU Text Utilities` package, which is available for a wide range of platforms. You can download the source code from `http://www.gnu.org/software/textutils/` as well. If you have `OpenSSL` installed, you can also use the command `openssl md5 <package>` instead. A DOS/Windows implementation of the `md5` command is available from `http://www.fourmilab.ch/md5/`.

Example:

```
shell> md5sum mysql-standard-4.0.10-gamma-pc-linux-i686.tar.gz
155836a7ed8c93aee6728a827a6aa153
                  mysql-standard-4.0.10-gamma-pc-linux-i686.tar.gz
```

You should check, if the resulting checksum matches the one printed on the download page right below the respective package.

Signature Checking Using GnuPG

A more reliable method of verifying the integrity of a package is using cryptographic signatures. MySQL AB uses the GNU Privacy Guard (GnuPG), an Open Source alternative to the very well-known Pretty Good Privacy (PGP) by Phil Zimmermann. See http://www.gnupg.org/ and http://www.openpgp.org/ for more information about OpenPGP/GnuPG and how to obtain and install GnuPG on your system. Most Linux distributions already ship with GnuPG installed by default.

Beginning with MySQL 4.0.10 (February 2003), MySQL AB has started signing their downloadable packages with GnuPG. Cryptographic signatures are a much more reliable method of verifying the integrity and authenticity of a file.

To verify the signature for a specific package, you first need to obtain a copy of MySQL AB's public GPG build key build@mysql.com. You can either cut and paste it directly from here, or obtain it from http://www.keyserver.net/.

```
Key ID:
pub  1024D/5072E1F5 2003-02-03
     MySQL Package signing key (www.mysql.com) <build@mysql.com>
Fingerprint: A4A9 4068 76FC BD3C 4567  70C8 8C71 8D3B 5072 E1F5

Public Key (ASCII-armored):

-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v1.0.6 (GNU/Linux)
Comment: For info see http://www.gnupg.org

mQGiBD4+owwRBAC14GIfUfCyEDSIePvEW3SAFUdJBtoQHH/nJKZyQT7h9bPlUWC3
RODjQReyCITRrdwyrKUGku2FmeVGwn2u2WmDMNABLnpprWPkBdCk96+OmSLN9brZ
fw2vOUgCmYv2hWOhyDHuvYlQA/BThQoADgj8AW6/OLo7V1W9/8VuHPOgQwCgvzV3
BqOxRznNCRCRxAuAuVztHRcEAJooQK1+iSiunZMYD1WufeXfshc57S/+yeJkegNW
hxwR9pRWVArNYJdDRT+rf2RUe3vpquKNQU/hnEIUHJRQqYHo8gTxvxXNQc7fJYLV
K2HtkrPbP72vwsEKMYhhr0eKCbtLGfls9krjJ6sBgACyP/Vb7hiPwxh6rDZ7ITnE
kYpXBACmWpP8NJTkamEnPCia2ZoOHODANwpUkP43I7jsDmgtobZX9qnrAXw+uNDI
QJEXM6FSbi0LLtZciNlYsafwAPEOMDKpMqAK6IyisNtPvaLd8lH0bPAnWqcyefep
rv0sxxqUEMcM3o7wwgfN83POkDasDbs3pjwPhxvhz6//62zQJ7Q7TXlTUUwgUGFj
a2FnZSBzaWduaW5nIGtleSAod3d3Lm15c3FsLmNvbSkgPGJ1aWxkQG15c3FsLmNv
bT6IXQQTEQIAHQUCPj6jDAUJCWYBgAULBwoDBAMVAwIDFgIBAheAAAoJEIxxjTtQ
cuH1cY4AnilUwTXn8MatQOiG0a/bPxrvK/gCAJ4oinSNZRYTnblChwFaazt7PF3q
zIhMBBMRAgAMBQI+PqPRBYMJZgC7AAoJEElQ4SqycpHyJOEAn1mxHijft00bKXvu
cSo/pECUmppiAJ41M9MRVj5VcdH/KN/KjRtW6tHFPYhMBBMRAgAMBQI+QoIDBYMJ
YiKJAAoJELb1zU3GuiQ/lpEAoIhpp6BozKI8p6eaabzF5MlJH58pAKCu/ROofK8J
Eg2aLos+5zEYrB/LsrkCDQQ+PqMdEAgA7+GJfxbMdY4wslPnjH9rF4N2qfWsEN/l
xaZoJYc3a6M02WCnHl6ahT2/tBK2w1QI4YFteR47gCvtgb6O1JHffOo2HfLmRDRi
Rjd1DTCHqeyX7CHhcghj/dNRlW2ZOl5QFEcmV9UOVhp3aFfWC4Ujfs3LU+hkAWzE
7zaD5cH9J7yv/6xuZVw411x0h4UqsTcWMu0iM1BzELqX1DY7LwoPEb/O9Rkbf4fm
Le11EzIaCa4PqARXQZc4dhSinMt6K3X4BrRsKTfozBu74F47D8Ilbf5vSYHbuE5p
/1oIDznkg/p8kW+3FxuWrycciqFTcNz215yyX39LXFnlLzKUb/F5GwADBQf+Lwqq
```

```
a8CGrRfsOAJxim63CHfty5mUc5rUSnTslGYEIOCR1BeQauyPZbPDsDD9MZ1ZaSaf
anFvwFG6Llx9xkU7tzq+vKLoWkm4u5xf3vn55VjnSd1aQ9eQnUcXiL4cnBGoTbOW
I39EcyzgslzBdC++MPjcQTcA7p6JUVsP6oAB3FQWg54tuUo0Ec8bsM8b3Ev42Lmu
QT5NdKHGwHsXTPtl0klk4bQk4OajHsiy1BMahpT27jWjJlMiJc+IWJ0mghkKHt92
6s/ymfdf5HkdQ1cyvsz5tryVI3Fx78XeSYfQvuuwqp2H139pXGEkg0n6KdUOetdZ
Whe7OYGNPw1yjWJT1IhMBBgRAgAMBQI+PqMdBQkJZgGAAAoJEIxxjTtQcuH17p4A
n3r1QpVC9yhnW2cSAjq+kr72GX0eAJ4295kl6NxYEuFApmr1+0uUq/SlsQ==
=YJkx
-----END PGP PUBLIC KEY BLOCK-----
```

You can import this key into your public GPG keyring by using gpg --import. See the GPG documentation for more info on how to work with public keys.

After you have downloaded and imported the public build key, now download your desired MySQL package and the corresponding signature, which is also available from the download page. The signature has the file name extension '.asc'. For example, the signature for 'mysql-standard-4.0.10-gamma-pc-linux-i686.tar.gz' would be 'mysql-standard-4.0.10-gamma-pc-linux-i686.tar.gz.asc'. Make sure that both files are stored in the same directory and then run the following command to verify the signature for this file:

```
shell> gpg --verify <package>.asc

Example:

shell> gpg --verify mysql-standard-4.0.10-gamma-pc-linux-i686.tar.gz.asc
gpg: Warning: using insecure memory!
gpg: Signature made Mon 03 Feb 2003 08:50:39 PM MET using DSA key ID 5072E1F5
gpg: Good signature from
     "MySQL Package signing key (www.mysql.com) <build@mysql.com>"
```

The "Good signature" message indicates that everything is all right.

Signature Checking Using RPM

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

```
shell> rpm --checksig <package>.rpm

Example:

shell> rpm --checksig MySQL-server-4.0.10-0.i386.rpm
MySQL-server-4.0.10-0.i386.rpm: md5 gpg OK
```

Note: If you are using RPM 4.1 and it complains about (GPG) NOT OK (MISSING KEYS: GPG#5072e1f5) (even though you have imported it into your GPG public keyring), you need to import the key into the RPM keyring first. RPM 4.1 no longer uses your GPG keyring (and GPG itself), but rather maintains its own keyring (because it's a system wide application and the GPG public keyring is user-specific file). To import the MySQL public key into the RPM keyring, please use the following command:

```
shell> rpm --import <pubkey>

Example:

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

In case you notice that the `MD5 checksum` or `GPG` signatures do not match, first try to download the respective package one more time, maybe from another mirror site. If you repeatedly can not successfully verify the integrity of the package, please notify us about such incidents including the full package name and the download site you have been using at `webmaster@mysql.com` or `build@mysql.com`.

2.2.3 Operating Systems Supported by MySQL

We use GNU Autoconf, so it is possible to port MySQL to all modern systems with working Posix threads and a C++ compiler. (To compile only the client code, a C++ compiler is required but not threads.) We use and develop the software ourselves primarily on Linux (SuSE and Red Hat), FreeBSD and Sun Solaris (Versions 8 and 9).

Note that for many operating systems, the native thread support works only in the latest versions. MySQL has been reported to compile successfully on the following operating system/thread package combinations:

- AIX 4.x, 5.x with native threads. See Section 2.6.6.4 [IBM-AIX], page 144.
- Amiga.
- BSDI 2.x with the MIT-pthreads package. See Section 2.6.4.5 [BSDI], page 139.
- BSDI 3.0, 3.1 and 4.x with native threads. See Section 2.6.4.5 [BSDI], page 139.
- SCO OpenServer with a recent port of the FSU Pthreads package. See Section 2.6.6.9 [SCO], page 149.
- SCO UnixWare 7.1.x. See Section 2.6.6.10 [SCO UnixWare], page 151.
- DEC Unix 4.x with native threads. See Section 2.6.6.6 [Alpha-DEC-UNIX], page 146.
- FreeBSD 2.x with the MIT-pthreads package. See Section 2.6.4.1 [FreeBSD], page 137.
- FreeBSD 3.x and 4.x with native threads. See Section 2.6.4.1 [FreeBSD], page 137.
- FreeBSD 4.x with Linuxthreads. See Section 2.6.4.1 [FreeBSD], page 137.
- HP-UX 10.20 with the DCE threads or the MIT-pthreads package. See Section 2.6.6.2 [HP-UX 10.20], page 142.
- HP-UX 11.x with the native threads. See Section 2.6.6.3 [HP-UX 11.x], page 142.
- Linux 2.0+ with LinuxThreads 0.7.1+ or `glibc` 2.0.7+. See Section 2.6.2 [Linux], page 126.
- Mac OS X. See Section 2.6.5 [Mac OS X], page 140.
- NetBSD 1.3/1.4 Intel and NetBSD 1.3 Alpha (Requires GNU make). See Section 2.6.4.2 [NetBSD], page 139.
- Novell NetWare 6.0. See Section 2.6.8 [Novell NetWare], page 152.
- OpenBSD > 2.5 with native threads. OpenBSD < 2.5 with the MIT-pthreads package. See Section 2.6.4.3 [OpenBSD], page 139.

- OS/2 Warp 3, FixPack 29 and OS/2 Warp 4, FixPack 4. See Section 2.6.7 [OS/2], page 151.
- SGI Irix 6.x with native threads. See Section 2.6.6.8 [SGI-Irix], page 148.
- Solaris 2.5 and above with native threads on SPARC and x86. See Section 2.6.3 [Solaris], page 133.
- SunOS 4.x with the MIT-pthreads package. See Section 2.6.3 [Solaris], page 133.
- Tru64 Unix
- Windows 9x, Me, NT, 2000 and XP. See Section 2.6.1 [Windows], page 122.

Note that not all platforms are suited equally well for running MySQL. How well a certain platform is suited for a high-load mission-critical MySQL server is determined by the following factors:

- General stability of the thread library. A platform may have excellent reputation otherwise, but if the thread library is unstable in the code that is called by MySQL, even if everything else is perfect, MySQL will be only as stable as the thread library.
- The ability of the kernel and/or thread library to take advantage of **SMP** on multiprocessor systems. In other words, when a process creates a thread, it should be possible for that thread to run on a different CPU than the original process.
- The ability of the kernel and/or the thread library to run many threads which acquire/release a mutex over a short critical region frequently without excessive context switches. In other words, if the implementation of `pthread_mutex_lock()` is too anxious to yield CPU time, this will hurt MySQL tremendously. If this issue is not taken care of, adding extra CPUs will actually make MySQL slower.
- General filesystem stability/performance.
- Ability of the filesystem to deal with large files at all and deal with them efficiently, if your tables are big.
- Our level of expertise here at MySQL AB with the platform. If we know a platform well, we introduce platform-specific optimisations/fixes enabled at compile time. We can also provide advice on configuring your system optimally for MySQL.
- The amount of testing of similar configurations we have done internally.
- The number of users that have successfully run MySQL on that platform in similar configurations. If this number is high, the chances of hitting some platform-specific surprises are much smaller.

Based on the preceding criteria, the best platforms for running MySQL at this point are x86 with SuSE Linux 8.2, 2.4 kernel, and ReiserFS (or any similar Linux distribution) and SPARC with Solaris (2.7-9). FreeBSD comes third, but we really hope it will join the top club once the thread library is improved. We also hope that at some point we will be able to include all other platforms on which MySQL compiles, runs okay, but not quite with the same level of stability and performance, into the top category. This will require some effort on our part in cooperation with the developers of the OS/library components MySQL depends upon. If you are interested in making one of those components better, are in a position to influence their development, and need more detailed instructions on what MySQL needs to run better, send an e-mail to the MySQL internals mailing list. See Section 1.6.1.1 [Mailing-list], page 25.

Please note that the preceding comparison is not to say that one OS is better or worse than the other in general. We are talking about choosing a particular OS for a dedicated purpose—running MySQL, and compare platforms in that regard only. With this in mind, the result of this comparison would be different if we included more issues into it. And in some cases, the reason one OS is better than the other could simply be that we have put forth more effort into testing on and optimising for that particular platform. We are just stating our observations to help you decide on which platform to use MySQL on in your setup.

2.2.4 Which MySQL Version to Use

The first decision to make is whether you want to use the latest development release or the last production (stable) release:

- Normally, if you are beginning to use MySQL for the first time or trying to port it to some system for which there is no binary distribution, we recommend going with the production release (currently version 4.0). Note that all MySQL releases are checked with the MySQL benchmarks and an extensive test suite before each release (even the development releases).
- Otherwise, if you are running an old system and want to upgrade, but don't want to take chances with a non-seamless upgrade, you should upgrade to the latest in the same branch you are using (where only the last version number is newer than yours). We have tried to fix only fatal bugs and make small, relatively safe changes to that version.

The second decision to make is whether you want to use a source distribution or a binary distribution. In most cases you should probably use a binary distribution, if one exists for your platform, as this generally will be easier to install than a source distribution.

In the following cases you probably will be better off with a source installation:

- If you want to install MySQL at some explicit location. (The standard binary distributions are "ready to run" at any place, but you may want to get even more flexibility).
- To be able to satisfy different user requirements, we are providing two different binary versions: one compiled with the non-transactional storage engines (a small, fast binary), and one configured with the most important extended options like transaction-safe tables. Both versions are compiled from the same source distribution. All native `MySQL` clients can connect to both MySQL versions.

  The extended MySQL binary distribution is marked with the `-max` suffix and is configured with the same options as `mysqld-max`. See Section 4.8.5 [`mysqld-max`], page 323.

  If you want to use the `MySQL-Max` RPM, you must first install the standard `MySQL-server` RPM.
- If you want to configure `mysqld` with some extra features that are not in the standard binary distributions. Here is a list of the most common extra options that you may want to use:
  - `--with-innodb` (default for MySQL 4.0 and onwards)
  - `--with-berkeley-db` (not available on all platforms)
  - `--with-raid`
  - `--with-libwrap`

  - `--with-named-z-libs` (This is done for some of the binaries)
  - `--with-debug[=full]`
- The default binary distribution is normally compiled with support for all character sets and should work on a variety of processors from the same processor family.

  If you want a faster MySQL server you may want to recompile it with support for only the character sets you need, use a better compiler (like `pgcc`), or use compiler options that are better optimised for your processor.
- If you have found a bug and reported it to the MySQL development team you will probably receive a patch that you need to apply to the source distribution to get the bug fixed.
- If you want to read (and/or modify) the C and C++ code that makes up MySQL, you should get a source distribution. The source code is always the ultimate manual. Source distributions also contain more tests and examples than binary distributions.

The MySQL naming scheme uses release numbers that consist of three numbers and a suffix. For example, a release name like `mysql-4.1.0-alpha` is interpreted like this:

- The first number (`4`) is the major version and also describes the file format. All Version 4 releases have the same file format.
- The second number (`1`) is the release level.
- The third number (`0`) is the version number within the release level. This is incremented for each new distribution. Usually you want the latest version for the release level you have chosen.
- The suffix (`alpha`) indicates the stability level of the release. The possible suffixes are:
  - `alpha` indicates that the release contains some large section of new code that hasn't been 100% tested. Known bugs (usually there are none) should be documented in the News section. See Appendix D [News], page 889. There are also new commands and extensions in most alpha releases. Active development that may involve major code changes can occur on an alpha release, but everything will be tested before doing a release. There should be no known bugs in any MySQL release.
  - `beta` means that all new code has been tested. No major new features that could cause corruption on old code are added. There should be no known bugs. A version changes from alpha to beta when there haven't been any reported fatal bugs within an alpha version for at least a month and we don't plan to add any features that could make any old command more unreliable.
  - `gamma` is a beta that has been around a while and seems to work fine. Only minor fixes are added. This is what many other companies call a release.
  - If there is no suffix, it means that the version has been run for a while at many different sites with no reports of bugs other than platform-specific bugs. Only critical bug fixes are applied to the release. This is what we call a production (stable) release.

In the MySQL development process, multiple versions co-exist and are at a different stage. Naturally, relevant bugfixes from an earlier series also propagate upward.

- For the old stable/production series `3.23`, new versions are only released for critical bugs.
- The current series `4.0`) is stable/production quality, with new versions released for bugfixes. No new features are added that could influence the code stability.
- In the alpha branch `4.1` major new features are added. Sources and binaries are available for use and testing on development systems.
- The development branch `5.0` is only available from the BitKeeper tree.

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

Note that all releases have been tested at least with:

An internal test suite
: This is part of a production system for a customer. It has many tables with hundreds of megabytes of data.

The MySQL benchmark suite
: This runs a range of common queries. It is also a test to see whether the latest batch of optimisations actually made the code faster. See Section 5.1.4 [MySQL Benchmarks], page 397.

The `crash-me` test
: This tries to determine what features the database supports and what its capabilities and limitations are. See Section 5.1.4 [MySQL Benchmarks], page 397.

Another test is that we use the newest MySQL version in our internal production environment, on at least one machine. We have more than 100 gigabytes of data to work with.

2.2.5 Installation Layouts

This section describes the default layout of the directories created by installing binary and source distributions.

A binary distribution is installed by unpacking it at the installation location you choose (typically '`/usr/local/mysql`') and creates the following directories in that location:

Directory	**Contents of directory**
'`bin`'	Client programs and the `mysqld` server
'`data`'	Log files, databases
'`docs`'	Documentation, ChangeLog
'`include`'	Include (header) files
'`lib`'	Libraries
'`scripts`'	`mysql_install_db`
'`share/mysql`'	Error message files
'`sql-bench`'	Benchmarks

A source distribution is installed after you configure and compile it. By default, the installation step installs files under '`/usr/local`', in the following subdirectories:

Directory	**Contents of directory**
'`bin`'	Client programs and scripts

'include/mysql'	Include (header) files
'info'	Documentation in Info format
'lib/mysql'	Libraries
'libexec'	The mysqld server
'share/mysql'	Error message files
'sql-bench'	Benchmarks and crash-me test
'var'	Databases and log files

Within an installation directory, the layout of a source installation differs from that of a binary installation in the following ways:

- The mysqld server is installed in the 'libexec' directory rather than in the 'bin' directory.
- The data directory is 'var' rather than 'data'.
- mysql_install_db is installed in the '/usr/local/bin' directory rather than in '/usr/local/mysql/scripts'.
- The header file and library directories are 'include/mysql' and 'lib/mysql' rather than 'include' and 'lib'.

You can create your own binary installation from a compiled source distribution by executing the script 'scripts/make_binary_distribution'.

2.2.6 How and When Updates Are Released

MySQL is evolving quite rapidly here at MySQL AB and we want to share this with other MySQL users. We try to make a release when we have very useful features that others seem to have a need for.

We also try to help out users who request features that are easy to implement. We take note of what our licensed users want to have, and we especially take note of what our extended e-mail supported customers want and try to help them out.

No one has to download a new release. The News section will tell you if the new release has something you really want. See Appendix D [News], page 889.

We use the following policy when updating MySQL:

- For each minor update, the last number in the version string is incremented. When there are major new features or minor incompatibilities with previous versions, the second number in the version string is incremented. When the file format changes, the first number is increased.
- Production (stable-tested) releases are meant to appear about 1-2 times a year, but if small bugs are found, a release with only bug fixes will be released.
- Working releases/bug fixes to old releases are meant to appear about every 1-8 weeks.
- Binary distributions for some platforms will be made by us for major releases. Other people may make binary distributions for other systems but probably less frequently.
- We usually make patches available as soon as we have located and fixed small bugs. They usually are immediately available from our public BitKeeper repositories. They will also be included in the next release.
- Non-critical but annoying bugs will be added to the MySQL source repository and they will be fixed in the next release.

- If there is, by any chance, a fatal bug in a release we will make a new release as soon as possible. We would like other companies to do this, too.

The current production release is Version 4.0; we have already moved active development to Version 4.1 and 5.0. Bugs will still be fixed in the 4.0 version, and critical bugs also in the 3.23 series. We don't believe in a complete freeze, as this also leaves out bug fixes and things that "must be done." "Somewhat frozen" means that we may add small things that "almost surely will not affect anything that's already working."

MySQL uses a slightly different naming scheme from most other products. In general it's relatively safe to use any version that has been out for a couple of weeks without being replaced with a new version. See Section 2.2.4 [Which version], page 75.

2.2.7 Release Philosophy - No Known Bugs in Releases

We put a lot of time and effort into making our releases bug free. To our knowledge, we have not released a single MySQL version with any *known* 'fatal' repeatable bugs.

A fatal bug is something that crashes MySQL under normal usage, gives wrong answers for normal queries, or has a security problem.

We have documented all open problems, bugs and things that are dependent on design decisions. See Section 1.7.6 [Bugs], page 44.

Our aim is to fix everything that is fixable, but without risking making a stable MySQL version less stable. In certain cases, this means we can fix an issue in the development version(s), but not in the stable (production) version. Naturally, we document such issues so that users are aware.

Here is a description of how our build process works:

- We monitor bugs from our customer support list, the MySQL external mailing lists and the bugs database at `http://bugs.mysql.com/`.
- All reported bugs for live versions are entered into the bugs database.
- When we fix a bug, we always try to make a test case of it and include this into our test system to ensure that the bug will never come back. (About 90% of all fixed bugs have a test case.)
- We also create test cases for all new features we add to MySQL.
- Before we start to build a new MySQL release, we ensure that all reported repeatable bugs for the MySQL version (3.23.x, 4.0.x, etc) are fixed. If something is impossible to fix (because some internal design decision in MySQL) we document this in the manual. See Section 1.7.6 [Bugs], page 44.
- We do a build on all platforms for which we support binaries (15+ platforms) and run our test suite and benchmark suite on all of them.
- We will not publish a binary for a platform for which the test or benchmark suite fails. If it's a general error in the source, we fix this and do the build plus tests on all systems again, from scratch.
- If we, during the build and test process (which takes 2-3 days), receive a report regarding a fatal bug (for example, one that causes a core dump), we fix this and restart the build process.

- After publishing the binaries on `http://www.mysql.com/`, we send out an announce email on the `mysql` and `announce` mailing lists. See Section 1.6.1.1 [Mailing-list], page 25. The announcement message contains a list of all changes to the release and any known problems with the release. (The 'known problems' section in the release notes has only been needed in a handful of releases.)
- To quickly give our users access to the latest MySQL features, we do a new MySQL release every 4-5 weeks.
- If we, after the release is done, get any bug reports that there was (after all) anything critically wrong with the build on a specific platform, we will fix this at once and build a new `'a'` release for that platform. Thanks to our large user base, problems are found quickly.
- Our track record for making good releases is quite good. In the last 150 releases, we had to do a new build for less than 10 releases (in 3 of these cases, the bug was a faulty glibc library on one of our build machines that took us a long time to track down).

2.2.8 MySQL Binaries Compiled by MySQL AB

As a service, we at MySQL AB provide a set of binary distributions of MySQL that are compiled at our site or at sites where customers kindly have given us access to their machines.

In addition to the binaries provided in platform-specific package formats (see Section 2.1 [Quick Standard Installation], page 56), we do offer binary distributions for a number of platforms by means of compressed tar archives (`.tar.gz`).

These distributions are generated using the script `Build-tools/Do-compile` which compiles the source code and creates the binary `tar.gz` archive using `scripts/make_binary_distribution` These binaries are configured and built with the following compilers and options.

Binaries built on MySQL AB development systems:

Linux 2.4.xx x86 with `gcc` 2.95.3

```
CFLAGS="-O2 -mcpu=pentiumpro" CXX=gcc CXXFLAGS="-O2 -
mcpu=pentiumpro -felide-constructors" ./configure --prefix=/usr/local/mysql
--with-extra-charsets=complex --enable-thread-safe-client
--enable-local-infile --enable-assembler --disable-shared --with-
client-ldflags=-all-static --with-mysqld-ldflags=-all-static
```

Linux 2.4.xx Intel Itanium 2 with `ecc` (Intel C++ Itanium Compiler 7.0)

```
CC=ecc CFLAGS="-O2 -tpp2 -ip -nolib_inline" CXX=ecc CXXFLAGS="-O2
-tpp2 -ip -nolib_inline" ./configure --prefix=/usr/local/mysql
--with-extra-charsets=complex --enable-thread-safe-client
--enable-local-infile
```

Linux 2.4.xx Intel Itanium with `ecc` (Intel C++ Itanium Compiler 7.0)

```
CC=ecc CFLAGS=-tpp1 CXX=ecc CXXFLAGS=-tpp1 ./configure --
prefix=/usr/local/mysql --with-extra-charsets=complex --enable-
thread-safe-client --enable-local-infile
```

Linux 2.4.xx alpha with ccc (Compaq C V6.2-505 / Compaq C++ V6.3-006)

```
CC=ccc CFLAGS="-fast -arch generic" CXX=cxx CXXFLAGS="-
fast -arch generic -noexceptions -nortti" ./configure -
-prefix=/usr/local/mysql --with-extra-charsets=complex
--enable-thread-safe-client --enable-local-infile --with-
mysqld-ldflags=-non_shared --with-client-ldflags=-non_shared
--disable-shared
```

Linux 2.4.xx s390 with gcc 2.95.3

```
CFLAGS="-O2" CXX=gcc CXXFLAGS="-O2 -felide-constructors"
./configure --prefix=/usr/local/mysql --with-extra-charsets=complex
--enable-thread-safe-client --enable-local-infile --disable-shared
--with-client-ldflags=-all-static --with-mysqld-ldflags=-all-
static
```

Linux 2.4.xx x86_64 (AMD64) with gcc 3.2.1

```
CXX=gcc ./configure --prefix=/usr/local/mysql --with-extra-
charsets=complex --enable-thread-safe-client --enable-local-infile
--disable-shared
```

Sun Solaris 8 x86 with gcc 3.2.3

```
CC=gcc CFLAGS="-O3 -fno-omit-frame-pointer" CXX=gcc CXXFLAGS="-
O3 -fno-omit-frame-pointer -felide-constructors -fno-
exceptions -fno-rtti" ./configure --prefix=/usr/local/mysql --
localstatedir=/usr/local/mysql/data --libexecdir=/usr/local/mysql/bin
--with-extra-charsets=complex --enable-thread-safe-client
--enable-local-infile --disable-shared --with-innodb
```

Sun Solaris 8 sparc with gcc 3.2

```
CC=gcc CFLAGS="-O3 -fno-omit-frame-pointer" CXX=gcc CXXFLAGS="-O3
-fno-omit-frame-pointer -felide-constructors -fno-exceptions
-fno-rtti" ./configure --prefix=/usr/local/mysql --with-extra-
charsets=complex --enable-thread-safe-client --enable-local-infile
--enable-assembler --with-named-z-libs=no --with-named-curses-
libs=-lcurses --disable-shared
```

Sun Solaris 8 sparc 64bit with gcc 3.2

```
CC=gcc CFLAGS="-O3 -m64 -fno-omit-frame-pointer" CXX=gcc
CXXFLAGS="-O3 -m64 -fno-omit-frame-pointer -felide-constructors
-fno-exceptions -fno-rtti" ./configure --prefix=/usr/local/mysql
--with-extra-charsets=complex --enable-thread-safe-client
--enable-local-infile --enable-assembler --with-named-z-libs=no
--with-named-curses-libs=-lcurses --disable-shared
```

Sun Solaris 9 sparc with gcc 2.95.3

```
CC=gcc CFLAGS="-O3 -fno-omit-frame-pointer" CXX=gcc CXXFLAGS="-O3
-fno-omit-frame-pointer -felide-constructors -fno-exceptions
-fno-rtti" ./configure --prefix=/usr/local/mysql --with-extra-
charsets=complex --enable-thread-safe-client --enable-local-infile
--enable-assembler --with-named-curses-libs=-lcurses --disable-
shared
```

Sun Solaris 9 sparc with `cc-5.0` (Sun Forte 5.0)

```
CC=cc-5.0 CXX=CC ASFLAGS="-xarch=v9" CFLAGS="-Xa -xstrconst
-mt -D_FORTEC_ -xarch=v9" CXXFLAGS="-noex -mt -D_FORTEC_
-xarch=v9" ./configure --prefix=/usr/local/mysql --with-extra-
charsets=complex --enable-thread-safe-client --enable-local-infile
--enable-assembler --with-named-z-libs=no --enable-thread-safe-
client --disable-shared
```

IBM AIX 4.3.2 ppc with `gcc` 3.2.3

```
CFLAGS="-O2 -mcpu=powerpc -Wa,-many " CXX=gcc CXXFLAGS="-O2
-mcpu=powerpc -Wa,-many -felide-constructors -fno-exceptions
-fno-rtti" ./configure --prefix=/usr/local/mysql --with-extra-
charsets=complex --enable-thread-safe-client --enable-local-infile
--with-named-z-libs=no --disable-shared
```

IBM AIX 4.3.3 ppc with `xlC_r` (IBM Visual Age C/C++ 6.0)

```
CC=xlc_r CFLAGS="-ma -O2 -qstrict -qoptimize=2 -qmaxmem=8192"
CXX=xlC_r CXXFLAGS ="-ma -O2 -qstrict -qoptimize=2 -qmaxmem=8192"
./configure --prefix=/usr/local/mysql --localstatedir=/usr/local/mysql/data
--libexecdir=/usr/local/mysql/bin --with-extra-charsets=complex
--enable-thread-safe-client --enable-local-infile --with-named-z-
libs=no --disable-shared --with-innodb
```

IBM AIX 5.1.0 ppc with `gcc` 3.3

```
CFLAGS="-O2 -mcpu=powerpc -Wa,-many" CXX=gcc CXXFLAGS="-O2
-mcpu=powerpc -Wa,-many -felide-constructors -fno-exceptions
-fno-rtti" ./configure --prefix=/usr/local/mysql --with-extra-
charsets=complex --with-server-suffix="-pro" --enable-thread-
safe-client --enable-local-infile --with-named-z-libs=no
--disable-shared
```

HP-UX 10.20 pa-risc1.1 with `gcc` 3.1

```
CFLAGS="-DHPUX -I/opt/dce/include -O3 -fPIC" CXX=gcc CXXFLAGS="-
DHPUX -I/opt/dce /include -felide-constructors -fno-exceptions
-fno-rtti -O3 -fPIC" ./configure --prefix=/usr/local/mysql
--with-extra-charsets=complex --enable-thread-safe-client --
enable-local-infile --with-pthread --with-named-thread-libs=-ldce
--with-lib-ccflags=-fPIC --disable-shared
```

HP-UX 11.11 pa-risc2.0 64bit with `aCC` (HP ANSI C++ B3910B A.03.33)

```
CC=cc CXX=aCC CFLAGS=+DD64 CXXFLAGS=+DD64 ./configure --
prefix=/usr/local/mysql --with-extra-charsets=complex --enable-
thread-safe-client --enable-local-infile --disable-shared
```

HP-UX 11.11 pa-risc2.0 32bit with `aCC` (HP ANSI C++ B3910B A.03.33)

```
CC=cc CXX=aCC CFLAGS="+DAportable" CXXFLAGS="+DAportable"
./configure --prefix=/usr/local/mysql --localstatedir=/usr/local/mysql/data
--libexecdir=/usr/local/mysql/bin --with-extra-charsets=complex
--enable-thread-safe-client --enable-local-infile --disable-shared
--with-innodb
```

Apple Mac OS X 10.2 powerpc with gcc 3.1

```
CC=gcc CFLAGS="-O3 -fno-omit-frame-pointer" CXX=gcc CXXFLAGS="-O3
-fno-omit-frame-pointer -felide-constructors -fno-exceptions
-fno-rtti" ./configure --prefix=/usr/local/mysql --with-extra-
charsets=complex --enable-thread-safe-client --enable-local-infile
--disable-shared
```

FreeBSD 4.7 i386 with gcc 2.95.4

```
CFLAGS=-DHAVE_BROKEN_REALPATH ./configure --prefix=/usr/local/mysql
--with-extra-charsets=complex --enable-thread-safe-client
--enable-local-infile --enable-assembler --with-named-z-libs=not-
used --disable-shared
```

QNX Neutrino 6.2.1 i386 with gcc 2.95.3qnx-nto 20010315

```
CC=gcc CFLAGS="-O3 -fno-omit-frame-pointer" CXX=gcc CXXFLAGS="-O3
-fno-omit-frame-pointer -felide-constructors -fno-exceptions
-fno-rtti" ./configure --prefix=/usr/local/mysql --with-extra-
charsets=complex --enable-thread-safe-client --enable-local-infile
--disable-shared
```

The following binaries are built on third-party systems kindly provided to MySQL AB by other users. Please note that these are only provided as a courtesy. Since MySQL AB does not have full control over these systems, we can only provide limited support for the binaries built on these systems.

SCO Unix 3.2v5.0.6 i386 with gcc 2.95.3

```
CFLAGS="-O3 -mpentium" LDFLAGS=-static CXX=gcc CXXFLAGS="-O3 -
mpentium -felide-constructors" ./configure --prefix=/usr/local/mysql
--with-extra-charsets=complex --enable-thread-safe-client
--enable-local-infile --with-named-z-libs=no --enable-thread-safe-
client --disable-shared
```

SCO OpenUnix 8.0.0 i386 with CC 3.2

```
CC=cc CFLAGS="-O" CXX=CC ./configure --prefix=/usr/local/mysql
--with-extra-charsets=complex --enable-thread-safe-client
--enable-local-infile --with-named-z-libs=no --enable-thread-safe-
client --disable-shared
```

Compaq Tru64 OSF/1 V5.1 732 alpha with cc/cxx (Compaq C V6.3-029i / DIGITAL C++ V6.1-027)

```
CC="cc -pthread" CFLAGS="-O4 -ansi_alias -ansi_args -fast -
inline speed -speculate all" CXX="cxx -pthread" CXXFLAGS="-O4
-ansi_alias -fast -inline speed -speculate all -noexceptions
-nortti" ./configure --prefix=/usr/local/mysql --with-extra-
charsets=complex --enable-thread-safe-client --enable-local-infile
--with-prefix=/usr/local/mysql --with-named-thread-libs="-
lpthread -lmach -lexc -lc" --disable-shared --with-mysqld-ldflags=-
all-static
```

SGI Irix 6.5 IP32 with gcc 3.0.1

```
CC=gcc CFLAGS="-O3 -fno-omit-frame-pointer" CXXFLAGS="-O3
-fno-omit-frame-pointer -felide-constructors -fno-exceptions
-fno-rtti" ./configure --prefix=/usr/local/mysql --with-extra-
charsets=complex --enable-thread-safe-client --enable-local-infile
--disable-shared
```

FreeBSD 5.0 sparc64 with gcc 3.2.1

```
CFLAGS=-DHAVE_BROKEN_REALPATH ./configure --prefix=/usr/local/mysql
--localstatedir=/usr/local/mysql/data --libexecdir=/usr/local/mysql/bin
--with-extra-charsets=complex --enable-thread-safe-client
--enable-local-infile --disable-shared --with-innodb
```

The following compile options have been used for binary packages MySQL AB used to provide in the past. These binaries are no longer being updated, but the compile options are kept here for reference purposes.

Linux 2.2.xx sparc with egcs 1.1.2

```
CC=gcc CFLAGS="-O3 -fno-omit-frame-pointer" CXX=gcc CXXFLAGS="-O3
-fno-omit-frame-pointer -felide-constructors -fno-exceptions
-fno-rtti" ./configure --prefix=/usr/local/mysql --with-extra-
charsets=complex --enable-thread-safe-client --enable-local-infile
--enable-assembler --disable-shared
```

Linux 2.2.x with x686 with gcc 2.95.2

```
CFLAGS="-O3 -mpentiumpro" CXX=gcc CXXFLAGS="-O3 -mpentiumpro
-felide-constructors -fno-exceptions -fno-rtti" ./configure
--prefix=/usr/local/mysql --enable-assembler --with-mysqld-
ldflags=-all-static --disable-shared --with-extra-charsets=complex
```

SunOS 4.1.4 2 sun4c with gcc 2.7.2.1

```
CC=gcc CXX=gcc CXXFLAGS="-O3 -felide-constructors" ./configure
--prefix=/usr/local/mysql --disable-shared --with-extra-
charsets=complex --enable-assembler
```

SunOS 5.5.1 (and above) sun4u with egcs 1.0.3a or 2.90.27 or gcc 2.95.2 and newer

```
CC=gcc CFLAGS="-O3" CXX=gcc CXXFLAGS="-O3 -felide-constructors
-fno-exceptions -fno-rtti" ./configure --prefix=/usr/local/mysql
--with-low-memory --with-extra-charsets=complex --enable-assembler
```

SunOS 5.6 i86pc with gcc 2.8.1

```
CC=gcc CXX=gcc CXXFLAGS=-O3 ./configure --prefix=/usr/local/mysql
--with-low-memory --with-extra-charsets=complex
```

BSDI BSD/OS 3.1 i386 with gcc 2.7.2.1

```
CC=gcc CXX=gcc CXXFLAGS=-O ./configure --prefix=/usr/local/mysql
--with-extra-charsets=complex
```

BSDI BSD/OS 2.1 i386 with gcc 2.7.2

```
CC=gcc CXX=gcc CXXFLAGS=-O3 ./configure --prefix=/usr/local/mysql
--with-extra-charsets=complex
```

AIX 2 4 with `gcc` 2.7.2.2

```
CC=gcc CXX=gcc CXXFLAGS=-O3 ./configure --prefix=/usr/local/mysql
--with-extra-charsets=complex
```

Anyone who has more optimal options for any of the preceding configurations listed can always mail them to the MySQL internals s mailing list. See Section 1.6.1.1 [Mailing-list], page 25.

RPM distributions prior to MySQL Version 3.22 are user-contributed. Beginning with Version 3.22, the RPMs are generated by us at MySQL AB.

If you want to compile a debug version of MySQL, you should add `--with-debug` or `--with-debug=full` to the preceding configure lines and remove any `-fomit-frame-pointer` options.

For the Windows distribution, please see Section 2.1.1 [Windows installation], page 56.

2.2.9 Installing a MySQL Binary Distribution

This chapter covers the installation of MySQL binary distributions (`.tar.gz` Archives) for various platforms (see Section 2.2.8 [MySQL binaries], page 80 for a detailed list).

In addition to these generic packages, we also offer binaries in platform-specific package formats for selected platforms. See Section 2.1 [Quick Standard Installation], page 56 for more information on how to install these.

The generic MySQL binary distributions are packaged as gzip-compressed GNU tar archives (`.tar.gz`). You need the following tools to install a MySQL binary distribution:

- GNU `gunzip` to uncompress the distribution.
- A reasonable `tar` to unpack the distribution. GNU `tar` is known to work. Some `tar` implementations that come pre-installed with the operating system (e.g. Sun `tar`) are known to have problems (with long file names, for example). In that case, you should install GNU `tar` first.

If you run into problems, **please always use** `mysqlbug` when posting questions to a MySQL mailing list. Even if the problem isn't a bug, `mysqlbug` gathers system information that will help others solve your problem. By not using `mysqlbug`, you lessen the likelihood of getting a solution to your problem. You will find `mysqlbug` in the '`bin`' directory after you unpack the distribution. See Section 1.6.1.3 [Bug reports], page 27.

The basic commands you must execute to install and use a MySQL binary distribution are:

```
shell> groupadd mysql
shell> useradd -g mysql mysql
shell> cd /usr/local
shell> gunzip < /path/to/mysql-VERSION-OS.tar.gz | tar xvf -
shell> ln -s full-path-to-mysql-VERSION-OS mysql
shell> cd mysql
shell> scripts/mysql_install_db
shell> chown -R root  .
shell> chown -R mysql data
shell> chgrp -R mysql .
shell> bin/mysqld_safe --user=mysql &
```

If your version of MySQL is older than 4.0, substitute `bin/safe_mysqld` for `bin/mysqld_safe` in the final command.

You can add new users using the `bin/mysql_setpermission` script if you install the `DBI` and `DBD-mysql` Perl modules.

A more detailed description follows.

To install a binary distribution, follow these steps, then proceed to Section 2.4 [Post-installation], page 101, for post-installation setup and testing:

1. Pick the directory under which you want to unpack the distribution, and move into it. In the following example, we unpack the distribution under '`/usr/local`' (The following instructions, therefore, assume you have permission to create files and directories in '`/usr/local`'. If that directory is protected, you will need to perform the installation as `root`.)
2. Obtain a distribution file from one of the sites listed in Section 2.2.1 [Getting MySQL], page 70.

   MySQL binary distributions are provided as compressed `tar` archives and have names like '`mysql-VERSION-OS.tar.gz`', where `VERSION` is a number (for example, `3.21.15`), and `OS` indicates the type of operating system for which the distribution is intended (for example, `pc-linux-gnu-i586`). Note that all binaries are built from the same MySQL source distribution.
3. Add a user and group for `mysqld` to run as:

   ```
   shell> groupadd mysql
   shell> useradd -g mysql mysql
   ```

   These commands add the `mysql` group and the `mysql` user. The syntax for `useradd` and `groupadd` may differ slightly on different versions of Unix. They may also be called `adduser` and `addgroup`. You may wish to call the user and group something else instead of `mysql`.
4. Change into the intended installation directory:

   ```
   shell> cd /usr/local
   ```
5. Unpack the distribution, which will create the installation directory. Then create a symbolic link to that directory:

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

   Using GNU tar, you can also replace the first line with the following alternative command to decompress and extract the distribution in one go:

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

   The first command creates a directory named '`mysql-VERSION-OS`'. The second command makes a symbolic link to that directory. This lets you refer more easily to the installation directory as '`/usr/local/mysql`'.
6. Change into the installation directory:

   ```
   shell> cd mysql
   ```

   You will find several files and subdirectories in the `mysql` directory. The most important for installation purposes are the '`bin`' and '`scripts`' subdirectories.

'`bin`' This directory contains client programs and the server You should add the full pathname of this directory to your `PATH` environment variable so that your shell finds the MySQL programs properly. See Appendix F [Environment variables], page 1019.

'`scripts`' This directory contains the `mysql_install_db` script used to initialise the `mysql` database containing the grant tables that store the server access permissions.

7. If you would like to use `mysqlaccess` and have the MySQL distribution in some non-standard place, you must change the location where `mysqlaccess` expects to find the `mysql` client. Edit the '`bin/mysqlaccess`' script at approximately line 18. Search for a line that looks like this:

```
$MYSQL     = '/usr/local/bin/mysql';    # path to mysql executable
```

   Change the path to reflect the location where `mysql` actually is stored on your system. If you do not do this, you will get a `Broken pipe` error when you run `mysqlaccess`.

8. Create the MySQL grant tables (necessary only if you haven't installed MySQL before):

```
shell> scripts/mysql_install_db
```

   Note that MySQL versions older than Version 3.22.10 started the MySQL server when you run `mysql_install_db`. This is no longer true.

9. Change ownership of binaries to `root` and ownership of the data directory to the user that you will run `mysqld` as:

```
shell> chown -R root  /usr/local/mysql/.
shell> chown -R mysql /usr/local/mysql/data
shell> chgrp -R mysql /usr/local/mysql/.
```

   The first command changes the `owner` attribute of the files to the `root` user, the second one changes the `owner` attribute of the data directory to the `mysql` user, and the third one changes the `group` attribute to the `mysql` group.

10. If you want to install support for the Perl `DBI/DBD` interface, see Section 2.7 [Perl support], page 152.

11. If you would like MySQL to start automatically when you boot your machine, you can copy `support-files/mysql.server` to the location where your system has its startup files. More information can be found in the `support-files/mysql.server` script itself and in Section 2.4.3 [Automatic start], page 108.

After everything has been unpacked and installed, you should initialise and test your distribution.

You can start the MySQL server with the following command:

```
shell> bin/mysqld_safe --user=mysql &
```

If your version of MySQL is older than 4.0, substitute `bin/safe_mysqld` for `bin/mysqld_safe` in the command.

Now proceed to Section 4.8.2 [`mysqld_safe`], page 312, and See Section 2.4 [Post-installation], page 101.

2.3 Installing a MySQL Source Distribution

Before you proceed with the source installation, check first to see if our binary is available for your platform and if it will work for you. We put a lot of effort into making sure that our binaries are built with the best possible options.

You need the following tools to build and install MySQL from source:

- GNU `gunzip` to uncompress the distribution.
- A reasonable `tar` to unpack the distribution. GNU `tar` is known to work. Some `tar` implementations that come pre-installed with the operating system (e.g. Sun `tar`) are known to have problems (with long file names, for example). In that case, you should install GNU `tar` first.
- A working ANSI C++ compiler. `gcc` >= 2.95.2, `egcs` >= 1.0.2 or `egcs 2.91.66`, SGI C++, and SunPro C++ are some of the compilers that are known to work. `libg++` is not needed when using `gcc`. `gcc` 2.7.x has a bug that makes it impossible to compile some perfectly legal C++ files, such as '`sql/sql_base.cc`'. If you only have `gcc` 2.7.x, you must upgrade your `gcc` to be able to compile MySQL. `gcc` 2.8.1 is also known to have problems on some platforms, so it should be avoided if a new compiler exists for the platform.

  `gcc` >= 2.95.2 is recommended when compiling MySQL Version 3.23.x.
- A good `make` program. GNU `make` is always recommended and is sometimes required. If you have problems, we recommend trying GNU `make` 3.75 or newer.

If you are using a recent version of `gcc`, recent enough to understand the `-fno-exceptions` option, it is **very important** that you use it. Otherwise, you may compile a binary that crashes randomly. We also recommend that you use `-felide-constructors` and `-fno-rtti` along with `-fno-exceptions`. When in doubt, do the following:

```
CFLAGS="-O3" CXX=gcc CXXFLAGS="-O3 -felide-constructors -fno-exceptions \
       -fno-rtti" ./configure --prefix=/usr/local/mysql --enable-assembler \
       --with-mysqld-ldflags=-all-static
```

On most systems this will give you a fast and stable binary.

If you run into problems, **please always use** `mysqlbug` when posting questions to a MySQL mailing list. Even if the problem isn't a bug, `mysqlbug` gathers system information that will help others solve your problem. By not using `mysqlbug`, you lessen the likelihood of getting a solution to your problem. You will find `mysqlbug` in the '`scripts`' directory after you unpack the distribution. See Section 1.6.1.3 [Bug reports], page 27.

2.3.1 Quick Installation Overview

The basic commands you must execute to install a MySQL source distribution are:

```
shell> groupadd mysql
shell> useradd -g mysql mysql
shell> gunzip < mysql-VERSION.tar.gz | tar -xvf -
shell> cd mysql-VERSION
```

```
shell> ./configure --prefix=/usr/local/mysql
shell> make
shell> make install
shell> scripts/mysql_install_db
shell> chown -R root  /usr/local/mysql
shell> chown -R mysql /usr/local/mysql/var
shell> chgrp -R mysql /usr/local/mysql
shell> cp support-files/my-medium.cnf /etc/my.cnf
shell> /usr/local/mysql/bin/mysqld_safe --user=mysql &
```

If your version of MySQL is older than 4.0, substitute `bin/safe_mysqld` for `bin/mysqld_safe` in the final command.

If you want to have support for InnoDB tables, you should edit the `/etc/my.cnf` file and remove the `#` character before the parameter that starts with `innodb_...`. See Section 4.1.2 [Option files], page 203, and Section 7.5.3 [InnoDB start], page 607.

If you start from a source RPM, do the following:

```
shell> rpm --rebuild --clean MySQL-VERSION.src.rpm
```

This will make a binary RPM that you can install.

You can add new users using the `bin/mysql_setpermission` script if you install the `DBI` and `DBD-mysql` Perl modules.

A more detailed description follows.

To install a source distribution, follow these steps, then proceed to Section 2.4 [Post-installation], page 101, for post-installation initialisation and testing:

1. Pick the directory under which you want to unpack the distribution, and move into it.
2. Obtain a distribution file from one of the sites listed in Section 2.2.1 [Getting MySQL], page 70.
3. If you are interested in using Berkeley DB tables with MySQL, you will need to obtain a patched version of the Berkeley DB source code. Please read the chapter on Berkeley DB tables before proceeding. See Section 7.6 [BDB], page 654.

   MySQL source distributions are provided as compressed `tar` archives and have names like '`mysql-VERSION.tar.gz`', where `VERSION` is a number like 4.1.1-alpha.
4. Add a user and group for `mysqld` to run as:

   ```
   shell> groupadd mysql
   shell> useradd -g mysql mysql
   ```

   These commands add the `mysql` group and the `mysql` user. The syntax for `useradd` and `groupadd` may differ slightly on different versions of Unix. They may also be called `adduser` and `addgroup`. You may wish to call the user and group something else instead of `mysql`.
5. Unpack the distribution into the current directory:

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

   This command creates a directory named '`mysql-VERSION`'.
6. Change into the top-level directory of the unpacked distribution:

```
shell> cd mysql-VERSION
```

Note that currently you must configure and build MySQL from this top-level directory. You cannot build it in a different directory.

7. Configure the release and compile everything:

   ```
   shell> ./configure --prefix=/usr/local/mysql
   shell> make
   ```

   When you run `configure`, you might want to specify some options. Run `./configure --help` for a list of options. Section 2.3.3 [`configure` options], page 91, discusses some of the more useful options.

   If `configure` fails, and you are going to send mail to a MySQL mailing list to ask for assistance, please include any lines from '`config.log`' that you think can help solve the problem. Also include the last couple of lines of output from `configure` if `configure` aborts. Post the bug report using the `mysqlbug` script. See Section 1.6.1.3 [Bug reports], page 27.

   If the compile fails, see Section 2.3.5 [Compilation problems], page 96, for help with a number of common problems.

8. Install everything:

   ```
   shell> make install
   ```

   You might need to run this command as `root`.

9. Create the MySQL grant tables (necessary only if you haven't installed MySQL before):

   ```
   shell> scripts/mysql_install_db
   ```

   Note that MySQL versions older than Version 3.22.10 started the MySQL server when you run `mysql_install_db`. This is no longer true.

10. Change ownership of binaries to `root` and ownership of the data directory to the user that you will run `mysqld` as:

    ```
    shell> chown -R root  /usr/local/mysql
    shell> chown -R mysql /usr/local/mysql/var
    shell> chgrp -R mysql /usr/local/mysql
    ```

    The first command changes the `owner` attribute of the files to the `root` user, the second one changes the `owner` attribute of the data directory to the `mysql` user, and the third one changes the `group` attribute to the `mysql` group.

11. If you want to install support for the Perl `DBI/DBD` interface, see Section 2.7 [Perl support], page 152.

12. If you would like MySQL to start automatically when you boot your machine, you can copy `support-files/mysql.server` to the location where your system has its startup files. More information can be found in the `support-files/mysql.server` script itself and in Section 2.4.3 [Automatic start], page 108.

After everything has been installed, you should initialise and test your distribution using this command:

```
shell> /usr/local/mysql/bin/mysqld_safe --user=mysql &
```

If your version of MySQL is older than 4.0, substitute `safe_mysqld` for `mysqld_safe` in the command.

If that command fails immediately with `mysqld daemon ended`, you can find some information in the file '`mysql-data-directory/'hostname'.err`'. The likely reason is that you already have another `mysqld` server running. See Section 4.2 [Multiple servers], page 206.

Now proceed to Section 2.4 [Post-installation], page 101.

2.3.2 Applying Patches

Sometimes patches appear on the mailing list or are placed in the patches area of the MySQL web site (`http://www.mysql.com/downloads/patches.html`).

To apply a patch from the mailing list, save the message in which the patch appears in a file, change into the top-level directory of your MySQL source tree, and run these commands:

```
shell> patch -p1 < patch-file-name
shell> rm config.cache
shell> make clean
```

Patches from the FTP site are distributed as plain text files or as files compressed with `gzip`. Apply a plain patch as shown previously for mailing list patches. To apply a compressed patch, change into the top-level directory of your MySQL source tree and run these commands:

```
shell> gunzip < patch-file-name.gz | patch -p1
shell> rm config.cache
shell> make clean
```

After applying a patch, follow the instructions for a normal source install, beginning with the `./configure` step. After running the `make install` step, restart your MySQL server.

You may need to bring down any currently running server before you run `make install`. (Use `mysqladmin shutdown` to do this.) Some systems do not allow you to install a new version of a program if it replaces the version that is currently executing.

2.3.3 Typical `configure` Options

The `configure` script gives you a great deal of control over how you configure your MySQL distribution. Typically you do this using options on the `configure` command-line. You can also affect `configure` using certain environment variables. See Appendix F [Environment variables], page 1019. For a list of options supported by `configure`, run this command:

```
shell> ./configure --help
```

Some of the more commonly-used `configure` options are described here:

- To compile just the MySQL client libraries and client programs and not the server, use the `--without-server` option:

  ```
  shell> ./configure --without-server
  ```

  If you don't have a C++ compiler, `mysql` will not compile (it is the one client program that requires C++). In this case, you can remove the code in `configure` that tests for the C++ compiler and then run `./configure` with the `--without-server` option. The compile step will still try to build `mysql`, but you can ignore any warnings about '`mysql.cc`'. (If `make` stops, try `make -k` to tell it to continue with the rest of the build even if errors occur.)

- If you want to get an embedded MySQL library (`libmysqld.a`) you should use the `--with-embedded-server` option.
- If you don't want your log files and database directories located under '`/usr/local/var`', use a `configure` command, something like one of these:

```
shell> ./configure --prefix=/usr/local/mysql
shell> ./configure --prefix=/usr/local \
           --localstatedir=/usr/local/mysql/data
```

  The first command changes the installation prefix so that everything is installed under '`/usr/local/mysql`' rather than the default of '`/usr/local`'. The second command preserves the default installation prefix, but overrides the default location for database directories (normally '`/usr/local/var`') and changes it to `/usr/local/mysql/data`. After you have compiled MySQL, you can change these options with option files. See Section 4.1.2 [Option files], page 203.
- If you are using Unix and you want the MySQL socket located somewhere other than the default location (normally in the directory '`/tmp`' or '`/var/run`') use a `configure` command like this:

```
shell> ./configure --with-unix-socket-path=/usr/local/mysql/tmp/mysql.sock
```

  Note that the given file must be an absolute pathname. You can also later change the location '`mysql.sock`' by using the MySQL option files. See Section A.4.5 [Problems with mysql.sock], page 863.
- If you want to compile statically linked programs (for example, to make a binary distribution, to get more speed, or to work around problems with some Red Hat Linux distributions), run `configure` like this:

```
shell> ./configure --with-client-ldflags=-all-static \
           --with-mysqld-ldflags=-all-static
```

- If you are using `gcc` and don't have `libg++` or `libstdc++` installed, you can tell `configure` to use `gcc` as your C++ compiler:

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

  When you use `gcc` as your C++ compiler, it will not attempt to link in `libg++` or `libstdc++`. This may be a good idea to do even if you have the above libraries installed, as some versions of these libraries have caused strange problems for MySQL users in the past.

  Here are some common environment variables to set depending on the compiler you are using:

Compiler	**Recommended options**
gcc 2.7.2.1	CC=gcc CXX=gcc CXXFLAGS="-O3 -felide-constructors"
egcs 1.0.3a	CC=gcc CXX=gcc CXXFLAGS="-O3 -felide-constructors -fno-exceptions -fno-rtti"
gcc 2.95.2	CFLAGS="-O3 -mpentiumpro" CXX=gcc CXXFLAGS="-O3 -mpentiumpro \ -felide-constructors -fno-exceptions -fno-rtti"
pgcc 2.90.29 or newer	CFLAGS="-O3 -mpentiumpro -mstack-align-double" CXX=gcc \ CXXFLAGS="-O3 -mpentiumpro -mstack-align-double -felide-constructors \ -fno-exceptions -fno-rtti"

  In most cases you can get a reasonably optimal MySQL binary by using the options from the preceding table and adding the following options to the configure line:

```
--prefix=/usr/local/mysql --enable-assembler \
--with-mysqld-ldflags=-all-static
```

The full configure line would, in other words, be something like the following for all recent gcc versions:

```
CFLAGS="-O3 -mpentiumpro" CXX=gcc CXXFLAGS="-O3 -mpentiumpro \
-felide-constructors -fno-exceptions -fno-rtti" ./configure \
--prefix=/usr/local/mysql --enable-assembler \
--with-mysqld-ldflags=-all-static
```

The binaries we provide on the MySQL web site at `http://www.mysql.com/` are all compiled with full optimisation and should be perfect for most users. See Section 2.2.8 [MySQL binaries], page 80. There are some things you can tweak to make an even faster binary, but this is only for advanced users. See Section 5.5.3 [Compile and link options], page 429.

If the build fails and produces errors about your compiler or linker not being able to create the shared library '`libmysqlclient.so.#`' ('`#`' is a version number), you can work around this problem by giving the `--disable-shared` option to `configure`. In this case, `configure` will not build a shared '`libmysqlclient.so.#`' library.

- You can configure MySQL not to use `DEFAULT` column values for non-`NULL` columns (that is, columns that are not allowed to be `NULL`). See Section 1.7.5.2 [constraint NOT NULL], page 43.

  ```
  shell> CXXFLAGS=-DDONT_USE_DEFAULT_FIELDS ./configure
  ```

- By default, MySQL uses the ISO-8859-1 (Latin1) character set. To change the default set, use the `--with-charset` option:

  ```
  shell> ./configure --with-charset=CHARSET
  ```

  `CHARSET` may be one of `big5`, `cp1251`, `cp1257`, `czech`, `danish`, `dec8`, `dos`, `euc_kr`, `gb2312`, `gbk`, `german1`, `hebrew`, `hp8`, `hungarian`, `koi8_ru`, `koi8_ukr`, `latin1`, `latin2`, `sjis`, `swe7`, `tis620`, `ujis`, `usa7`, or `win1251ukr`. See Section 4.7.1 [Character sets], page 306.

  If you want to convert characters between the server and the client, you should take a look at the `SET CHARACTER SET` command. See Section 5.5.6 [SET], page 432.

  Warning: If you change character sets after having created any tables, you will have to run `myisamchk -r -q --set-character-set=charset` on every table. Your indexes may be sorted incorrectly otherwise. (This can happen if you install MySQL, create some tables, then reconfigure MySQL to use a different character set and reinstall it.)

  With the option `--with-extra-charsets=LIST` you can define which additional character sets should be compiled into the server.

  Here `LIST` is either a list of character sets separated with spaces, `complex` to include all characters that can't be dynamically loaded, or `all` to include all character sets into the binaries.

- To configure MySQL with debugging code, use the `--with-debug` option:

  ```
  shell> ./configure --with-debug
  ```

  This causes a safe memory allocator to be included that can find some errors and that provides output about what is happening. See Section E.1 [Debugging server], page 1007.

- If your client programs are using threads, you need to also compile a thread-safe version of the MySQL client library with the `--enable-thread-safe-client` configure options. This will create a `libmysqlclient_r` library with which you should link your threaded applications. See Section 11.1.14 [Threaded clients], page 799.
- Options that pertain to particular systems can be found in the system-specific section of this manual. See Section 2.6 [Operating System Specific Notes], page 122.

2.3.4 Installing from the Development Source Tree

Caution: You should read this section only if you are interested in helping us test our new code. If you just want to get MySQL up and running on your system, you should use a standard release distribution (either a source or binary distribution will do).

To obtain our most recent development source tree, use these instructions:

1. Download `BitKeeper` from `http://www.bitmover.com/cgi-bin/download.cgi`. You will need `Bitkeeper` 3.0 or newer to access our repository.
2. Follow the instructions to install it.
3. After `BitKeeper` is installed, first go to the directory you want to work from, and then use one of the following commands to clone the MySQL version branch of your choice:

   To clone the 3.23 (old) branch, use this command:

   ```
   shell> bk clone bk://mysql.bkbits.net/mysql-3.23 mysql-3.23
   ```

   To clone the 4.0 (stable/production) branch, use this command:

   ```
   shell> bk clone bk://mysql.bkbits.net/mysql-4.0 mysql-4.0
   ```

   To clone the 4.1 alpha branch, use this command:

   ```
   shell> bk clone bk://mysql.bkbits.net/mysql-4.1 mysql-4.1
   ```

   To clone the 5.0 development branch, use this command:

   ```
   shell> bk clone bk://mysql.bkbits.net/mysql-5.0 mysql-5.0
   ```

   In the preceding examples the source tree will be set up in the '`mysql-3.23/`', '`mysql-4.0/`', '`mysql-4.1/`', or '`mysql-5.0/`' subdirectory of your current directory.

   If you are behind a firewall and can only initiate HTTP connections, you can also use `BitKeeper` via HTTP.

   If you are required to use a proxy server, simply set the environment variable `http_proxy` to point to your proxy:

   ```
   shell> export http_proxy="http://your.proxy.server:8080/"
   ```

   Now, simply replace the `bk://` with `http://` when doing a clone. Example:

   ```
   shell> bk clone http://mysql.bkbits.net/mysql-4.1 mysql-4.1
   ```

   The initial download of the source tree may take a while, depending on the speed of your connection - please be patient.
4. You will need **GNU** `make`, `autoconf 2.53 (or newer)`, `automake 1.5`, `libtool 1.4`, and `m4` to run the next set of commands. Even though many operating system already come with their own implementation of `make`, chances are high that the compilation fails with strange error messages. Therefore it is highly recommended to use GNU `make` (sometimes also named `gmake`) by all means.

Fortunately, a large number of operating systems already ship with the GNU toolchain preinstalled or supply installable packages of these. In any case, they can also be downloaded from the following locations:

- `http://www.gnu.org/software/autoconf/`
- `http://www.gnu.org/software/automake/`
- `http://www.gnu.org/software/libtool/`
- `http://www.gnu.org/software/make/`

If you are trying to configure MySQL 4.1, you will also need GNU `bison 1.75`. Older versions of `bison` may report this error: `sql_yacc.yy:#####: fatal error: maximum table size (32767) exceeded`. Note: the maximum table size is not actually exceeded, the error is caused by bugs in these earlier `bison` versions.

Versions of MySQL before version 4.1 may also compile with other `yacc` implementations (e.g. BSD `yacc` 91.7.30). For later versions, GNU `bison` is a requirement.

The typical command to do in a shell is:

```
cd mysql-4.0
bk -r edit
aclocal; autoheader; autoconf; automake
(cd innobase; aclocal; autoheader; autoconf; automake) # for InnoDB
(cd bdb/dist; sh s_all ) # for Berkeley DB
./configure  # Add your favorite options here
make
```

If you get some strange error during this stage, check that you really have `libtool` installed.

A collection of our standard configure scripts is located in the '`BUILD/`' subdirectory. If you are lazy, you can use '`BUILD/compile-pentium-debug`'. To compile on a different architecture, modify the script by removing flags that are Pentium-specific.

5. When the build is done, run `make install`. Be careful with this on a production machine; the command may overwrite your live release installation. If you have another installation of MySQL, we recommend that you run `./configure` with different values for the `prefix`, `with-tcp-port`, and `unix-socket-path` options than those used for your production server.
6. Play hard with your new installation and try to make the new features crash. Start by running `make test`. See Section 13.1.2 [MySQL test suite], page 832.
7. If you have gotten to the `make` stage and the distribution does not compile, please report it in our bugs database at `http://bugs.mysql.com/`. If you have installed the latest versions of the required GNU tools, and they crash trying to process our configuration files, please report that also. However, if you execute `aclocal` and get a `command not found` error or a similar problem, do not report it. Instead, make sure all the necessary tools are installed and that your `PATH` variable is set correctly so that your shell can find them.
8. After the initial `bk clone` operation to get the source tree, you should run `bk pull` periodically to get the updates.
9. You can examine the change history for the tree with all the diffs by using `bk sccstool`. If you see some funny diffs or code that you have a question about, do not hesitate

to send e-mail to the MySQL internals mailing list. See Section 1.6.1.1 [Mailing-list], page 25. Also, if you think you have a better idea on how to do something, send an e-mail to the same address with a patch. `bk diffs` will produce a patch for you after you have made changes to the source. If you do not have the time to code your idea, just send a description.

10. `BitKeeper` has a nice help utility that you can access via `bk helptool`.
11. Please note that any commits (`bk ci` or `bk citool`) will trigger the posting of a message with the changeset to our internals mailing list, as well as the usual openlogging.org submission with just the changeset comments. Generally, you wouldn't need to use commit (since the public tree will not allow `bk push`), but rather use the `bk diffs` method described previously.

You can also browse changesets, comments and sourcecode online by browsing to for example, `http://mysql.bkbits.net:8080/mysql-4.1` For MySQL 4.1.

The manual is in a separate tree which can be cloned with:

```
shell> bk clone bk://mysql.bkbits.net/mysqldoc mysqldoc
```

There are also public BitKeeper trees for MySQL Control Center and Connector/ODBC. They can be cloned respectively as follows.

To clone MySQL Control center, use this command:

```
shell> bk clone http://mysql.bkbits.net/mysqlcc mysqlcc
```

To clone Connector/ODBC, use this command:

```
shell> bk clone http://mysql.bkbits.net/myodbc3 myodbc3
```

2.3.5 Dealing With Problems Compiling MySQL

All MySQL programs compile cleanly for us with no warnings on Solaris or Linux using `gcc`. On other systems, warnings may occur due to differences in system include files. See Section 2.3.6 [MIT-pthreads], page 99 for warnings that may occur when using MIT-pthreads. For other problems, check the following list.

The solution to many problems involves reconfiguring. If you do need to reconfigure, take note of the following:

- If `configure` is run after it already has been run, it may use information that was gathered during its previous invocation. This information is stored in '`config.cache`'. When `configure` starts up, it looks for that file and reads its contents if it exists, on the assumption that the information is still correct. That assumption is invalid when you reconfigure.
- Each time you run `configure`, you must run `make` again to recompile. However, you may want to remove old object files from previous builds first because they were compiled using different configuration options.

To prevent old configuration information or object files from being used, run these commands before rerunning `configure`:

```
shell> rm config.cache
shell> make clean
```

Alternatively, you can run `make distclean`.

The following list describes some of the problems when compiling MySQL that have been found to occur most often:

- If you get errors when compiling 'sql_yacc.cc', such as the ones shown here, you have probably run out of memory or swap space:

```
Internal compiler error: program cc1plus got fatal signal 11
  or
Out of virtual memory
  or
Virtual memory exhausted
```

  The problem is that gcc requires huge amounts of memory to compile 'sql_yacc.cc' with inline functions. Try running configure with the --with-low-memory option:

```
shell> ./configure --with-low-memory
```

  This option causes -fno-inline to be added to the compile line if you are using gcc and -O0 if you are using something else. You should try the --with-low-memory option even if you have so much memory and swap space that you think you can't possibly have run out. This problem has been observed to occur even on systems with generous hardware configurations, and the --with-low-memory option usually fixes it.

- By default, configure picks c++ as the compiler name and GNU c++ links with -lg++. If you are using gcc, that behaviour can cause problems during configuration such as this:

```
configure: error: installation or configuration problem:
C++ compiler cannot create executables.
```

  You might also observe problems during compilation related to g++, libg++, or libstdc++.

  One cause of these problems is that you may not have g++, or you may have g++ but not libg++, or libstdc++. Take a look at the 'config.log' file. It should contain the exact reason why your C++ compiler didn't work. To work around these problems, you can use gcc as your C++ compiler. Try setting the environment variable CXX to "gcc -O3". For example:

```
shell> CXX="gcc -O3" ./configure
```

  This works because gcc compiles C++ sources as well as g++ does, but does not link in libg++ or libstdc++ by default.

  Another way to fix these problems, of course, is to install g++, libg++, and libstdc++. We would however like to recommend you to not use libg++ or libstdc++ with MySQL as this will only increase the binary size of mysqld without giving you any benefits. Some versions of these libraries have also caused strange problems for MySQL users in the past.

  Using gcc as the C++ compiler is also required, if you want to compile MySQL with RAID functionality (see Section 6.5.3 [CREATE TABLE], page 564 for more info on RAID table type) and you are using GNU gcc version 3 and above. If you get errors like the ones below during the linking stage when you configure MySQL to compile with the option --with-raid, try to use gcc as your C++ compiler by defining the above mentioned environment variable CXX:

```
gcc -O3 -DDBUG_OFF -rdynamic -o isamchk isamchk.o sort.o  libnisam.a
```

```
../mysys/libmysys.a ../dbug/libdbug.a ../strings/libmystrings.a -lpthread
-lz -lcrypt -lnsl -lm -lpthread
../mysys/libmysys.a(raid.o)(.text+0x79): In function `my_raid_create':
: undefined reference to `operator new(unsigned)'
../mysys/libmysys.a(raid.o)(.text+0xdd): In function `my_raid_create':
: undefined reference to `operator delete(void*)'
../mysys/libmysys.a(raid.o)(.text+0x129): In function `my_raid_open':
: undefined reference to `operator new(unsigned)'
../mysys/libmysys.a(raid.o)(.text+0x189): In function `my_raid_open':
: undefined reference to `operator delete(void*)'
../mysys/libmysys.a(raid.o)(.text+0x64b): In function `my_raid_close':
: undefined reference to `operator delete(void*)'
collect2: ld returned 1 exit status
```

- If your compile fails with errors, such as any of the following, you must upgrade your version of `make` to GNU `make`:

  ```
  making all in mit-pthreads
  make: Fatal error in reader: Makefile, line 18:
  Badly formed macro assignment
    or
  make: file `Makefile' line 18: Must be a separator (:
    or
  pthread.h: No such file or directory
  ```

  Solaris and FreeBSD are known to have troublesome `make` programs.

  GNU `make` Version 3.75 is known to work.

- If you want to define flags to be used by your C or C++ compilers, do so by adding the flags to the `CFLAGS` and `CXXFLAGS` environment variables. You can also specify the compiler names this way using `CC` and `CXX`. For example:

  ```
  shell> CC=gcc
  shell> CFLAGS=-O3
  shell> CXX=gcc
  shell> CXXFLAGS=-O3
  shell> export CC CFLAGS CXX CXXFLAGS
  ```

  See Section 2.2.8 [MySQL binaries], page 80, for a list of flag definitions that have been found to be useful on various systems.

- If you get an error message like this, you need to upgrade your `gcc` compiler:

  ```
  client/libmysql.c:273: parse error before `__attribute__'
  ```

  `gcc` 2.8.1 is known to work, but we recommend using `gcc` 2.95.2 or `egcs` 1.0.3a instead.

- If you get errors such as those shown here when compiling `mysqld`, `configure` didn't correctly detect the type of the last argument to `accept()`, `getsockname()`, or `getpeername()`:

  ```
  cxx: Error: mysqld.cc, line 645: In this statement, the referenced
       type of the pointer value ''length'' is ''unsigned long'', which
       is not compatible with ''int''.
  new_sock = accept(sock, (struct sockaddr *)&cAddr, &length);
  ```

To fix this, edit the '`config.h`' file (which is generated by `configure`). Look for these lines:

```
/* Define as the base type of the last arg to accept */
#define SOCKET_SIZE_TYPE XXX
```

Change `XXX` to `size_t` or `int`, depending on your operating system. (Note that you will have to do this each time you run `configure` because `configure` regenerates '`config.h`'.)

- The '`sql_yacc.cc`' file is generated from '`sql_yacc.yy`'. Normally the build process doesn't need to create '`sql_yacc.cc`', because MySQL comes with an already generated copy. However, if you do need to re-create it, you might encounter this error:

  ```
  "sql_yacc.yy", line xxx fatal: default action causes potential...
  ```

  This is a sign that your version of `yacc` is deficient. You probably need to install `bison` (the GNU version of `yacc`) and use that instead.
- If you need to debug `mysqld` or a MySQL client, run `configure` with the `--with-debug` option, then recompile and link your clients with the new client library. See Section E.2 [Debugging client], page 1012.
- If you get a compilation error on Linux (e.g. SuSE Linux 8.1 or Red Hat Linux 7.3) similar to the following one:

  ```
  libmysql.c:1329: warning: passing arg 5 of 'gethostbyname_r' from incompatible poi
  libmysql.c:1329: too few arguments to function 'gethostbyname_r'
  libmysql.c:1329: warning: assignment makes pointer from integer without a cast
  make[2]: *** [libmysql.lo] Error 1
  ```

  By default, the `configure` script attempts to determine the correct number of arguments by using `g++` the GNU C++ compiler. This test yields wrong results, if `g++` is not installed. There are two ways to work around this problem:
  - Make sure that the GNU C++ `g++` is installed. On some Linux distributions, the required package is called `gpp`, on others it is named `gcc-c++`.
  - Use `gcc` as your C++ compiler by setting the `CXX` environment variable to `gcc`:

    ```
    export CXX="gcc"
    ```

  Please note that you need to run `configure` again afterwards.

2.3.6 MIT-pthreads Notes

This section describes some of the issues involved in using MIT-pthreads.

Note that on Linux you should **not** use MIT-pthreads but use the installed LinuxThreads implementation instead. See Section 2.6.2 [Linux], page 126.

If your system does not provide native thread support, you will need to build MySQL using the MIT-pthreads package. This includes older FreeBSD systems, SunOS 4.x, Solaris 2.4 and earlier, and some others. See Section 2.2.3 [Which OS], page 73.

Note, that beginning with MySQL 4.0.2 MIT-pthreads are no longer part of the source distribution. If you require this package, you need to download it separately from `http://www.mysql.com/Downloads/Contrib/pthreads-1_60_beta6-mysql.tar.gz`

After downloading, extract this source archive into the top level of the MySQL source directory. It will create a new subdirectory `mit-pthreads`.

- On most systems, you can force MIT-pthreads to be used by running `configure` with the `--with-mit-threads` option:

  ```
  shell> ./configure --with-mit-threads
  ```

  Building in a non-source directory is not supported when using MIT-pthreads because we want to minimise our changes to this code.
- The checks that determine whether to use MIT-pthreads occur only during the part of the configuration process that deals with the server code. If you have configured the distribution using `--without-server` to build only the client code, clients will not know whether MIT-pthreads is being used and will use Unix socket connections by default. Because Unix sockets do not work under MIT-pthreads on some platforms, this means you will need to use `-h` or `--host` when you run client programs.
- When MySQL is compiled using MIT-pthreads, system locking is disabled by default for performance reasons. You can tell the server to use system locking with the `--external-locking` option. This is only needed if you want to be able to run two MySQL servers against the same datafiles (not recommended).
- Sometimes the pthread `bind()` command fails to bind to a socket without any error message (at least on Solaris). The result is that all connections to the server fail. For example:

  ```
  shell> mysqladmin version
  mysqladmin: connect to server at '' failed;
  error: 'Can't connect to mysql server on localhost (146)'
  ```

  The solution to this is to kill the `mysqld` server and restart it. This has only happened to us when we have forced down the server and done a restart immediately.
- With MIT-pthreads, the `sleep()` system call isn't interruptible with `SIGINT` (break). This is only noticeable when you run `mysqladmin --sleep`. You must wait for the `sleep()` call to terminate before the interrupt is served and the process stops.
- When linking, you may receive warning messages like these (at least on Solaris); they can be ignored:

  ```
  ld: warning: symbol `_iob' has differing sizes:
      (file /my/local/pthreads/lib/libpthread.a(findfp.o) value=0x4;
  file /usr/lib/libc.so value=0x140);
      /my/local/pthreads/lib/libpthread.a(findfp.o) definition taken
  ld: warning: symbol `__iob' has differing sizes:
      (file /my/local/pthreads/lib/libpthread.a(findfp.o) value=0x4;
  file /usr/lib/libc.so value=0x140);
      /my/local/pthreads/lib/libpthread.a(findfp.o) definition taken
  ```
- Some other warnings also can be ignored:

  ```
  implicit declaration of function `int strtoll(...)'
  implicit declaration of function `int strtoul(...)'
  ```
- We haven't gotten `readline` to work with MIT-pthreads. (This isn't needed, but may be interesting for someone.)

2.3.7 Installing MySQL from Source on Windows

To install MySQL on Windows using a source distribution, you will need the following:

- VC++ 6.0 compiler (updated with 4 or 5 SP and Pre-processor package) The Pre-processor package is necessary for the macro assembler. More details at: `http://msdn.microsoft.com/vstudio/downloads/updates/sp/vs6/sp5/faq.aspx`.
- The MySQL source distribution for Windows, which can be downloaded from `http://www.mysql.com/downloads/`.

Follow this procedure to build MySQL:

1. Create a work directory (for example, '`workdir`').
2. Unpack the source distribution in the aforementioned directory.
3. Start the VC++ 6.0 compiler.
4. In the `File` menu, select `Open Workspace`.
5. Open the '`mysql.dsw`' workspace you find on the work directory.
6. From the `Build` menu, select the `Set Active Configuration` menu.
7. Click over the screen selecting `mysqld - Win32 Debug` and click OK.
8. Press `F7` to begin the build of the debug server, libraries, and some client applications.
9. When the compilation finishes, copy the libraries and the executables to a separate directory.
10. Compile the release versions that you want, in the same way.
11. Create the directory into which to install the MySQL stuff (for example, '`c:\mysql`').
12. From the '`workdir`' directory copy into the `c:\mysql` directory the following directories:
    - '`Data`'
    - '`Docs`'
    - '`Share`'
13. Create the directory '`c:\mysql\bin`' and copy into it all the servers and clients that you just compiled.
14. If you want, also create the '`c:\mysql\lib`' directory and copy the libraries that you just compiled.
15. Do a clean using Visual Studio.

Set up and start the server in the same way as for the binary Windows distribution. See Section 2.1.1.3 [Windows prepare environment], page 58.

2.4 Post-installation Setup and Testing

Once you've installed MySQL (from either a binary or source distribution), you need to initialise the grant tables, start the server, and make sure that the server works okay. You may also wish to arrange for the server to be started and stopped automatically when your system starts up and shuts down.

Normally you install the grant tables and start the server like this for installation from a source distribution:

```
shell> ./scripts/mysql_install_db
shell> cd mysql_installation_directory
shell> ./bin/mysqld_safe --user=mysql &
```

For a binary distribution (not RPM or pkg packages), do this:

```
shell> cd mysql_installation_directory
shell> ./scripts/mysql_install_db
shell> ./bin/mysqld_safe --user=mysql &
```

The `mysql_install_db` script creates the `mysql` database which will hold all database privileges, the `test` database which you can use to test MySQL, and also privilege entries for the user that runs `mysql_install_db` and a `root` user. The entries are created without passwords. The `mysqld_safe` script starts the `mysqld` server. (If your version of MySQL is older than 4.0, use `safe_mysqld` rather than `mysqld_safe`.)

`mysql_install_db` will not overwrite any old privilege tables, so it should be safe to run in any circumstances. If you don't want to have the `test` database you can remove it with `mysqladmin -u root drop test` after starting the server.

Testing is most easily done from the top-level directory of the MySQL distribution. For a binary distribution, this is your installation directory (typically something like '`/usr/local/mysql`'). For a source distribution, this is the main directory of your MySQL source tree.

In the commands shown in this section and in the following subsections, `BINDIR` is the path to the location in which programs like `mysqladmin` and `mysqld_safe` are installed. For a binary distribution, this is the '`bin`' directory within the distribution. For a source distribution, `BINDIR` is probably '`/usr/local/bin`', unless you specified an installation directory other than '`/usr/local`' when you ran `configure`. `EXECDIR` is the location in which the `mysqld` server is installed. For a binary distribution, this is the same as `BINDIR`. For a source distribution, `EXECDIR` is probably '`/usr/local/libexec`'.

Testing is described in detail:

1. If necessary, start the `mysqld` server and set up the initial MySQL grant tables containing the privileges that determine how users are allowed to connect to the server. This is normally done with the `mysql_install_db` script:

   ```
   shell> scripts/mysql_install_db
   ```

   Typically, `mysql_install_db` needs to be run only the first time you install MySQL. Therefore, if you are upgrading an existing installation, you can skip this step. (However, `mysql_install_db` is quite safe to use and will not update any tables that already exist, so if you are unsure of what to do, you can always run `mysql_install_db`.)

   `mysql_install_db` creates six tables (`user`, `db`, `host`, `tables_priv`, `columns_priv`, and `func`) in the `mysql` database. A description of the initial privileges is given in Section 4.4.4 [Default privileges], page 245. Briefly, these privileges allow the MySQL `root` user to do anything, and allow anybody to create or use databases with a name of `test` or starting with `test_`.

   If you don't set up the grant tables, the following error will appear in the log file when you start the server:

   ```
   mysqld: Can't find file: 'host.frm'
   ```

   This may also happen with a binary MySQL distribution if you don't start MySQL by executing exactly `./bin/mysqld_safe`. See Section 4.8.2 [mysqld_safe], page 312.

   You might need to run `mysql_install_db` as `root`. However, if you prefer, you can run the MySQL server as an unprivileged (non-`root`) user, provided that the user can

read and write files in the database directory. Instructions for running MySQL as an unprivileged user are given in Section A.3.2 [Changing MySQL user], page 858.

If you have problems with `mysql_install_db`, see Section 2.4.1 [`mysql_install_db`], page 105.

There are some alternatives to running the `mysql_install_db` script as it is provided in the MySQL distribution:

- You may want to edit `mysql_install_db` before running it, to change the initial privileges that are installed into the grant tables. This is useful if you want to install MySQL on a lot of machines with the same privileges. In this case you probably should need only to add a few extra `INSERT` statements to the `mysql.user` and `mysql.db` tables.
- If you want to change things in the grant tables after installing them, you can run `mysql_install_db`, then use `mysql -u root mysql` to connect to the grant tables as the MySQL `root` user and issue SQL statements to modify the grant tables directly.
- It is possible to re-create the grant tables completely after they have already been created. You might want to do this if you've already installed the tables but then want to re-create them after editing `mysql_install_db`.

For more information about these alternatives, see Section 4.4.4 [Default privileges], page 245.

2. Start the MySQL server like this:

```
shell> cd mysql_installation_directory
shell> bin/mysqld_safe &
```

If your version of MySQL is older than 4.0, substitute `bin/safe_mysqld` for `bin/mysqld_safe` in the final command.

If you have problems starting the server, see Section 2.4.2 [Starting server], page 107.

3. Use `mysqladmin` to verify that the server is running. The following commands provide a simple test to check that the server is up and responding to connections:

```
shell> BINDIR/mysqladmin version
shell> BINDIR/mysqladmin variables
```

The output from `mysqladmin version` varies slightly depending on your platform and version of MySQL, but should be similar to that shown here:

```
shell> BINDIR/mysqladmin version
mysqladmin  Ver 8.14 Distrib 3.23.32, for linux on i586
Copyright (C) 2000 MySQL AB & MySQL Finland AB & TCX DataKonsult AB
This software comes with ABSOLUTELY NO WARRANTY. This is free software,
and you are welcome to modify and redistribute it under the GPL license.

Server version          3.23.32-debug
Protocol version        10
Connection              Localhost via Unix socket
TCP port                3306
UNIX socket             /tmp/mysql.sock
Uptime:                 16 sec
```

```
Threads: 1  Questions: 9  Slow queries: 0
Opens: 7  Flush tables: 2  Open tables: 0
Queries per second avg: 0.000
Memory in use: 132K  Max memory used: 16773K
```

To get a feeling for what else you can do with `BINDIR/mysqladmin`, invoke it with the `--help` option.

4. Verify that you can shut down the server:

```
shell> BINDIR/mysqladmin -u root shutdown
```

5. Verify that you can restart the server. Do this using `mysqld_safe` or by invoking `mysqld` directly. For example:

```
shell> BINDIR/mysqld_safe --log &
```

If `mysqld_safe` fails, try running it from the MySQL installation directory (if you are not already there). If that doesn't work, see Section 2.4.2 [Starting server], page 107.

6. Run some simple tests to verify that the server is working. The output should be similar to what is shown here:

```
shell> BINDIR/mysqlshow
+-----------+
| Databases |
+-----------+
| mysql     |
+-----------+

shell> BINDIR/mysqlshow mysql
Database: mysql
+--------------+
|    Tables    |
+--------------+
| columns_priv |
| db           |
| func         |
| host         |
| tables_priv  |
| user         |
+--------------+

shell> BINDIR/mysql -e "SELECT host,db,user FROM db" mysql
+------+--------+------+
| host | db     | user |
+------+--------+------+
| %    | test   |      |
| %    | test_% |      |
+------+--------+------+
```

There is also a benchmark suite in the '`sql-bench`' directory (under the MySQL installation directory) that you can use to compare how MySQL performs on different

platforms. The benchmark suite is written in Perl, using the Perl DBI module to provide a database-independent interface to the various databases. The following additional Perl modules are required to run the benchmark suite:

```
DBI
DBD-mysql
Data-Dumper
Data-ShowTable
```

These modules can be obtained from CPAN `http://www.cpan.org/`. See Section 2.7.1 [Perl installation], page 153.

The '`sql-bench/Results`' directory contains the results from many runs against different databases and platforms. To run all tests, execute these commands:

```
shell> cd sql-bench
shell> run-all-tests
```

If you don't have the '`sql-bench`' directory, you are probably using an RPM for a binary distribution. (Source distribution RPMs include the benchmark directory.) In this case, you must first install the benchmark suite before you can use it. Beginning with MySQL Version 3.22, there are benchmark RPM files named '`mysql-bench-VERSION-i386.rpm`' that contain benchmark code and data.

If you have a source distribution, you can also run the tests in the '`tests`' subdirectory. For example, to run '`auto_increment.tst`', do this:

```
shell> BINDIR/mysql -vvf test < ./tests/auto_increment.tst
```

The expected results are shown in the '`./tests/auto_increment.res`' file.

2.4.1 Problems Running `mysql_install_db`

The purpose of the `mysql_install_db` script is to generate new MySQL privilege tables. It will not affect any other data. It will also not do anything if you already have MySQL privilege tables installed.

If you want to re-create your privilege tables, you should take down the `mysqld` server, if it's running, and then do something like:

```
mv mysql-data-directory/mysql mysql-data-directory/mysql-old
mysql_install_db
```

This section lists problems you might encounter when you run `mysql_install_db`:

`mysql_install_db` doesn't install the grant tables

You may find that `mysql_install_db` fails to install the grant tables and terminates after displaying the following messages:

```
starting mysqld daemon with databases from XXXXXX
mysql daemon ended
```

In this case, you should examine the log file very carefully. The log should be located in the directory '`XXXXXX`' named by the error message, and should indicate why `mysqld` didn't start. If you don't understand what happened, include the log when you post a bug report using `mysqlbug`. See Section 1.6.1.3 [Bug reports], page 27.

There is already a `mysqld` daemon running

In this case, you probably don't have to run `mysql_install_db` at all. You have to run `mysql_install_db` only once, when you install MySQL the first time.

Installing a second `mysqld` daemon doesn't work when one daemon is running

This can happen when you already have an existing MySQL installation, but want to put a new installation in a different place (for example, for testing, or perhaps you simply want to run two installations at the same time). Generally the problem that occurs when you try to run the second server is that it tries to use the same socket and port as the old one. In this case you will get the error message: `Can't start server: Bind on TCP/IP port: Address already in use` or `Can't start server: Bind on unix socket...`. See Section 4.2 [Multiple servers], page 206.

You don't have write access to '`/tmp`'

If you don't have write access to create a socket file at the default place (in '`/tmp`') or permission to create temporary files in '`/tmp,`' you will get an error when running `mysql_install_db` or when starting or using `mysqld`.

You can specify a different socket and temporary directory as follows:

```
shell> TMPDIR=/some_tmp_dir/
shell> MYSQL_UNIX_PORT=/some_tmp_dir/mysqld.sock
shell> export TMPDIR MYSQL_UNIX_PORT
```

See Section A.4.5 [Problems with mysql.sock], page 863.

'`some_tmp_dir`' should be the path to some directory for which you have write permission. See Appendix F [Environment variables], page 1019.

After this you should be able to run `mysql_install_db` and start the server with these commands:

```
shell> scripts/mysql_install_db
shell> BINDIR/mysqld_safe &
```

`mysqld` crashes immediately

If you are running Red Hat Version 5.0 with a version of `glibc` older than 2.0.7-5, you should make sure you have installed all `glibc` patches. There is a lot of information about this in the MySQL mail archives. Links to the mail archives are available online at `http://lists.mysql.com/`. Also, see Section 2.6.2 [Linux], page 126.

You can also start `mysqld` manually using the `--skip-grant-tables` option and add the privilege information yourself using `mysql`:

```
shell> BINDIR/mysqld_safe --skip-grant-tables &
shell> BINDIR/mysql -u root mysql
```

From `mysql`, manually execute the SQL commands in `mysql_install_db`. Make sure you run `mysqladmin flush-privileges` or `mysqladmin reload` afterward to tell the server to reload the grant tables.

2.4.2 Problems Starting the MySQL Server

If you are going to use tables that support transactions (InnoDB, BDB), you should first create a '`my.cnf`' file and set startup options for the table types you plan to use. See Chapter 7 [Table types], page 594.

Generally, you start the `mysqld` server in one of these ways:

- By invoking `mysql.server`. This script is used primarily at system startup and shutdown, and is described more fully in Section 2.4.3 [Automatic start], page 108.
- By invoking `mysqld_safe`, which tries to determine the proper options for `mysqld` and then runs it with those options. See Section 4.8.2 [`mysqld_safe`], page 312.
- For Windows NT/2000/XP, please see Section 2.1.1.7 [NT start], page 61.
- By invoking `mysqld` directly.

When the `mysqld` daemon starts up, it changes the directory to the data directory. This is where it expects to write log files and the pid (process ID) file, and where it expects to find databases.

The data directory location is hardwired in when the distribution is compiled. However, if `mysqld` expects to find the data directory somewhere other than where it really is on your system, it will not work properly. If you have problems with incorrect paths, you can find out what options `mysqld` allows and what the default path settings are by invoking `mysqld` with the `--help` option. You can override the defaults by specifying the correct pathnames as command-line arguments to `mysqld`. (These options can be used with `mysqld_safe` as well.)

Normally you should need to tell `mysqld` only the base directory under which MySQL is installed. You can do this with the `--basedir` option. You can also use `--help` to check the effect of changing path options (note that `--help` **must** be the final option of the `mysqld` command). For example:

```
shell> EXECDIR/mysqld --basedir=/usr/local --help
```

Once you determine the path settings you want, start the server without the `--help` option.

Whichever method you use to start the server, if it fails to start up correctly, check the log file to see if you can find out why. Log files are located in the data directory (typically '`/usr/local/mysql/data`' for a binary distribution, '`/usr/local/var`' for a source distribution, and '`\mysql\data\mysql.err`' on Windows). Look in the data directory for files with names of the form '`host_name.err`' and '`host_name.log`' where `host_name` is the name of your server host. Then check the last few lines of these files:

```
shell> tail host_name.err
shell> tail host_name.log
```

Look for something like the following in the log file:

```
000729 14:50:10  bdb:  Recovery function for LSN 1 27595 failed
000729 14:50:10  bdb:  warning: ./test/t1.db: No such file or directory
000729 14:50:10  Can't init databases
```

This means that you didn't start `mysqld` with `--bdb-no-recover` and Berkeley DB found something wrong with its log files when it tried to recover your databases. To be able to continue, you should move away the old Berkeley DB log file from the database directory to

some other place, where you can later examine it. The log files are named '`log.0000000001`', where the number will increase over time.

If you are running `mysqld` with BDB table support and `mysqld` core dumps at start this could be because of some problems with the BDB recover log. In this case you can try starting `mysqld` with `--bdb-no-recover`. If this helps, then you should remove all '`log.*`' files from the data directory and try starting `mysqld` again.

If you get the following error, it means that some other program (or another `mysqld` server) is already using the TCP/IP port or socket `mysqld` is trying to use:

```
Can't start server: Bind on TCP/IP port: Address already in use
  or
Can't start server: Bind on unix socket...
```

Use `ps` to make sure that you don't have another `mysqld` server running. If you can't find another server running, you can try to execute the command `telnet your-host-name tcp-ip-port-number` and press Enter a couple of times. If you don't get an error message like `telnet: Unable to connect to remote host: Connection refused`, something is using the TCP/IP port `mysqld` is trying to use. See Section 2.4.1 [mysql_install_db], page 105 and Section 4.2 [Multiple servers], page 206.

If `mysqld` is currently running, you can find out what path settings it is using by executing this command:

```
shell> mysqladmin variables
```

or

```
shell> mysqladmin -h 'your-host-name' variables
```

If you get `Errcode 13`, which means `Permission denied`, when starting `mysqld` this means that you didn't have the right to read/create files in the MySQL database or log directory. In this case you should either start `mysqld` as the `root` user or change the permissions for the involved files and directories so that you have the right to use them.

If `mysqld_safe` starts the server but you can't connect to it, you should make sure you have an entry in '`/etc/hosts`' that looks like this:

```
127.0.0.1       localhost
```

This problem occurs only on systems that don't have a working thread library and for which MySQL must be configured to use MIT-pthreads.

If you can't get `mysqld` to start you can try to make a trace file to find the problem. See Section E.1.2 [Making trace files], page 1008.

If you are using InnoDB tables, refer to the InnoDB-specific startup options. See Section 7.5.3 [InnoDB start], page 607.

If you are using BDB (Berkeley DB) tables, you should familiarise yourself with the different BDB-specific startup options. See Section 7.6.3 [BDB start], page 655.

2.4.3 Starting and Stopping MySQL Automatically

The `mysql.server` and `mysqld_safe` scripts can be used to start the server automatically at system startup time. `mysql.server` can also be used to stop the server.

The `mysql.server` script can be used to start or stop the server by invoking it with `start` or `stop` arguments:

```
shell> mysql.server start
shell> mysql.server stop
```

`mysql.server` can be found in the '`share/mysql`' directory under the MySQL installation directory or in the '`support-files`' directory of the MySQL source tree.

Note that if you use the Linux RPM package (`MySQL-server-VERSION.rpm`), the `mysql.server` script has already been installed as '`/etc/init.d/mysql`' - you don't have to install it manually. See Section 2.1.2 [Linux-RPM], page 64 for more information on the Linux RPM packages.

On Mac OS X, you can install a separate MySQL Startup Item package to enable the automatic startup of MySQL on system bootup. See Section 2.1.3 [Mac OS X installation], page 66 for details.

Before `mysql.server` starts the server, it changes the directory to the MySQL installation directory, then invokes `mysqld_safe`. You might need to edit `mysql.server` if you have a binary distribution that you've installed in a non-standard location. Modify it to `cd` into the proper directory before it runs `mysqld_safe`. If you want the server to run as some specific user, add an appropriate `user` line to the '`/etc/my.cnf`' file, as shown later in this section.

`mysql.server stop` brings down the server by sending a signal to it. You can also take down the server manually by executing `mysqladmin shutdown`.

You need to add these start and stop commands to the appropriate places in your '`/etc/rc*`' files when you want to start up MySQL automatically on your server.

On most current Linux distributions, it is sufficient to copy the file `mysql.server` into the '`/etc/init.d`' directory (or '`/etc/rc.d/init.d`' on older Red Hat systems). Afterwards, run the following command to enable the startup of MySQL on system bootup:

```
shell> chkconfig --add mysql.server
```

On FreeBSD startup scripts generally should go in '`/usr/local/etc/rc.d/`'. The `rc(8)` manual page also states that scripts in this directory are only executed, if their basename matches the shell globbing pattern `*.sh`. Any other files or directories present within the directory are silently ignored. In other words, on FreeBSD you should install the file '`mysql.server`' as '`/usr/local/etc/rc.d/mysql.server.sh`' to enable automatic startup.

As an alternative to the above, some operating systems also use '`/etc/rc.local`' or '`/etc/init.d/boot.local`' to start additional services on bootup. To start up MySQL using this method, you could append something like the following to it:

```
/bin/sh -c 'cd /usr/local/mysql; ./bin/mysqld_safe --user=mysql &'
```

You can also add options for `mysql.server` in a global '`/etc/my.cnf`' file. A typical '`/etc/my.cnf`' file might look like this:

```
[mysqld]
datadir=/usr/local/mysql/var
socket=/var/tmp/mysql.sock
port=3306
user=mysql

[mysql.server]
basedir=/usr/local/mysql
```

The `mysql.server` script understands the following options: `datadir`, `basedir`, and `pid-file`.

The following table shows which option groups each startup script reads from option files:

Script	Option groups
`mysqld`	`[mysqld]`, `[server]` and `[mysqld-major-version]`
`mysql.server`	`[mysql.server]`, `[mysqld]`, and `[server]`
`mysqld_safe`	`[mysqld]`, `[server]`, and `[mysqld_safe]`

For backward compatibility, `mysql.server` also reads the `[mysql_server]` group and `mysqld_safe` also reads the `[safe_mysqld]` group. However, you should update your option files to use the `[mysql.server]` and `[mysqld_safe]` groups instead.

See Section 4.1.2 [Option files], page 203.

2.5 Upgrading/Downgrading MySQL

Before you do an upgrade, you should back up your old databases.

You can always move the MySQL format files and datafiles between different versions on the same architecture as long as you have the same base version of MySQL. The current base version is 4. If you change the character set when running MySQL, you must run `myisamchk -r -q --set-character-set=charset` on all tables. Otherwise, your indexes may not be ordered correctly, because changing the character set may also change the sort order.

If you are afraid of new versions, you can always rename your old `mysqld` to something like `mysqld-old-version-number`. If your new `mysqld` then does something unexpected, you can simply shut it down and restart with your old `mysqld`.

If, after an upgrade, you experience problems with recompiled client programs, such as `Commands out of sync` or unexpected core dumps, you probably have used an old header or library file when compiling your programs. In this case you should check the date for your '`mysql.h`' file and '`libmysqlclient.a`' library to verify that they are from the new MySQL distribution. If not, please recompile your programs.

If problems occur, such as that the new `mysqld` server doesn't want to start or that you can't connect without a password, check that you don't have some old '`my.cnf`' file from your old installation. You can check this with: `program-name --print-defaults`. If this outputs anything other than the program name, you have an active '`my.cnf`' file that will affect things.

It is a good idea to rebuild and reinstall the Perl `DBD-mysql` module whenever you install a new release of MySQL. The same applies to other MySQL interfaces as well, such as the Python `MySQLdb` module.

2.5.1 Upgrading From Version 4.0 to 4.1

Several visible things have changed between MySQL 4.0 and MySQL 4.1 to fix some critical bugs and make MySQL more compatible with the ANSI SQL standard. These changes may affect your applications.

Some of the 4.1 behaviours can be tested in 4.0 before performing a full upgrade to 4.1. We have added to later MySQL 4.0 releases (from 4.0.12 on) a `--new` startup option for `mysqld`.

This option gives you the 4.1 behaviour for the most critical changes. You can also enable these behaviours for a given client connection with the `SET @@new=1` command, or turn them off if they are on with `SET @@new=0`.

If you believe that some of the 4.1 changes will affect you, we recommend that before upgrading to 4.1, you download the latest MySQL 4.0 version and run it with the `--new` option by adding the following to your config file:

```
[mysqld-4.0]
new
```

That way you can test the new behaviors in 4.0 to make sure that your applications work with them. This will help you have a smooth painless transition when you perform a full upgrade to 4.1 later. Doing it the above way will ensure that you don't accidently later run the 4.1 version with the `--new` option.

The following list describes changes that may affect applications and that you should watch out for when upgrading to version 4.1:

- `TIMESTAMP` is now returned as a string in `'YYYY-MM-DD HH:MM:SS'` format. (The `--new` option can be used from 4.0.12 on to make a 4.0 server behave as 4.1 in this respect.) If you want to have the value returned as a number (like Version 4.0 does) you should add `+0` to `TIMESTAMP` columns when you retrieve them:

  ```
  mysql> SELECT ts_col + 0 FROM tbl_name;
  ```

  Display widths for `TIMESTAMP` columns are no longer supported. For example, if you declare a column as `TIMESTAMP(10)`, the `(10)` is ignored.

  These changes were necessary for SQL standards compliance. In a future version, a further change will be made (backward compatible with this change), allowing the timestamp length to indicate the desired number of digits for fractions of a second.

- Binary values such as `0xFFDF` now are assumed to be strings instead of numbers. This fixes some problems with character sets where it's convenient to input a string as a binary value. With this change, you should use `CAST()` if you want to compare binary values numerically as integers:

  ```
  mysql> SELECT CAST(0xFEFF AS UNSIGNED INTEGER) < CAST(0xFF AS UNSIGNED INTEGER);
          -> 0
  ```

  If you don't use `CAST()`, a lexical string comparison will be done:

  ```
  mysql> SELECT 0xFEFF < 0xFF;
          -> 1
  ```

  Using binary items in a numeric context or comparing them using the `=` operator should work as before. (The `--new` option can be used from 4.0.13 on to make a 4.0 server behave as 4.1 in this respect.)

- For functions that produce a `DATE`, `DATETIME`, or `TIME` value, the result returned to the client now is fixed up to have a temporal type. For example, in MySQL 4.1, you get this result:

  ```
  mysql> SELECT CAST("2001-1-1" as DATETIME);
  ```

```
    -> '2001-01-01 00:00:00'
```

In MySQL 4.0, the result is different:

```
mysql> SELECT CAST("2001-1-1" as DATETIME);
    -> '2001-01-01'
```

- `DEFAULT` values no longer can be specified for `AUTO_INCREMENT` columns. (In 4.0, a `DEFAULT` value is silently ignored; in 4.1, an error occurs).
- `SERIALIZE` is no longer a valid option value for the `sql_mode` variable. You should use `SET TRANSACTION ISOLATION LEVEL SERIALIZABLE` instead. `SERIALIZE` is no longer valid for the `--sql-mode` option for `mysqld`, either. Use `--transaction-isolation=SERIALIZABLE` instead.
- All tables and string columns now have a character set. See Chapter 9 [Charset], page 665. Character set information is displayed by `SHOW CREATE TABLE` and `mysqldump`. (MySQL versions 4.0.6 and above can read the new dump files; older versions cannot.)
- The table definition format used in '`.frm`' files has changed slightly in 4.1. MySQL 4.0 versions from 4.0.11 on can read the new '`.frm`' format directly, but older versions cannot. If you need to move tables from 4.1 to a version earlier than 4.0.11, you should use `mysqldump`. See Section 4.9.6 [`mysqldump`], page 339.
- If you are running multiple servers on the same Windows machine, you should use a different `--shared_memory_base_name` option on all machines.
- The interface to aggregated UDF functions has changed a bit. You must now declare a `clear()` function for each aggregate function.

In general, upgrading to 4.1 from an earlier MySQL version involves the following steps:

- Check the changes listed earlier in this section to see if there are any that may affect your applications.
- Read the 4.1 news items to see what significant new features you can use in 4.1. See Section D.2 [News-4.1.x], page 889.
- If you are running MySQL Server on Windows, please also see Section 2.5.8 [Windows upgrading], page 121.
- After upgrading, update the grant tables to generate the new longer `Password` column that is needed for secure handling of passwords. The procedure uses `mysql_fix_privilege_tables` and is described in Section 2.5.6 [Upgrading-grant-tables], page 119.

The password hashing mechanism has changed in 4.1 to provide better security, but this may cause compatibility problems if you still have clients that use the client library from 4.0 or earlier. (It is very likely that you will have 4.0 clients in situations where clients connect from remote hosts that have not yet upgraded to 4.1). The following list indicates some possible upgrade strategies. They represent various tradeoffs between the goal of compatibility with old clients and the goal of security.

- Don't upgrade to 4.1. No behaviour will change, but of course you cannot use any of the new features provided by the 4.1 client/server protocol, either. (MySQL 4.1 has an extended client/server protocol that offers such features as prepared statements and multiple result sets.) See Section 11.1.4 [C API Prepared statements], page 765.

- Upgrade to 4.1 and run the `mysql_fix_privilege_tables` script to widen the `Password` column in the `user` table so that it can hold long password hashes. But run the server with the `--old-passwords` option to provide backward compatibility that allows pre-4.1 clients to continue to connect to their short-hash accounts. Eventually, when all your clients are upgraded to 4.1, you can stop using the `--old-passwords` server option. You can also change the passwords for your MySQL accounts to use the new more secure format.
- Upgrade to 4.1 and run the `mysql_fix_privilege_tables` script to widen the `Password` column in the `user` table. If you know that all clients also have been upgraded to 4.1, don't run the server with the `--old-passwords` option. Instead, change the passwords on all existing accounts so that they have the new format. A pure-4.1 installation is the most secure.

Further background on password hashing with respect to client authentication and password-changing operations may be found in Section 4.3.11 [Password hashing], page 230.

2.5.2 Upgrading From Version 3.23 to 4.0

In general, you should do the following when upgrading to 4.0 from an earlier MySQL version:

- After upgrading, update the grant tables to add new privileges and features. The procedure uses the `mysql_fix_privilege_tables` script and is described in Section 2.5.6 [Upgrading-grant-tables], page 119.
- Edit any MySQL startup scripts or configure files to not use any of the deprecated options described later in this section.
- Convert your old `ISAM` files to `MyISAM` files with the `mysql_convert_table_format database` script. (This is a Perl script; it requires that DBI be installed.) To convert the tables in a given database, use this command:

  ```
  shell> mysql_convert_table_format database db_name
  ```

  Note that this should only be used if all tables in the given database are `ISAM` or `MyISAM` tables. To avoid converting tables of other types to `MyISAM`, you can explicitly list the names of your `ISAM` tables after the database name on the command line. You can also issue a `ALTER TABLE table_name TYPE=MyISAM` statement for each `ISAM` table to convert it to `MyISAM`.

  To find out the table type for a given table, use this statement:

  ```
  mysql> SHOW TABLE STATUS LIKE 'tbl_name';
  ```

- Ensure that you don't have any MySQL clients that use shared libraries (like the Perl `DBD-mysql` mode). If you do, you should recompile them, because the data structures used in '`libmysqlclient.so`' have changed. The same applies to other MySQL interfaces as well, such as the Python `MySQLdb` module.

MySQL 4.0 will work even if you don't do the above, but you will not be able to use the new security privileges that MySQL 4.0 and you may run into problems when upgrading later to MySQL 4.1 or newer. The `ISAM` file format still works in MySQL 4.0 but it's deprecated

and will be disabled (not compiled in by default) in MySQL 4.1. `MyISAM` tables should be used instead.

Old clients should work with a Version 4.0 server without any problems.

Even if you do the above, you can still downgrade to MySQL 3.23.52 or newer if you run into problems with the MySQL 4.0 series. In this case, you must use `mysqldump` to dump any tables that use full-text indexes and reload the dump file into the 3.23 server. This is necessary because 4.0 uses a new format for full-text indexing.

The following is a more complete list that tells what you must watch out for when upgrading to version 4.0:

- MySQL 4.0 has a lot of new privileges in the `mysql.user` table. See Section 4.4.1 [`GRANT`], page 239.

  To get these new privileges to work, you must update the grant tables. The procedure is described in Section 2.5.6 [Upgrading-grant-tables], page 119. Until you do this, all users have the `SHOW DATABASES`, `CREATE TEMPORARY TABLES`, and `LOCK TABLES` privileges. `SUPER` and `EXECUTE` privileges take their value from `PROCESS`. `REPLICATION SLAVE` and `REPLICATION CLIENT` take their values from `FILE`.

  If you have any scripts that create new users, you may want to change them to use the new privileges. If you are not using `GRANT` commands in the scripts, this is a good time to change your scripts to use `GRANT` instead of modifying the grant tables directly..

  From version 4.0.2 on, the option `--safe-show-database` is deprecated (and no longer does anything). See Section 4.3.3 [Privileges options], page 217.

  If you get `Access denied` errors for new users in version 4.0.2 and up, you should check if you need some of the new grants that you didn't need before. In particular, you will need `REPLICATION SLAVE` (instead of `FILE`) for new slaves.
- '`safe_mysqld`' is renamed to '`mysqld_safe`'. For backward compatibility, binary distributions will for some time include `safe_mysqld` as a symlink to `mysqld_safe`.
- InnoDB support is now included by default in binary distributions. If you build MySQL from source, InnoDB is configured in by default. If you do not use InnoDB and want to save memory when running a server that has InnoDB support enabled, use the `--skip-innodb` server startup option. To compile MySQL without InnoDB support, run `configure` with the `--without-innodb` option.
- The startup parameters `myisam_max_extra_sort_file_size` and `myisam_max_extra_sort_file_size` are now given in bytes (they were given in megabytes before 4.0.3).
- External system locking of `MyISAM`/`ISAM` files is now turned off by default. Your can turn this on by doing `--external-locking`. (However, this is never needed for most users.)
- The following startup variables/options have been renamed:

Old Name	**New Name**
`myisam_bulk_insert_tree_size`	`bulk_insert_buffer_size`
`query_cache_startup_type`	`query_cache_type`
`record_buffer`	`read_buffer_size`
`record_rnd_buffer`	`read_rnd_buffer_size`
`sort_buffer`	`sort_buffer_size`

`warnings`	`log-warnings`
`--err-log`	`--log-error` (for `mysqld_safe`)

The startup options `record_buffer`, `sort_buffer` and `warnings` will still work in MySQL 4.0 but are deprecated.

- The following SQL variables have changed name.

Old Name	**New Name**
`SQL_BIG_TABLES`	`BIG_TABLES`
`SQL_LOW_PRIORITY_UPDATES`	`LOW_PRIORITY_UPDATES`
`SQL_MAX_JOIN_SIZE`	`MAX_JOIN_SIZE`
`SQL_QUERY_CACHE_TYPE`	`QUERY_CACHE_TYPE`

  The old names still work in MySQL 4.0 but are deprecated.
- You have to use `SET GLOBAL SQL_SLAVE_SKIP_COUNTER=#` instead of `SET SQL_SLAVE_SKIP_COUNTER=#`.
- The `mysqld` startup options `--skip-locking` and `--enable-locking` were renamed to `--skip-external-locking` and `--external-locking`.
- `SHOW MASTER STATUS` now returns an empty set if binary logging is not enabled.
- `SHOW SLAVE STATUS` now returns an empty set if slave is not initialised.
- `mysqld` now has the option `--temp-pool` enabled by default as this gives better performance with some operating systems (most notably Linux).
- `DOUBLE` and `FLOAT` columns now honour the `UNSIGNED` flag on storage (before, `UNSIGNED` was ignored for these columns).
- `ORDER BY col_name DESC` sorts `NULL` values last, as of MySQL 4.0.11. In 3.23 and in earlier 4.0 versions, this was not always consistent.
- `SHOW INDEX` has two more columns (`Null` and `Index_type`) than it had in 3.23.
- `CHECK`, `SIGNED`, `LOCALTIME` and `LOCALTIMESTAMP` are now reserved words.
- The result of all bitwise operators (`|`, `&`, `<<`, `>>`, and `~`)) is now unsigned. This may cause problems if you are using them in a context where you want a signed result. See Section 6.3.5 [Cast Functions], page 513.
- **Note**: when you use subtraction between integer values where one is of type `UNSIGNED`, the result will be unsigned. In other words, before upgrading to MySQL 4.0, you should check your application for cases where you are subtracting a value from an unsigned entity and want a negative answer or subtracting an unsigned value from an integer column. You can disable this behaviour by using the `--sql-mode=NO_UNSIGNED_SUBTRACTION` option when starting `mysqld`. See Section 6.3.5 [Cast Functions], page 513.
- To use `MATCH ... AGAINST (... IN BOOLEAN MODE)` with your tables, you need to rebuild them with `REPAIR TABLE table_name USE_FRM`.
- `LOCATE()` and `INSTR()` are case-sensitive if one of the arguments is a binary string. Otherwise they are case-insensitive.
- `STRCMP()` now uses the current character set when doing comparisons, which means that the default comparison behaviour now is case-insensitive.
- `HEX(string)` now returns the characters in `string` converted to hexadecimal. If you want to convert a number to hexadecimal, you should ensure that you call `HEX()` with a numeric argument.

- In 3.23, `INSERT INTO ... SELECT` always had `IGNORE` enabled. In 4.0.1, MySQL will stop (and possibly roll back) by default in case of an error unless you specify `IGNORE`.
- The old C API functions `mysql_drop_db()`, `mysql_create_db()`, and `mysql_connect()` are no longer supported unless you compile MySQL with `CFLAGS=-DUSE_OLD_FUNCTIONS`. However, it is preferable to change client programs to use the new 4.0 API instead.
- In the `MYSQL_FIELD` structure, `length` and `max_length` have changed from `unsigned int` to `unsigned long`. This should not cause any problems, except that they may generate warning messages when used as arguments in the `printf()` class of functions.
- You should use `TRUNCATE TABLE` when you want to delete all rows from a table and you don't need to obtain a count of the number of rows that were deleted. (`DELETE FROM table_name` returns a row count in 4.0, and `TRUNCATE TABLE` is faster.)
- You will get an error if you have an active `LOCK TABLES` or transaction when trying to execute `TRUNCATE TABLE` or `DROP DATABASE`.
- You should use integers to store values in `BIGINT` columns (instead of using strings, as you did in MySQL 3.23). Using strings will still work, but using integers is more efficient.
- The format of `SHOW OPEN TABLES` has changed.
- Multi-threaded clients should use `mysql_thread_init()` and `mysql_thread_end()`. See Section 11.1.14 [Threaded clients], page 799.
- If you want to recompile the Perl `DBD::mysql` module, you must get `DBD-mysql` version 1.2218 or newer because older DBD modules used the deprecated `mysql_drop_db()` call. Version 2.1022 or newer is recommended.
- `RAND(seed)` returns a different random number series in 4.0 than in 3.23; this was done to further differentiate `RAND(seed)` and `RAND(seed+1)`.
- The default type returned by `IFNULL(A,B)` is now set to be the more 'general' of the types of `A` and `B`. (The general-to-specific order is string, `REAL` or `INTEGER`).

If you are running MySQL Server on Windows, please also see Section 2.5.8 [Windows upgrading], page 121. If you are using replication, please also see Section 4.11.2 [Replication Implementation], page 356.

2.5.3 Upgrading From Version 3.22 to 3.23

MySQL Version 3.23 supports tables of the new `MyISAM` type and the old `ISAM` type. You don't have to convert your old tables to use these with Version 3.23. By default, all new tables will be created with type `MyISAM` (unless you start `mysqld` with the `--default-table-type=isam` option). You can convert an `ISAM` table to `MyISAM` format with `ALTER TABLE table_name TYPE=MyISAM` or the Perl script `mysql_convert_table_format`.

Version 3.22 and 3.21 clients will work without any problems with a Version 3.23 server.

The following list tells what you have to watch out for when upgrading to Version 3.23:

- All tables that use the `tis620` character set must be fixed with `myisamchk -r` or `REPAIR TABLE`.

- If you do a `DROP DATABASE` on a symbolically-linked database, both the link and the original database are deleted. (This didn't happen in 3.22 because `configure` didn't detect the availability of the `readlink()` system call.)
- `OPTIMIZE TABLE` now works only for `MyISAM` tables. For other table types, you can use `ALTER TABLE` to optimise the table. During `OPTIMIZE TABLE`, the table is now locked to prevent it from being used by other threads.
- The MySQL client `mysql` is now by default started with the option `--no-named-commands (-g)`. This option can be disabled with `--enable-named-commands (-G)`. This may cause incompatibility problems in some cases—for example, in SQL scripts that use named commands without a semicolon. Long format commands still work from the first line.
- Date functions that work on parts of dates (like `MONTH()`) will now return 0 for `0000-00-00` dates. (In MySQL 3.22, these functions returned `NULL`.)
- If you are using the `german` character sort order for `ISAM` tables, you must repair them with `isamchk -r`, because we have made some changes in the sort order.
- The default return type of `IF()` now depends on both arguments and not only the first argument.
- `AUTO_INCREMENT` columns should not be used to store negative numbers. The reason for this is that negative numbers caused problems when wrapping from -1 to 0. You should not store 0 in `AUTO_INCREMENT` columns, either; `CHECK TABLE` will complain about 0 values because they may change if you dump and restore the table. `AUTO_INCREMENT` for `MyISAM` tables is now handled at a lower level and is much faster than before. In addition, for `MyISAM` tables, old numbers are no longer reused, even if you delete rows from the table.
- `CASE`, `DELAYED`, `ELSE`, `END`, `FULLTEXT`, `INNER`, `RIGHT`, `THEN`, and `WHEN` are now reserved words.
- `FLOAT(X)` is now a true floating-point type and not a value with a fixed number of decimals.
- When declaring columns using a `DECIMAL(length,dec)` type, the `length` argument no longer includes a place for the sign or the decimal point.
- A `TIME` string must now be of one of the following formats: `[[[DAYS] [H]H:]MM:]SS[.fraction]` or `[[[[[H]H]H]H]MM]SS[.fraction]`.
- `LIKE` now compares strings using the same character comparison rules as for the `=` operator. If you require the old behaviour, you can compile MySQL with the `CXXFLAGS=-DLIKE_CMP_TOUPPER` flag.
- `REGEXP` is now case-insensitive if neither of the strings are binary strings.
- When you check or repair `MyISAM` (`.MYI`) tables, you should use the `CHECK TABLE` statement or the `myisamchk` command. For `ISAM` (`.ISM`) tables, use the `isamchk` command.
- If you want your `mysqldump` files to be compatible between MySQL Version 3.22 and Version 3.23, you should not use the `--opt` or `--all` option to `mysqldump`.
- Check all your calls to `DATE_FORMAT()` to make sure there is a '`%`' before each format character. (MySQL Version 3.22 and later already allowed this syntax.)

- `mysql_fetch_fields_direct()` is now a function (it used to be a macro) and it returns a pointer to a `MYSQL_FIELD` instead of a `MYSQL_FIELD`.
- `mysql_num_fields()` can no longer be used on a `MYSQL*` object (it's now a function that takes a `MYSQL_RES*` value as an argument). With a `MYSQL*` object, you should now use `mysql_field_count()` instead.
- In MySQL Version 3.22, the output of `SELECT DISTINCT ...` was almost always sorted. In Version 3.23, you must use `GROUP BY` or `ORDER BY` to obtain sorted output.
- `SUM()` now returns `NULL` instead of 0 if there are no matching rows. This is required by SQL-99.
- An `AND` or `OR` with `NULL` values will now return `NULL` instead of 0. This mostly affects queries that use `NOT` on an `AND/OR` expression as `NOT NULL = NULL`.
- `LPAD()` and `RPAD()` now shorten the result string if it's longer than the length argument.

2.5.4 Upgrading from Version 3.21 to 3.22

Nothing that affects compatibility has changed between versions 3.21 and 3.22. The only pitfall is that new tables that are created with `DATE` type columns will use the new way to store the date. You can't access these new columns from an old version of `mysqld`.

After installing MySQL Version 3.22, you should start the new server and then run the `mysql_fix_privilege_tables` script. This will add the new privileges that you need to use the `GRANT` command. If you forget this, you will get `Access denied` when you try to use `ALTER TABLE`, `CREATE INDEX`, or `DROP INDEX`. The procedure for updating the grant tables is described in Section 2.5.6 [Upgrading-grant-tables], page 119.

The C API interface to `mysql_real_connect()` has changed. If you have an old client program that calls this function, you must place a `0` for the new `db` argument (or recode the client to send the `db` element for faster connections). You must also call `mysql_init()` before calling `mysql_real_connect()`. This change was done to allow the new `mysql_options()` function to save options in the `MYSQL` handler structure.

The `mysqld` variable `key_buffer` has been renamed to `key_buffer_size`, but you can still use the old name in your startup files.

2.5.5 Upgrading from Version 3.20 to 3.21

If you are running a version older than Version 3.20.28 and want to switch to Version 3.21, you need to do the following:

You can start the `mysqld` Version 3.21 server with the `--old-protocol` option to use it with clients from a Version 3.20 distribution. In this case, the new client function `mysql_errno()` will not return any server error, only `CR_UNKNOWN_ERROR` (but it works for client errors), and the server uses the old pre-3.21 `password()` checking rather than the new method.

If you are **not** using the `--old-protocol` option to `mysqld`, you will need to make the following changes:

- All client code must be recompiled. If you are using ODBC, you must get the new `MyODBC` 2.x driver.

- The script `scripts/add_long_password` must be run to convert the `Password` field in the `mysql.user` table to `CHAR(16)`.
- All passwords must be reassigned in the `mysql.user` table (to get 62-bit rather than 31-bit passwords).
- The table format hasn't changed, so you don't have to convert any tables.

MySQL Version 3.20.28 and above can handle the new `user` table format without affecting clients. If you have a MySQL version earlier than Version 3.20.28, passwords will no longer work with it if you convert the `user` table. So to be safe, you should first upgrade to at least Version 3.20.28 and then upgrade to Version 3.21.

The new client code works with a 3.20.x `mysqld` server, so if you experience problems with 3.21.x, you can use the old 3.20.x server without having to recompile the clients again.

If you are not using the `--old-protocol` option to `mysqld`, old clients will be unable to connect and will issue the following error message:

```
ERROR: Protocol mismatch. Server Version = 10 Client Version = 9
```

The new Perl `DBI/DBD` interface also supports the old `mysqlperl` interface. The only change you have to make if you use `mysqlperl` is to change the arguments to the `connect()` function. The new arguments are: `host`, `database`, `user`, and `password` (note that the `user` and `password` arguments have changed places). See Section 11.5.2 [Perl `DBI` Class], page 817.

The following changes may affect queries in old applications:

- `HAVING` must now be specified before any `ORDER BY` clause.
- The parameters to `LOCATE()` have been swapped.
- There are some new reserved words. The most notable are `DATE`, `TIME`, and `TIMESTAMP`.

2.5.6 Upgrading the Grant Tables

Some releases introduce changes to the structure of the grant tables (the tables in the `mysql` database) to add new privileges or features. To make sure that your grant tables are current when you update to a new version of MySQL, you should update your grant tables as well.

On Unix or Unix-like systems, update the grant tables by running the `mysql_fix_privilege_tables` script:

```
shell> mysql_fix_privilege_tables
```

You must run this script while the server is running. It attempts to connect to the server running on the local host as `root`. If your `root` account requires a password, indicate the password on the command line. For MySQL 4.1 and up, specify the password like this:

```
shell> mysql_fix_privilege_tables --password=root_password
```

Prior to MySQL 4.1, specify the password like this:

```
shell> mysql_fix_privilege_tables root_password
```

The `mysql_fix_privilege_tables` script performs any actions necessary to convert your grant tables to the current format. You may see some `Duplicate column name` warnings as it runs; they can be ignored.

After running the script, stop the server and restart it.

On Windows systems, there isn't an easy way to update the grant tables until MySQL 4.0.15. From version 4.0.15 on, MySQL distributions include a `mysql_fix_privilege_tables.sql` SQL script that you can run using the `mysql` client. If your MySQL installation is located at '`C:\mysql`', the command looks like this (enter it all on one line):

```
shell> C:\mysql\bin\mysql -f -u root -p mysql
           < C:\mysql\scripts\mysql_fix_privilege_tables.sql
```

If your installation is located in some other directory, adjust the pathnames appropriately.

The command will prompt you for the `root` password; enter it when prompted.

As with the Unix procedure, you may see some `Duplicate column name` warnings as `mysql` processes the statements in the `mysql_fix_privilege_tables.sql` script; they can be ignored.

After running the script, stop the server and restart it.

2.5.7 Upgrading to Another Architecture

If you are using MySQL Version 3.23, you can copy the '`.frm`', '`.MYI`', and '`.MYD`' files for `MyISAM` tables between different architectures that support the same floating-point format. (MySQL takes care of any byte-swapping issues.) See Section 7.1 [`MyISAM` Tables], page 595.

The MySQL `ISAM` data and index files ('`.ISD`' and '`*.ISM`', respectively) are architecture-dependent and in some cases OS-dependent. If you want to move your applications to another machine that has a different architecture or OS than your current machine, you should not try to move a database by simply copying the files to the other machine. Use `mysqldump` instead.

By default, `mysqldump` will create a file containing SQL statements. You can then transfer the file to the other machine and feed it as input to the `mysql` client.

Try `mysqldump --help` to see what options are available. If you are moving the data to a newer version of MySQL, you should use `mysqldump --opt` with the newer version to get a fast, compact dump.

The easiest (although not the fastest) way to move a database between two machines is to run the following commands on the machine on which the database is located:

```
shell> mysqladmin -h 'other hostname' create db_name
shell> mysqldump --opt db_name \
        | mysql -h 'other hostname' db_name
```

If you want to copy a database from a remote machine over a slow network, you can use:

```
shell> mysqladmin create db_name
shell> mysqldump -h 'other hostname' --opt --compress db_name \
        | mysql db_name
```

You can also store the result in a file, then transfer the file to the target machine and load the file into the database there. For example, you can dump a database to a file on the source machine like this:

```
shell> mysqldump --quick db_name | gzip > db_name.contents.gz
```

(The file created in this example is compressed.) Transfer the file containing the database contents to the target machine and run these commands there:

```
shell> mysqladmin create db_name
shell> gunzip < db_name.contents.gz | mysql db_name
```

You can also use `mysqldump` and `mysqlimport` to transfer the database. For big tables, this is much faster than simply using `mysqldump`. In the following commands, `DUMPDIR` represents the full pathname of the directory you use to store the output from `mysqldump`.

First, create the directory for the output files and dump the database:

```
shell> mkdir DUMPDIR
shell> mysqldump --tab=DUMPDIR db_name
```

Then transfer the files in the `DUMPDIR` directory to some corresponding directory on the target machine and load the files into MySQL there:

```
shell> mysqladmin create db_name           # create database
shell> cat DUMPDIR/*.sql | mysql db_name   # create tables in database
shell> mysqlimport db_name DUMPDIR/*.txt   # load data into tables
```

Also, don't forget to copy the `mysql` database because that's where the grant tables (`user`, `db`, `host`) are stored. You may have to run commands as the MySQL `root` user on the new machine until you have the `mysql` database in place.

After you import the `mysql` database on the new machine, execute `mysqladmin flush-privileges` so that the server reloads the grant table information.

2.5.8 Upgrading MySQL under Windows

When upgrading MySQL under Windows, please follow these steps:

1. Download the latest Windows distribution of MySQL.
2. Choose a time of day with low usage, where a maintenance break is acceptable.
3. Alert the users that still are active about the maintenance break.
4. Stop the running MySQL Server (for example, with `NET STOP mysql` or with the `Services` utility if you are running MySQL as a service, or with `mysqladmin shutdown` otherwise).
5. Exit the `WinMySQLAdmin` program if it is running.
6. Run the installation script of the Windows distribution, by clicking the "Install" button in WinZip and following the installation steps of the script.
7. You may either overwrite your old MySQL installation (usually located at '`C:\mysql`'), or install it into a different directory, such as `C:\mysql4`. Overwriting the old installation is recommended.
8. Restart the server (for example, with `NET START mysql` if you run MYSQL as a service, or by invoking `mysqld` directly otherwise).
9. Update the grant tables. The procedure is described in Section 2.5.6 [Upgrading-grant-tables], page 119.

Possible error situations:

```
A system error has occurred.
System error 1067 has occurred.
The process terminated unexpectedly.
```

This error means that your '`my.cnf`' file (by default '`C:\my.cnf`') contains an option that cannot be recognised by MySQL. You can verify that this is the case by trying to restart MySQL with the '`my.cnf`' file renamed, for example, to '`my_cnf.old`' to prevent the server from using it. Once you have verified it, you need to identify which option is the culprit. Create a new '`my.cnf`' file and move parts of the old file to it (restarting the server after you move each part) until you determine which option causes server startup to fail.

2.6 Operating System Specific Notes

2.6.1 Windows Notes

This section describes issues specific to using MySQL on Windows.

2.6.1.1 Connecting to MySQL Remotely from Windows with SSH

Here is a note about how to connect to get a secure connection to remote MySQL server with SSH (by David Carlson `dcarlson@mplcomm.com`):

1. Install an SSH client on your Windows machine. As a user, the best non-free one I've found is from `SecureCRT` from `http://www.vandyke.com/`. Another option is `f-secure` from `http://www.f-secure.com/`. You can also find some free ones on `Google` at `http://directory.google.com/Top/Computers/Security/Products_and_Tools/Cryptography/SSH/Clients/Windows/`.
2. Start your Windows SSH client. Set `Host_Name = yourmysqlserver_URL_or_IP`. Set `userid=your_userid` to log in to your server. This `userid` value may not be the same as the username of your MySQL account.
3. Set up port forwarding. Either do a remote forward (Set `local_port: 3306`, `remote_host: yourmysqlservername_or_ip`, `remote_port: 3306`) or a local forward (Set `port: 3306`, `host: localhost`, `remote port: 3306`).
4. Save everything, otherwise you'll have to redo it the next time.
5. Log in to your server with the SSH session you just created.
6. On your Windows machine, start some ODBC application (such as Access).
7. Create a new file in Windows and link to MySQL using the ODBC driver the same way you normally do, except type in `localhost` for the MySQL host server—not `yourmysqlservername`.

You should now have an ODBC connection to MySQL, encrypted using SSH.

2.6.1.2 Distributing Data Across Different Disks on Windows

Beginning with MySQL Version 3.23.16, the `mysqld-max` and `mysql-max-nt` servers in the MySQL distribution are compiled with the `-DUSE_SYMDIR` option. This allows you to put a database directory on a different disk by setting up a symbolic link to it. This is similar to the way that symbolic links work on Unix, though the procedure for setting up the link is different.

On Windows, you make a symbolic link to a MySQL database by creating a file that contains the path to the destination directory. Save the file in the data directory using the filename '`db_name.sym`', where `db_name` is the database name.

For example, if the MySQL data directory is '`C:\mysql\data`' and you want to have database `foo` located at '`D:\data\foo`', you should create the file '`C:\mysql\data\foo.sym`' that contains the pathname `D:\data\foo\`. After that, all tables created in the database `foo` will be created in '`D:\data\foo`'. The '`D:\data\foo`' directory must exist for this to work. Also, note that the symbolic link will not be used if a directory with the database name exists in the MySQL data directory. This means that if you already have a database directory named '`foo`' in the data directory, you must move it to '`D:\data`' before the symbolic link will be effective. (To avoid problems, the server should not be running when you move the database directory.)

Note that because of the speed penalty you get when opening every table, we have not enabled this by default even if you have compiled MySQL with support for this. To enable symlinks you should put in your '`my.cnf`' or '`my.ini`' file the following entry:

```
[mysqld]
symbolic-links
```

In MySQL 4.0, symbolic links are enabled by default. If you don't need them, you can disable them with the `skip-symbolic-links` option.

2.6.1.3 Compiling MySQL Clients on Windows

In your source files, you should include '`my_global.h`' before '`mysql.h`':

```
#include <my_global.h>
#include <mysql.h>
```

'`my_global.h`' includes any other files needed for Windows compatibility (such as '`windows.h`') if you compile your program on Windows.

You can either link your code with the dynamic '`libmysql.lib`' library, which is just a wrapper to load in '`libmysql.dll`' on demand, or link with the static '`mysqlclient.lib`' library.

Note that because the MySQL client libraries are compiled as threaded libraries, you should also compile your code to be multi-threaded!

2.6.1.4 MySQL on Windows Compared to MySQL on Unix

MySQL for Windows has by now proven itself to be very stable. The Windows version of MySQL has the same features as the corresponding Unix version, with the following exceptions:

Windows 95 and threads

Windows 95 leaks about 200 bytes of main memory for each thread creation. Each connection in MySQL creates a new thread, so you shouldn't run `mysqld` for an extended time on Windows 95 if your server handles many connections! Other versions of Windows don't suffer from this bug.

Concurrent reads

MySQL depends on the `pread()` and `pwrite()` calls to be able to mix `INSERT` and `SELECT`. Currently we use mutexes to emulate `pread()`/`pwrite()`. We will, in the long run, replace the file level interface with a virtual interface so that we can use the `readfile()`/`writefile()` interface on NT/2000/XP to get more speed. The current implementation limits the number of open files MySQL can use to 1024, which means that you will not be able to run as many concurrent threads on NT/2000/XP as on Unix.

Blocking read

MySQL uses a blocking read for each connection, which has the following implications:

- A connection will not be disconnected automatically after 8 hours, as happens with the Unix version of MySQL.
- If a connection hangs, it's impossible to break it without killing MySQL.
- `mysqladmin kill` will not work on a sleeping connection.
- `mysqladmin shutdown` can't abort as long as there are sleeping connections.

We plan to fix this problem when our Windows developers have figured out a nice workaround.

`DROP DATABASE`

You can't drop a database that is in use by some thread.

Killing MySQL from the task manager

You can't kill MySQL from the task manager or with the shutdown utility in Windows 95. You must take it down with `mysqladmin shutdown`.

Case-insensitive names

Filenames are not case sensitive on Windows, so MySQL database and table names are also not case sensitive on Windows. The only restriction is that database and table names must be specified using the same case throughout a given statement. See Section 6.1.3 [Name case sensitivity], page 445.

The '\' directory character

Pathname components in Windows 95 are separated by the '\' character, which is also the escape character in MySQL. If you are using `LOAD DATA INFILE` or `SELECT ... INTO OUTFILE`, use Unix style filenames with '/' characters:

```
mysql> LOAD DATA INFILE "C:/tmp/skr.txt" INTO TABLE skr;
mysql> SELECT * INTO OUTFILE 'C:/tmp/skr.txt' FROM skr;
```

Alternatively, you must double the '\' character:

```
mysql> LOAD DATA INFILE "C:\\tmp\\skr.txt" INTO TABLE skr;
mysql> SELECT * INTO OUTFILE 'C:\\tmp\\skr.txt' FROM skr;
```

Problems with pipes.

Pipes doesn't work reliably in the Windows command-line prompt. If the pipe includes the character `^Z` / `CHAR(24)`, Windows will think it has encountered end-of-file and abort the program.

This is mainly a problem when you try to apply a binary log as follows:

```
mysqlbinlog binary-log-name | mysql --user=root
```

If you get a problem applying the log and suspect it's because of an `^Z` / `CHAR(24)` character you can use the following workaround:

```
mysqlbinlog binary-log-file --result-file=/tmp/bin.sql
mysql --user=root --execute "source /tmp/bin.sql"
```

The latter command also can be used to reliably read in any SQL file that may contain binary data.

`Can't open named pipe` **error**

If you use a MySQL Version 3.22 server on NT with the newest MySQL client programs, you will get the following error:

```
error 2017: can't open named pipe to host: . pipe...
```

This is because the release version of MySQL uses named pipes on NT by default. You can avoid this error by using the `--host=localhost` option to the new MySQL clients or create an option file '`C:\my.cnf`' that contains the following information:

```
[client]
host = localhost
```

Starting from 3.23.50, named pipes are enabled only if `mysqld-nt` or `mysqld-max-nt` is started with `--enable-named-pipe`.

`Access denied for user` **error**

If you attempt to run a MySQL client program to connect to a server running on the same machine, but get the error `Access denied for user: 'someuser@unknown' to database 'mysql'`, this means that MySQL can't resolve your host name properly.

To fix this, you should create a file '`\windows\hosts`' with the following information:

```
127.0.0.1       localhost
```

`ALTER TABLE`

While you are executing an `ALTER TABLE` statement, the table is locked from being used by other threads. This has to do with the fact that on Windows, you can't delete a file that is in use by another threads. In the future, we may find some way to work around this problem.

`DROP TABLE`

`DROP TABLE` on a table that is in use by a `MERGE` table will not work on Windows because the `MERGE` handler does the table mapping hidden from the upper layer of MySQL. Because Windows doesn't allow you to drop files that are open, you first must flush all `MERGE` tables (with `FLUSH TABLES`) or drop the `MERGE` table before dropping the table. We will fix this at the same time we introduce views.

`DATA DIRECTORY` **and** `INDEX DIRECTORY`

The `DATA DIRECTORY` and `INDEX DIRECTORY` options for `CREATE TABLE` are ignored on Windows, because Windows doesn't support symbolic links.

Here are some open issues for anyone who might want to help us improve MySQL on Windows:

- Add some nice start and shutdown icons to the MySQL installation.
- It would be really nice to be able to kill `mysqld` from the task manager. For the moment, you must use `mysqladmin shutdown`.
- Port `readline` to Windows for use in the `mysql` command-line tool.
- GUI versions of the standard MySQL clients (`mysql`, `mysqlshow`, `mysqladmin`, and `mysqldump`) would be nice.
- It would be nice if the socket read and write functions in '`net.c`' were interruptible. This would make it possible to kill open threads with `mysqladmin kill` on Windows.
- Add macros to use the faster thread-safe increment/decrement methods provided by Windows.

2.6.2 Linux Notes (All Linux Versions)

The following notes regarding `glibc` apply only to the situation when you build MySQL yourself. If you are running Linux on an x86 machine, in most cases it is much better for you to just use our binary. We link our binaries against the best patched version of `glibc` we can come up with and with the best compiler options, in an attempt to make it suitable for a high-load server. For a typical user, even for setups with a lot of concurrent connections and/or tables exceeding the 2G limit, our binary in most cases is the best choice. So if you read the following text, and are in doubt about what you should do, try our binary first to see if it meets your needs, and worry about your own build only after you have discovered that our binary is not good enough. In that case, we would appreciate a note about it, so we can build a better binary next time.

MySQL uses LinuxThreads on Linux. If you are using an old Linux version that doesn't have `glibc2`, you must install LinuxThreads before trying to compile MySQL. You can get LinuxThreads at `http://www.mysql.com/downloads/os-linux.html`.

Note: we have seen some strange problems with Linux 2.2.14 and MySQL on SMP systems. If you have a SMP system, we recommend you upgrade to Linux 2.4 as soon as possible. Your system will be faster and more stable.

Note that `glibc` versions before and including Version 2.1.1 have a fatal bug in `pthread_mutex_timedwait` handling, which is used when you issue `INSERT DELAYED` statements. We recommend that you not use `INSERT DELAYED` before upgrading `glibc`.

If you plan to have 1000+ concurrent connections, you will need to make some changes to LinuxThreads, recompile it, and relink MySQL against the new '`libpthread.a`'. Increase `PTHREAD_THREADS_MAX` in '`sysdeps/unix/sysv/linux/bits/local_lim.h`' to 4096 and decrease `STACK_SIZE` in '`linuxthreads/internals.h`' to 256 KB. The paths are relative to the root of `glibc` Note that MySQL will not be stable with around 600-1000 connections if `STACK_SIZE` is the default of 2 MB.

If MySQL can't open enough files, or connections, it may be that you haven't configured Linux to handle enough files.

In Linux 2.2 and onward, you can check the number of allocated file handles by doing:

```
cat /proc/sys/fs/file-max
cat /proc/sys/fs/dquot-max
cat /proc/sys/fs/super-max
```

If you have more than 16 MB of memory, you should add something like the following to your init scripts (for example, '`/etc/init.d/boot.local`' on SuSE Linux):

```
echo 65536 > /proc/sys/fs/file-max
echo 8192 > /proc/sys/fs/dquot-max
echo 1024 > /proc/sys/fs/super-max
```

You can also run the preceding commands from the command-line as root, but these settings will be lost the next time your computer reboots.

Alternatively, you can set these parameters on bootup by using the `sysctl` tool, which is used by many Linux distributions (SuSE has added it as well, beginning with SuSE Linux 8.0). Just put the following values into a file named '`/etc/sysctl.conf`':

```
# Increase some values for MySQL
fs.file-max = 65536
fs.dquot-max = 8192
fs.super-max = 1024
```

You should also add the following to '`/etc/my.cnf`':

```
[mysqld_safe]
open-files-limit=8192
```

This should allow MySQL to create up to 8192 connections + files.

The `STACK_SIZE` constant in LinuxThreads controls the spacing of thread stacks in the address space. It needs to be large enough so that there will be plenty of room for the stack of each individual thread, but small enough to keep the stack of some threads from running into the global `mysqld` data. Unfortunately, the Linux implementation of `mmap()`, as we have experimentally discovered, will successfully unmap an already mapped region if you ask it to map out an address already in use, zeroing out the data on the entire page, instead of returning an error. So, the safety of `mysqld` or any other threaded application depends on the "gentleman" behaviour of the code that creates threads. The user must take measures to make sure the number of running threads at any time is sufficiently low for thread stacks to stay away from the global heap. With `mysqld`, you should enforce this "gentleman" behaviour by setting a reasonable value for the `max_connections` variable.

If you build MySQL yourself and do not want to mess with patching LinuxThreads, you should set `max_connections` to a value no higher than 500. It should be even less if you have a large key buffer, large heap tables, or some other things that make `mysqld` allocate a lot of memory, or if you are running a 2.2 kernel with a 2G patch. If you are using our binary or RPM version 3.23.25 or later, you can safely set `max_connections` at 1500, assuming no large key buffer or heap tables with lots of data. The more you reduce `STACK_SIZE` in LinuxThreads the more threads you can safely create. We recommend the values between 128K and 256K.

If you use a lot of concurrent connections, you may suffer from a "feature" in the 2.2 kernel that penalises a process for forking or cloning a child in an attempt to prevent a fork bomb attack. This will cause MySQL not to scale well as you increase the number of concurrent clients. On single-CPU systems, we have seen this manifested in a very slow thread creation, which means it may take a long time to connect to MySQL (as long as 1 minute), and it may take just as long to shut it down. On multiple-CPU systems, we have observed a gradual drop in query speed as the number of clients increases. In the process of trying to find a solution, we have received a kernel patch from one of

our users, who claimed it made a lot of difference for his site. The patch is available at `http://www.mysql.com/Downloads/Patches/linux-fork.patch`. We have now done rather extensive testing of this patch on both development and production systems. It has significantly improved `MySQL` performance without causing any problems and we now recommend it to our users who are still running high-load servers on 2.2 kernels. This issue has been fixed in the 2.4 kernel, so if you are not satisfied with the current performance of your system, rather than patching your 2.2 kernel, it might be easier to just upgrade to 2.4, which will also give you a nice SMP boost in addition to fixing this fairness bug.

We have tested MySQL on the 2.4 kernel on a 2-CPU machine and found MySQL scales **much** better—there was virtually no slowdown on queries throughput all the way up to 1000 clients, and the MySQL scaling factor (computed as the ratio of maximum throughput to the throughput with one client) was 180%. We have observed similar results on a 4-CPU system—virtually no slowdown as the number of clients was increased up to 1000, and 300% scaling factor. So for a high-load SMP server we would definitely recommend the 2.4 kernel at this point. We have discovered that it is essential to run `mysqld` process with the highest possible priority on the 2.4 kernel to achieve maximum performance. This can be done by adding `renice -20 $$` command to `mysqld_safe`. In our testing on a 4-CPU machine, increasing the priority gave 60% increase in throughput with 400 clients.

We are currently also trying to collect more information on how well `MySQL` performs on 2.4 kernel on 4-way and 8-way systems. If you have access such a system and have done some benchmarks, please send a mail to `docs@mysql.com` with the results - we will include them in the manual.

There is another issue that greatly hurts MySQL performance, especially on SMP systems. The implementation of mutex in LinuxThreads in `glibc-2.1` is very bad for programs with many threads that only hold the mutex for a short time. On an SMP system, ironic as it is, if you link MySQL against unmodified `LinuxThreads`, removing processors from the machine improves MySQL performance in many cases. We have made a patch available for `glibc 2.1.3` to correct this behaviour (`http://www.mysql.com/Downloads/Linux/linuxthreads-2.1-patch`).

With `glibc-2.2.2` MySQL version 3.23.36 will use the adaptive mutex, which is much better than even the patched one in `glibc-2.1.3`. Be warned, however, that under some conditions, the current mutex code in `glibc-2.2.2` overspins, which hurts MySQL performance. The chance of this condition can be reduced by renicing `mysqld` process to the highest priority. We have also been able to correct the overspin behaviour with a patch, available at `http://www.mysql.com/Downloads/Linux/linuxthreads-2.2.2.patch`. It combines the correction of overspin, maximum number of threads, and stack spacing all in one. You will need to apply it in the `linuxthreads` directory with `patch -p0 </tmp/linuxthreads-2.2.2.patch`. We hope it will be included in some form in to the future releases of `glibc-2.2`. In any case, if you link against `glibc-2.2.2` you still need to correct `STACK_SIZE` and `PTHREAD_THREADS_MAX`. We hope that the defaults will be corrected to some more acceptable values for high-load MySQL setup in the future, so that your own build can be reduced to `./configure; make; make install`.

We recommend that you use the above patches to build a special static version of `libpthread.a` and use it only for statically linking against `MySQL`. We know that the patches are safe for `MySQL` and significantly improve its performance, but we cannot say anything about other applications. If you link other applications against the patched

version of the library, or build a patched shared version and install it on your system, you are doing it at your own risk with regard to other applications that depend on `LinuxThreads`.

If you experience any strange problems during the installation of MySQL, or with some common utilities hanging, it is very likely that they are either library or compiler related. If this is the case, using our binary will resolve them.

One known problem with the binary distribution is that with older Linux systems that use `libc` (like Red Hat 4.x or Slackware), you will get some non-fatal problems with hostname resolution. See Section 2.6.2.1 [Binary notes-Linux], page 130.

When using LinuxThreads you will see a minimum of three processes running. These are in fact threads. There will be one thread for the LinuxThreads manager, one thread to handle connections, and one thread to handle alarms and signals.

Note that the Linux kernel and the LinuxThread library can by default only have 1024 threads. This means that you can only have up to 1021 connections to MySQL on an unpatched system. The page `http://www.volano.com/linuxnotes.html` contains information how to go around this limit.

If you see a dead `mysqld` daemon process with `ps`, this usually means that you have found a bug in MySQL or you have a corrupted table. See Section A.4.1 [Crashing], page 859.

To get a core dump on Linux if `mysqld` dies with a `SIGSEGV` signal, you can start `mysqld` with the `--core-file` option. Note that you also probably need to raise the `core file size` by adding `ulimit -c 1000000` to `mysqld_safe` or starting `mysqld_safe` with `--core-file-size=1000000`. See Section 4.8.2 [`mysqld_safe`], page 312.

If you are linking your own MySQL client and get the error:

```
ld.so.1: ./my: fatal: libmysqlclient.so.4:
open failed: No such file or directory
```

When executing them, the problem can be avoided by one of the following methods:

- Link the client with the following flag (instead of `-Lpath`): `-Wl,r/path-libmysqlclient.so`.
- Copy `libmysqclient.so` to '`/usr/lib`'.
- Add the pathname of the directory where '`libmysqlclient.so`' is located to the `LD_RUN_PATH` environment variable before running your client.

If you are using the Fujitsu compiler (`fcc / FCC`) you will have some problems compiling MySQL because the Linux header files are very `gcc` oriented.

The following `configure` line should work with `fcc/FCC`:

```
CC=fcc CFLAGS="-O -K fast -K lib -K omitfp -Kpreex -D_GNU_SOURCE \
-DCONST=const -DNO_STRTOLL_PROTO" CXX=FCC CXXFLAGS="-O -K fast -K lib \
-K omitfp -K preex --no_exceptions --no_rtti -D_GNU_SOURCE -DCONST=const \
-Dalloca=__builtin_alloca -DNO_STRTOLL_PROTO \
'-D_EXTERN_INLINE=static __inline'" ./configure --prefix=/usr/local/mysql \
--enable-assembler --with-mysqld-ldflags=-all-static --disable-shared \
--with-low-memory
```

2.6.2.1 Linux Notes for Binary Distributions

MySQL needs at least Linux Version 2.0.

Warning: We have reports from some MySQL users that they have got serious stability problems with MySQL with Linux kernel 2.2.14. If you are using this kernel you should upgrade to 2.2.19 (or newer) or to a 2.4 kernel. If you have a multi-cpu box, then you should seriously consider using 2.4 as this will give you a significant speed boost.

The binary release is linked with `-static`, which means you do not normally need to worry about which version of the system libraries you have. You need not install LinuxThreads, either. A program linked with `-static` is slightly bigger than a dynamically linked program but also slightly faster (3-5%). One problem, however, is that you can't use user-definable functions (UDFs) with a statically linked program. If you are going to write or use UDFs (this is something for C or C++ programmers only), you must compile MySQL yourself, using dynamic linking.

If you are using a `libc`-based system (instead of a `glibc2` system), you will probably get some problems with hostname resolving and `getpwnam()` with the binary release. (This is because `glibc` unfortunately depends on some external libraries to resolve hostnames and `getpwent()`, even when compiled with `-static`). In this case you probably get the following error message when you run `mysql_install_db`:

```
Sorry, the host 'xxxx' could not be looked up
```

or the following error when you try to run `mysqld` with the `--user` option:

```
getpwnam: No such file or directory
```

You can solve this problem in one of the following ways:

- Get a MySQL source distribution (an RPM or the `tar.gz` distribution) and install this instead.
- Execute `mysql_install_db --force`; this will not execute the `resolveip` test in `mysql_install_db`. The downside is that you can't use host names in the grant tables; you must use IP numbers instead (except for `localhost`). If you are using an old MySQL release that doesn't support `--force`, you have to remove the `resolveip` test in `mysql_install` with an editor.
- Start `mysqld` with `su` instead of using `--user`.

The Linux-Intel binary and RPM releases of MySQL are configured for the highest possible speed. We are always trying to use the fastest stable compiler available.

MySQL Perl support requires Version Perl 5.004_03 or newer.

On some Linux 2.2 versions, you may get the error `Resource temporarily unavailable` when you do a lot of new connections to a `mysqld` server over TCP/IP.

The problem is that Linux has a delay between when you close a TCP/IP socket and until this is actually freed by the system. As there is only room for a finite number of TCP/IP slots, you will get the above error if you try to do too many new TCP/IP connections during a small time, like when you run the MySQL '`test-connect`' benchmark over TCP/IP.

We have mailed about this problem a couple of times to different Linux mailing lists but have never been able to resolve this properly.

The only known 'fix' to this problem is to use persistent connections in your clients or use sockets, if you are running the database server and clients on the same machine. We hope that the `Linux 2.4` kernel will fix this problem in the future.

2.6.2.2 Linux x86 Notes

MySQL requires `libc` Version 5.4.12 or newer. It's known to work with `libc` 5.4.46. `glibc` Version 2.0.6 and later should also work. There have been some problems with the `glibc` RPMs from Red Hat, so if you have problems, check whether there are any updates. The `glibc` 2.0.7-19 and 2.0.7-29 RPMs are known to work.

If you are using Red Hat 8.0 or a new `glibc` 2.2.x library, you should start `mysqld` with the option `--thread-stack=192K`. (Use `-O thread_stack=192K` before MySQL 4.) If you don't do this, `mysqld` will die in `gethostbyaddr()` because the new `glibc` library requires a stack size greater than 128K for this call. This stack size is now the default on MySQL 4.0.10 and above.

If you are using `gcc` 3.0 and above to compile MySQL, you must install the `libstdc++v3` library before compiling MySQL; if you don't do this, you will get an error about a missing `__cxa_pure_virtual` symbol during linking.

On some older Linux distributions, `configure` may produce an error like this:

```
Syntax error in sched.h. Change _P to __P in the /usr/include/sched.h file.
See the Installation chapter in the Reference Manual.
```

Just do what the error message says and add an extra underscore to the `_P` macro that has only one underscore, then try again.

You may get some warnings when compiling; those shown here can be ignored:

```
mysqld.cc -o objs-thread/mysqld.o
mysqld.cc: In function `void init_signals()':
mysqld.cc:315: warning: assignment of negative value `-1' to
`long unsigned int'
mysqld.cc: In function `void * signal_hand(void *)':
mysqld.cc:346: warning: assignment of negative value `-1' to
`long unsigned int'
```

`mysql.server` can be found in the '`share/mysql`' directory under the MySQL installation directory or in the '`support-files`' directory of the MySQL source tree.

If `mysqld` always core dumps when it starts up, the problem may be that you have an old '`/lib/libc.a`'. Try renaming it, then remove '`sql/mysqld`' and do a new `make install` and try again. This problem has been reported on some Slackware installations.

If you get the following error when linking `mysqld`, it means that your '`libg++.a`' is not installed correctly:

```
/usr/lib/libc.a(putc.o): In function `_IO_putc':
putc.o(.text+0x0): multiple definition of `_IO_putc'
```

You can avoid using '`libg++.a`' by running `configure` like this:

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

2.6.2.3 Linux SPARC Notes

In some implementations, `readdir_r()` is broken. The symptom is that `SHOW DATABASES` always returns an empty set. This can be fixed by removing `HAVE_READDIR_R` from '`config.h`' after configuring and before compiling.

2.6.2.4 Linux Alpha Notes

MySQL Version 3.23.12 is the first MySQL version that is tested on Linux-Alpha. If you plan to use MySQL on Linux-Alpha, you should ensure that you have this version or newer.

We have tested MySQL on Alpha with our benchmarks and test suite, and it appears to work nicely.

We currently build the MySQL binary packages on SuSE Linux 7.0 for AXP, kernel 2.4.4-SMP, Compaq C compiler (V6.2-505) and Compaq C++ compiler (V6.3-006) on a Compaq DS20 machine with an Alpha EV6 processor.

You can find the above compilers at `http://www.support.compaq.com/alpha-tools/`. By using these compilers, instead of gcc, we get about 9-14% better performance with MySQL.

Note that until MySQL version 3.23.52 and 4.0.2 we optimised the binary for the current CPU only (by using the `-fast` compile option); this meant that you could only use our binaries if you had an Alpha EV6 processor.

Starting with all following releases we added the `-arch generic` flag to our compile options, which makes sure the binary runs on all Alpha processors. We also compile statically to avoid library problems.

```
CC=ccc CFLAGS="-fast -arch generic" CXX=cxx \
CXXFLAGS="-fast -arch generic -noexceptions -nortti" \
./configure --prefix=/usr/local/mysql --disable-shared \
--with-extra-charsets=complex --enable-thread-safe-client \
--with-mysqld-ldflags=-non_shared --with-client-ldflags=-non_shared
```

If you want to use egcs the following configure line worked for us:

```
CFLAGS="-O3 -fomit-frame-pointer" CXX=gcc \
CXXFLAGS="-O3 -fomit-frame-pointer -felide-constructors \
-fno-exceptions -fno-rtti" ./configure --prefix=/usr/local/mysql \
--disable-shared
```

Some known problems when running MySQL on Linux-Alpha:

- Debugging threaded applications like MySQL will not work with `gdb 4.18`. You should download and use gdb 5.1 instead!
- If you try linking `mysqld` statically when using `gcc`, the resulting image will core dump at start. In other words, **don't** use `--with-mysqld-ldflags=-all-static` with `gcc`.

2.6.2.5 Linux PowerPC Notes

MySQL should work on MkLinux with the newest `glibc` package (tested with `glibc` 2.0.7).

2.6.2.6 Linux MIPS Notes

To get MySQL to work on Qube2, (Linux Mips), you need the newest `glibc` libraries (`glibc-2.0.7-29C2` is known to work). You must also use the `egcs` C++ compiler (`egcs-1.0.2-9`, `gcc 2.95.2` or newer).

2.6.2.7 Linux IA-64 Notes

To get MySQL to compile on Linux IA-64, we use the following compile line: Using `gcc-2.96`:

```
CC=gcc CFLAGS="-O3 -fno-omit-frame-pointer" CXX=gcc \
CXXFLAGS="-O3 -fno-omit-frame-pointer -felide-constructors \
-fno-exceptions -fno-rtti" ./configure --prefix=/usr/local/mysql \
"--with-comment=Official MySQL binary" --with-extra-charsets=complex
```

On IA-64, the MySQL client binaries use shared libraries. This means that if you install our binary distribution in some other place than '`/usr/local/mysql`' you need to add the path of the directory where you have '`libmysqlclient.so`' installed either to the '`/etc/ld.so.conf`' file or to the value of your `LD_LIBRARY_PATH` environment variable.

See Section A.3.1 [Link errors], page 857.

2.6.3 Solaris Notes

On Solaris, you may run into trouble even before you get the MySQL distribution unpacked! Solaris `tar` can't handle long file names, so you may see an error like this when you unpack MySQL:

```
x mysql-3.22.12-beta/bench/Results/ATIS-mysql_odbc-NT_4.0-cmp-db2,\
informix,ms-sql,mysql,oracle,solid,sybase, 0 bytes, 0 tape blocks
tar: directory checksum error
```

In this case, you must use GNU `tar` (`gtar`) to unpack the distribution. You can find a precompiled copy for Solaris at `http://www.mysql.com/downloads/os-solaris.html`.

Sun native threads only work on Solaris 2.5 and higher. For Version 2.4 and earlier, MySQL will automatically use MIT-pthreads. See Section 2.3.6 [MIT-pthreads], page 99.

If you get the following error from configure:

```
checking for restartable system calls... configure: error can not run test
programs while cross compiling
```

This means that you have something wrong with your compiler installation! In this case you should upgrade your compiler to a newer version. You may also be able to solve this problem by inserting the following row into the '`config.cache`' file:

```
ac_cv_sys_restartable_syscalls=${ac_cv_sys_restartable_syscalls='no'}
```

If you are using Solaris on a SPARC, the recommended compiler is `gcc` 2.95.2 or 3.2. You can find this at `http://gcc.gnu.org/`. Note that `egcs` 1.1.1 and `gcc` 2.8.1 don't work reliably on SPARC!

The recommended `configure` line when using `gcc` 2.95.2 is:

```
CC=gcc CFLAGS="-O3" \
CXX=gcc CXXFLAGS="-O3 -felide-constructors -fno-exceptions -fno-rtti" \
./configure --prefix=/usr/local/mysql --with-low-memory --enable-assembler
```

If you have an UltraSPARC, you can get 4% more performance by adding "-mcpu=v8 -Wa,-xarch=v8plusa" to CFLAGS and CXXFLAGS.

If you have Sun's Forte 5.0 (or newer) compiler, you can run `configure` like this:

```
CC=cc CFLAGS="-Xa -fast -native -xstrconst -mt" \
CXX=CC CXXFLAGS="-noex -mt" \
./configure --prefix=/usr/local/mysql --enable-assembler
```

You can create a 64 bit binary using Sun's Forte compiler with the following compile flags:

```
CC=cc CFLAGS="-Xa -fast -native -xstrconst -mt -xarch=v9" \
CXX=CC CXXFLAGS="-noex -mt -xarch=v9" ASFLAGS="-xarch=v9" \
./configure --prefix=/usr/local/mysql --enable-assembler
```

To create a 64bit Solaris binary using `gcc`, add `-m64` to `CFLAGS` and `CXXFLAGS`. Note that this only works with MySQL 4.0 and up - MySQL 3.23 does not include the required modifications to support this.

In the MySQL benchmarks, we got a 4% speedup on an UltraSPARC when using Forte 5.0 in 32 bit mode compared to using gcc 3.2 with -mcpu flags.

If you create a 64 bit binary, it's 4 % slower than the 32 bit binary, but `mysqld` can instead handle more treads and memory.

If you get a problem with `fdatasync` or `sched_yield`, you can fix this by adding `LIBS=-lrt` to the configure line

The following paragraph is only relevant for older compilers than WorkShop 5.3:

You may also have to edit the `configure` script to change this line:

```
#if !defined(__STDC__) || __STDC__ != 1
```

to this:

```
#if !defined(__STDC__)
```

If you turn on `__STDC__` with the `-Xc` option, the Sun compiler can't compile with the Solaris '`pthread.h`' header file. This is a Sun bug (broken compiler or broken include file).

If `mysqld` issues the error message shown here when you run it, you have tried to compile MySQL with the Sun compiler without enabling the multi-thread option (`-mt`):

```
libc internal error: _rmutex_unlock: rmutex not held
```

Add `-mt` to `CFLAGS` and `CXXFLAGS` and try again.

If you are using the SFW version of gcc (which comes with Solaris 8), you must add '`/opt/sfw/lib`' to the environment variable `LD_LIBRARY_PATH` before running configure.

If you are using the gcc available from `sunfreeware.com`, you may have many problems. You should recompile gcc and GNU binutils on the machine you will be running them from to avoid any problems.

If you get the following error when compiling MySQL with `gcc`, it means that your `gcc` is not configured for your version of Solaris:

```
shell> gcc -O3 -g -O2 -DDBUG_OFF  -o thr_alarm ...
./thr_alarm.c: In function ‘signal_hand’:
./thr_alarm.c:556: too many arguments to function ‘sigwait’
```

The proper thing to do in this case is to get the newest version of `gcc` and compile it with your current `gcc` compiler! At least for Solaris 2.5, almost all binary versions of `gcc` have old, unusable include files that will break all programs that use threads (and possibly other programs)!

Solaris doesn't provide static versions of all system libraries (`libpthreads` and `libdl`), so you can't compile MySQL with `--static`. If you try to do so, you will get the error:

```
ld: fatal: library -ldl: not found

or

undefined reference to ‘dlopen’

or

cannot find -lrt
```

If too many processes try to connect very rapidly to `mysqld`, you will see this error in the MySQL log:

```
Error in accept: Protocol error
```

You might try starting the server with the `--set-variable back_log=50` option as a workaround for this. Please note that `--set-variable` is deprecated since MySQL 4.0, just use `--back_log=50` on its own. See Section 4.1.1 [Command-line options], page 195.

If you are linking your own MySQL client, you might get the following error when you try to execute it:

```
ld.so.1: ./my: fatal: libmysqlclient.so.#:
open failed: No such file or directory
```

The problem can be avoided by one of the following methods:

- Link the client with the following flag (instead of `-Lpath`): `-Wl,r/full-path-to-libmysqlclient.so`.
- Copy ‘`libmysqclient.so`’ to ‘`/usr/lib`’.
- Add the pathname of the directory where ‘`libmysqlclient.so`’ is located to the `LD_RUN_PATH` environment variable before running your client.

If you have problems with configure trying to link with `-lz` and you don't have `zlib` installed, you have two options:

- If you want to be able to use the compressed communication protocol, you need to get and install zlib from ftp.gnu.org.
- Configure with `--with-named-z-libs=no`.

If you are using gcc and have problems with loading user defined functions (`UDF`s) into MySQL, try adding `-lgcc` to the link line for the `UDF`.

If you would like MySQL to start automatically, you can copy ‘`support-files/mysql.server`’ to ‘`/etc/init.d`’ and create a symbolic link to it named ‘`/etc/rc3.d/S99mysql.server`’.

As Solaris doesn't support core files for `setuid()` applications, you can't get a core file from `mysqld` if you are using the `--user` option.

2.6.3.1 Solaris 2.7/2.8 Notes

You can normally use a Solaris 2.6 binary on Solaris 2.7 and 2.8. Most of the Solaris 2.6 issues also apply for Solaris 2.7 and 2.8.

Note that MySQL Version 3.23.4 and above should be able to autodetect new versions of Solaris and enable workarounds for the following problems!

Solaris 2.7 / 2.8 has some bugs in the include files. You may see the following error when you use `gcc`:

```
/usr/include/widec.h:42: warning: 'getwc' redefined
/usr/include/wchar.h:326: warning: this is the location of the previous
definition
```

If this occurs, you can do the following to fix the problem:

Copy `/usr/include/widec.h` to `.../lib/gcc-lib/os/gcc-version/include` and change line 41 from:

```
#if     !defined(lint) && !defined(__lint)

to

#if     !defined(lint) && !defined(__lint) && !defined(getwc)
```

Alternatively, you can edit '`/usr/include/widec.h`' directly. Either way, after you make the fix, you should remove '`config.cache`' and run `configure` again!

If you get errors like this when you run `make`, it's because `configure` didn't detect the '`curses.h`' file (probably because of the error in '`/usr/include/widec.h`'):

```
In file included from mysql.cc:50:
/usr/include/term.h:1060: syntax error before ','
/usr/include/term.h:1081: syntax error before ';'
```

The solution to this is to do one of the following:

- Configure with `CFLAGS=-DHAVE_CURSES_H CXXFLAGS=-DHAVE_CURSES_H ./configure`.
- Edit '`/usr/include/widec.h`' as indicted above and rerun configure.
- Remove the `#define HAVE_TERM` line from '`config.h`' file and run `make` again.

If you get a problem that your linker can't find `-lz` when linking your client program, the problem is probably that your '`libz.so`' file is installed in '`/usr/local/lib`'. You can fix this by one of the following methods:

- Add '`/usr/local/lib`' to `LD_LIBRARY_PATH`.
- Add a link to '`libz.so`' from '`/lib`'.
- If you are using Solaris 8, you can install the optional zlib from your Solaris 8 CD distribution.
- Configure MySQL with the `--with-named-z-libs=no` option.

2.6.3.2 Solaris x86 Notes

On Solaris 8 on x86, `mysqld` will dump core if you remove the debug symbols using `strip`.

If you are using `gcc` or `egcs` on Solaris x86 and you experience problems with core dumps under load, you should use the following `configure` command:

```
CC=gcc CFLAGS="-O3 -fomit-frame-pointer -DHAVE_CURSES_H" \
CXX=gcc \
CXXFLAGS="-O3 -fomit-frame-pointer -felide-constructors -fno-exceptions \
-fno-rtti -DHAVE_CURSES_H" \
./configure --prefix=/usr/local/mysql
```

This will avoid problems with the `libstdc++` library and with C++ exceptions.

If this doesn't help, you should compile a debug version and run it with a trace file or under `gdb`. See Section E.1.3 [Using gdb on mysqld], page 1009.

2.6.4 BSD Notes

This section provides information for the various BSD flavours, as well as specific versions within those.

2.6.4.1 FreeBSD Notes

FreeBSD 4.x or newer is recommended for running MySQL since the thread package is much more integrated.

The easiest and therefore the preferred way to install is to use the mysql-server and mysql-client ports available on `http://www.freebsd.org/`.

Using these gives you:

- A working MySQL with all optimisations known to work on your version of FreeBSD enabled.
- Automatic configuration and build.
- Startup scripts installed in /usr/local/etc/rc.d.
- Ability to see which files that are installed with pkg_info -L. And to remove them all with pkg_delete if you no longer want MySQL on that machine.

It is recommended you use MIT-pthreads on FreeBSD 2.x and native threads on Versions 3 and up. It is possible to run with native threads on some late 2.2.x versions but you may encounter problems shutting down `mysqld`.

Unfortunately, certain function calls on FreeBSD are not yet fully thread-safe, most notably the `gethostbyname()` function, which is used by MySQL to convert host names into IP addresses. Under certain circumstances, the `mysqld` process will suddenly cause 100% CPU load and will be unresponsive. If you encounter this, try to start up MySQL using the `--skip-name-resolve` option.

Alternatively, you can link MySQL on FreeBSD 4.x against the LinuxThreads library, which avoids a few of the problems that the native FreeBSD thread implementation has. For a very good comparison of LinuxThreads vs. native threads have a look

at Jeremy Zawodny's article "FreeBSD or Linux for your MySQL Server?" at `http://jeremy.zawodny.com/blog/archives/000697.html`

The known problems when using LinuxThreads on FreeBSD are:

- `wait_timeout` is not working (probably signal handling problem in FreeBSD/LinuxThreads). This is supposed to get fixed in FreeBSD 5.0. The symptom is that persistent connections can hang for **a long** time without getting closed done.

The MySQL '`Makefile`'s require GNU make (`gmake`) to work. If you want to compile MySQL you need to install GNU `make` first.

Be sure to have your name resolver setup correct. Otherwise, you may experience resolver delays or failures when connecting to `mysqld`.

Make sure that the `localhost` entry in the '`/etc/hosts`' file is correct (otherwise, you will have problems connecting to the database). The '`/etc/hosts`' file should start with a line:

```
127.0.0.1       localhost localhost.your.domain
```

The recommended way to compile and install MySQL on FreeBSD with gcc (2.95.2 and up) is:

```
CC=gcc CFLAGS="-O2 -fno-strength-reduce" \
CXX=gcc CXXFLAGS="-O2 -fno-rtti -fno-exceptions -felide-constructors \
-fno-strength-reduce" \
./configure --prefix=/usr/local/mysql --enable-assembler
gmake
gmake install
./scripts/mysql_install_db
cd /usr/local/mysql
./bin/mysqld_safe &
```

If you notice that `configure` will use MIT-pthreads, you should read the MIT-pthreads notes. See Section 2.3.6 [MIT-pthreads], page 99.

If you get an error from `make install` that it can't find '`/usr/include/pthreads`', `configure` didn't detect that you need MIT-pthreads. This is fixed by executing these commands:

```
shell> rm config.cache
shell> ./configure --with-mit-threads
```

FreeBSD is also known to have a very low default file handle limit. See Section A.2.17 [Not enough file handles], page 856. Uncomment the `ulimit -n` section in `mysqld_safe` or raise the limits for the `mysqld` user in /etc/login.conf (and rebuild it with cap_mkdb /etc/login.conf). Also be sure you set the appropriate class for this user in the password file if you are not using the default (use: chpass mysqld-user-name). See Section 4.8.2 [`mysqld_safe`], page 312.

If you have a lot of memory you should consider rebuilding the kernel to allow MySQL to take more than 512M of RAM. Take a look at `option MAXDSIZ` in the LINT config file for more info.

If you get problems with the current date in MySQL, setting the `TZ` variable will probably help. See Appendix F [Environment variables], page 1019.

To get a secure and stable system you should only use FreeBSD kernels that are marked `-RELEASE`.

2.6.4.2 NetBSD Notes

To compile on NetBSD you need GNU `make`. Otherwise, the compile will crash when `make` tries to run `lint` on C++ files.

2.6.4.3 OpenBSD 2.5 Notes

On OpenBSD Version 2.5, you can compile MySQL with native threads with the following options:

```
CFLAGS=-pthread CXXFLAGS=-pthread ./configure --with-mit-threads=no
```

2.6.4.4 OpenBSD 2.8 Notes

Our users have reported that OpenBSD 2.8 has a threading bug which causes problems with MySQL. The OpenBSD Developers have fixed the problem, but as of January 25th, 2001, it's only available in the "-current" branch. The symptoms of this threading bug are: slow response, high load, high CPU usage, and crashes.

If you get an error like `Error in accept:: Bad file descriptor` or error 9 when trying to open tables or directories, the problem is probably that you haven't allocated enough file descriptors for MySQL.

In this case, try starting `mysqld_safe` as `root` with the following options:

```
shell> mysqld_safe --user=mysql --open-files-limit=2048 &
```

2.6.4.5 BSD/OS Version 2.x Notes

If you get the following error when compiling MySQL, your `ulimit` value for virtual memory is too low:

```
item_func.h: In method `Item_func_ge::Item_func_ge(const Item_func_ge &)':
item_func.h:28: virtual memory exhausted
make[2]: *** [item_func.o] Error 1
```

Try using `ulimit -v 80000` and run `make` again. If this doesn't work and you are using `bash`, try switching to `csh` or `sh`; some BSDI users have reported problems with `bash` and `ulimit`.

If you are using `gcc`, you may also use have to use the `--with-low-memory` flag for `configure` to be able to compile '`sql_yacc.cc`'.

If you get problems with the current date in MySQL, setting the `TZ` variable will probably help. See Appendix F [Environment variables], page 1019.

2.6.4.6 BSD/OS Version 3.x Notes

Upgrade to BSD/OS Version 3.1. If that is not possible, install BSDIpatch M300-038.

Use the following command when configuring MySQL:

```
shell> env CXX=shlicc++ CC=shlicc2 \
       ./configure \
           --prefix=/usr/local/mysql \
           --localstatedir=/var/mysql \
           --without-perl \
           --with-unix-socket-path=/var/mysql/mysql.sock
```

The following is also known to work:

```
shell> env CC=gcc CXX=gcc CXXFLAGS=-O3 \
       ./configure \
           --prefix=/usr/local/mysql \
           --with-unix-socket-path=/var/mysql/mysql.sock
```

You can change the directory locations if you wish, or just use the defaults by not specifying any locations.

If you have problems with performance under heavy load, try using the `--skip-thread-priority` option to `mysqld`! This will run all threads with the same priority; on BSDI Version 3.1, this gives better performance (at least until BSDI fixes their thread scheduler).

If you get the error `virtual memory exhausted` while compiling, you should try using `ulimit -v 80000` and run `make` again. If this doesn't work and you are using `bash`, try switching to `csh` or `sh`; some BSDI users have reported problems with `bash` and `ulimit`.

2.6.4.7 BSD/OS Version 4.x Notes

BSDI Version 4.x has some thread-related bugs. If you want to use MySQL on this, you should install all thread-related patches. At least M400-023 should be installed.

On some BSDI Version 4.x systems, you may get problems with shared libraries. The symptom is that you can't execute any client programs, for example, `mysqladmin`. In this case you need to reconfigure not to use shared libraries with the `--disable-shared` option to configure.

Some customers have had problems on BSDI 4.0.1 that the `mysqld` binary after a while can't open tables. This is because some library/system related bug causes `mysqld` to change current directory without asking for this!

The fix is to either upgrade to 3.23.34 or after running `configure` remove the line `#define HAVE_REALPATH` from `config.h` before running make.

Note that the above means that you can't symbolic link a database directories to another database directory or symbolic link a table to another database on BSDI! (Making a symbolic link to another disk is okay).

2.6.5 Mac OS X Notes

2.6.5.1 Mac OS X 10.x

MySQL should work without any problems on Mac OS X 10.x (Darwin). You don't need the pthread patches for this OS!

This also applies to Mac OS X 10.x Server. Compiling for the Server platform is the same as for the client version of Mac OS X. However please note that MySQL comes preinstalled on the Server!

Our binary for Mac OS X is compiled on Darwin 6.3 with the following configure line:

```
CC=gcc CFLAGS="-O3 -fno-omit-frame-pointer" CXX=gcc \
CXXFLAGS="-O3 -fno-omit-frame-pointer -felide-constructors \
-fno-exceptions -fno-rtti" ./configure --prefix=/usr/local/mysql \
--with-extra-charsets=complex --enable-thread-safe-client \
--enable-local-infile --disable-shared
```

See Section 2.1.3 [Mac OS X installation], page 66.

2.6.5.2 Mac OS X Server 1.2 (Rhapsody)

Before trying to configure MySQL on Mac OS X Server 1.2 (aka Rhapsody) you must first install the pthread package from `http://www.prnet.de/RegEx/mysql.html`.

See Section 2.1.3 [Mac OS X installation], page 66.

2.6.6 Other Unix Notes

2.6.6.1 HP-UX Notes for Binary Distributions

Some of the binary distributions of MySQL for HP-UX are distributed as an HP depot file and as a tar file. To use the depot file you must be running at least HP-UX 10.x to have access to HP's software depot tools.

The HP version of MySQL was compiled on an HP 9000/8xx server under HP-UX 10.20, and uses MIT-pthreads. It is known to work well under this configuration. MySQL Version 3.22.26 and newer can also be built with HP's native thread package.

Other configurations that may work:

- HP 9000/7xx running HP-UX 10.20+
- HP 9000/8xx running HP-UX 10.30

The following configurations almost definitely won't work:

- HP 9000/7xx or 8xx running HP-UX 10.x where x < 2
- HP 9000/7xx or 8xx running HP-UX 9.x

To install the distribution, use one of the commands here, where `/path/to/depot` is the full pathname of the depot file:

- To install everything, including the server, client and development tools:

```
shell> /usr/sbin/swinstall -s /path/to/depot mysql.full
```

- To install only the server:

```
shell> /usr/sbin/swinstall -s /path/to/depot mysql.server
```

- To install only the client package:

```
shell> /usr/sbin/swinstall -s /path/to/depot mysql.client
```

- To install only the development tools:

```
shell> /usr/sbin/swinstall -s /path/to/depot mysql.developer
```

The depot places binaries and libraries in '`/opt/mysql`' and data in '`/var/opt/mysql`'. The depot also creates the appropriate entries in '`/etc/init.d`' and '`/etc/rc2.d`' to start the server automatically at boot time. Obviously, this entails being `root` to install.

To install the HP-UX tar.gz distribution, you must have a copy of GNU `tar`.

2.6.6.2 HP-UX Version 10.20 Notes

There are a couple of small problems when compiling MySQL on HP-UX. We recommend that you use `gcc` instead of the HP-UX native compiler, because `gcc` produces better code!

We recommend using `gcc` 2.95 on HP-UX. Don't use high optimisation flags (like -O6) as this may not be safe on HP-UX.

The following `configure` line should work with `gcc` 2.95:

```
CFLAGS="-I/opt/dce/include -fpic" \
CXXFLAGS="-I/opt/dce/include -felide-constructors -fno-exceptions \
-fno-rtti" CXX=gcc ./configure --with-pthread \
--with-named-thread-libs='-ldce' --prefix=/usr/local/mysql --disable-shared
```

The following `configure` line should work with `gcc` 3.1:

```
CFLAGS="-DHPUX -I/opt/dce/include -O3 -fPIC" CXX=gcc \
CXXFLAGS="-DHPUX -I/opt/dce/include -felide-constructors -fno-exceptions \
-fno-rtti -O3 -fPIC" ./configure --prefix=/usr/local/mysql \
--with-extra-charsets=complex --enable-thread-safe-client \
--enable-local-infile  --with-pthread \
--with-named-thread-libs=-ldce --with-lib-ccflags=-fPIC
--disable-shared
```

2.6.6.3 HP-UX Version 11.x Notes

For HP-UX Version 11.x, we recommend MySQL Version 3.23.15 or later.

Because of some critical bugs in the standard HP-UX libraries, you should install the following patches before trying to run MySQL on HP-UX 11.0:

```
PHKL_22840 Streams cumulative
PHNE_22397 ARPA cumulative
```

This will solve the problem of getting `EWOULDBLOCK` from `recv()` and `EBADF` from `accept()` in threaded applications.

If you are using `gcc` 2.95.1 on an unpatched HP-UX 11.x system, you will get the error:

```
In file included from /usr/include/unistd.h:11,
                 from ../include/global.h:125,
                 from mysql_priv.h:15,
                 from item.cc:19:
/usr/include/sys/unistd.h:184: declaration of C function ...
/usr/include/sys/pthread.h:440: previous declaration ...
In file included from item.h:306,
                 from mysql_priv.h:158,
                 from item.cc:19:
```

The problem is that HP-UX doesn't define `pthreads_atfork()` consistently. It has conflicting prototypes in '`/usr/include/sys/unistd.h`':184 and '`/usr/include/sys/pthread.h`':440 (details below).

One solution is to copy '`/usr/include/sys/unistd.h`' into '`mysql/include`' and edit '`unistd.h`' and change it to match the definition in '`pthread.h`'. Here's the diff:

```
183,184c183,184
<      extern int pthread_atfork(void (*prepare)(), void (*parent)(),
<                                                 void (*child)());
---
>      extern int pthread_atfork(void (*prepare)(void), void (*parent)(void),
>                                                 void (*child)(void));
```

After this, the following configure line should work:

```
CFLAGS="-fomit-frame-pointer -O3 -fpic" CXX=gcc \
CXXFLAGS="-felide-constructors -fno-exceptions -fno-rtti -O3" \
./configure --prefix=/usr/local/mysql --disable-shared
```

If you are using MySQL 4.0.5 with the HP-UX compiler you can use: (tested with cc B.11.11.04):

```
CC=cc CXX=aCC CFLAGS=+DD64 CXXFLAGS=+DD64 ./configure --with-extra-character-set=compl
```

You can ignore any errors of the following type:

```
aCC: warning 901: unknown option: '-3': use +help for online documentation
```

If you get the following error from `configure`

```
checking for cc option to accept ANSI C... no
configure: error: MySQL requires a ANSI C compiler (and a C++ compiler).
Try gcc. See the Installation chapter in the Reference Manual.
```

Check that you don't have the path to the K&R compiler before the path to the HP-UX C and C++ compiler.

Another reason for not beeing able to compile is that you didn't define the `+DD64` flags above.

Another possibility for HP-UX 11 is to use MySQL binaries for HP-UX 10.20. We have received reports from some users that these binaries work fine on HP-UX 11.00. If you encounter problems, be sure to check your HP-UX patch level.

2.6.6.4 IBM-AIX notes

Automatic detection of `xlC` is missing from Autoconf, so a `configure` command something like this is needed when compiling MySQL (This example uses the IBM compiler):

```
export CC="xlc_r -ma -O3 -qstrict -qoptimize=3 -qmaxmem=8192 "
export CXX="xlC_r -ma -O3 -qstrict -qoptimize=3 -qmaxmem=8192"
export CFLAGS="-I /usr/local/include"
export LDFLAGS="-L /usr/local/lib"
export CPPFLAGS=$CFLAGS
export CXXFLAGS=$CFLAGS

./configure --prefix=/usr/local \
                --localstatedir=/var/mysql \
                --sysconfdir=/etc/mysql \
                --sbindir='/usr/local/bin' \
                --libexecdir='/usr/local/bin' \
                --enable-thread-safe-client \
                --enable-large-files
```

Above are the options used to compile the MySQL distribution that can be found at `http://www-frec.bull.com/`.

If you change the `-O3` to `-O2` in the above configure line, you must also remove the `-qstrict` option (this is a limitation in the IBM C compiler).

If you are using `gcc` or `egcs` to compile MySQL, you **must** use the `-fno-exceptions` flag, as the exception handling in `gcc`/`egcs` is not thread-safe! (This is tested with `egcs` 1.1.) There are also some known problems with IBM's assembler, which may cause it to generate bad code when used with gcc.

We recommend the following `configure` line with `egcs` and `gcc 2.95` on AIX:

```
CC="gcc -pipe -mcpu=power -Wa,-many" \
CXX="gcc -pipe -mcpu=power -Wa,-many" \
CXXFLAGS="-felide-constructors -fno-exceptions -fno-rtti" \
./configure --prefix=/usr/local/mysql --with-low-memory
```

The `-Wa,-many` is necessary for the compile to be successful. IBM is aware of this problem but is in to hurry to fix it because of the workaround available. We don't know if the `-fno-exceptions` is required with `gcc 2.95`, but as MySQL doesn't use exceptions and the above option generates faster code, we recommend that you should always use this option with `egcs / gcc`.

If you get a problem with assembler code try changing the -mcpu=xxx to match your CPU. Typically power2, power, or powerpc may need to be used, alternatively you might need to use 604 or 604e. I'm not positive but I would think using "power" would likely be safe most of the time, even on a power2 machine.

If you don't know what your CPU is then do a "uname -m", this will give you back a string that looks like "000514676700", with a format of xxyyyyyymmss where xx and ss are always 0's, yyyyyy is a unique system ID and mm is the ID of the CPU Planar. A chart of these values can be found at `http://publib.boulder.ibm.com/doc_link/en_US/a_doc_`

`lib/cmds/aixcmds5/uname.htm`. This will give you a machine type and a machine model you can use to determine what type of CPU you have.

If you have problems with signals (MySQL dies unexpectedly under high load) you may have found an OS bug with threads and signals. In this case you can tell MySQL not to use signals by configuring with:

```
shell> CFLAGS=-DDONT_USE_THR_ALARM CXX=gcc \
       CXXFLAGS="-felide-constructors -fno-exceptions -fno-rtti \
       -DDONT_USE_THR_ALARM" \
       ./configure --prefix=/usr/local/mysql --with-debug --with-low-memory
```

This doesn't affect the performance of MySQL, but has the side effect that you can't kill clients that are "sleeping" on a connection with `mysqladmin kill` or `mysqladmin shutdown`. Instead, the client will die when it issues its next command.

On some versions of AIX, linking with `libbind.a` makes `getservbyname` core dump. This is an AIX bug and should be reported to IBM.

For AIX 4.2.1 and gcc you have to do the following changes.

After configuring, edit '`config.h`' and '`include/my_config.h`' and change the line that says

```
#define HAVE_SNPRINTF 1
```

to

```
#undef HAVE_SNPRINTF
```

And finally, in '`mysqld.cc`' you need to add a prototype for initgoups.

```
#ifdef _AIX41
extern "C" int initgroups(const char *,int);
#endif
```

If you need to allocate a lot of memory to the mysqld process, it's not enough to just set 'ulimit -d unlimited'. You may also have to set in `mysqld_safe` something like:

```
export LDR_CNTRL='MAXDATA=0x80000000'
```

You can find more about using a lot of memory at: `http://publib16.boulder.ibm.com/pseries/en_US/aixprggd/genprogc/lrg_prg_support.htm`.

2.6.6.5 SunOS 4 Notes

On SunOS 4, MIT-pthreads is needed to compile MySQL, which in turn means you will need GNU `make`.

Some SunOS 4 systems have problems with dynamic libraries and `libtool`. You can use the following `configure` line to avoid this problem:

```
shell> ./configure --disable-shared --with-mysqld-ldflags=-all-static
```

When compiling `readline`, you may get warnings about duplicate defines. These may be ignored.

When compiling `mysqld`, there will be some `implicit declaration of function` warnings. These may be ignored.

2.6.6.6 Alpha-DEC-UNIX Notes (Tru64)

If you are using egcs 1.1.2 on Digital Unix, you should upgrade to gcc 2.95.2, as egcs on DEC has some serious bugs!

When compiling threaded programs under Digital Unix, the documentation recommends using the `-pthread` option for `cc` and `cxx` and the libraries `-lmach -lexc` (in addition to `-lpthread`). You should run `configure` something like this:

```
CC="cc -pthread" CXX="cxx -pthread -O" \
./configure --with-named-thread-libs="-lpthread -lmach -lexc -lc"
```

When compiling `mysqld`, you may see a couple of warnings like this:

```
mysqld.cc: In function void handle_connections()':
mysqld.cc:626: passing long unsigned int *' as argument 3 of
accept(int,sockadddr *, int *)'
```

You can safely ignore these warnings. They occur because `configure` can detect only errors, not warnings.

If you start the server directly from the command-line, you may have problems with it dying when you log out. (When you log out, your outstanding processes receive a `SIGHUP` signal.) If so, try starting the server like this:

```
shell> nohup mysqld [options] &
```

`nohup` causes the command following it to ignore any `SIGHUP` signal sent from the terminal. Alternatively, start the server by running `mysqld_safe`, which invokes `mysqld` using `nohup` for you. See Section 4.8.2 [mysqld_safe], page 312.

If you get a problem when compiling mysys/get_opt.c, just remove the line #define _NO_PROTO from the start of that file!

If you are using Compaq's CC compiler, the following configure line should work:

```
CC="cc -pthread"
CFLAGS="-O4 -ansi_alias -ansi_args -fast -inline speed all -arch host"
CXX="cxx -pthread"
CXXFLAGS="-O4 -ansi_alias -ansi_args -fast -inline speed all -arch host \
-noexceptions -nortti"
export CC CFLAGS CXX CXXFLAGS
./configure \
--prefix=/usr/local/mysql \
--with-low-memory \
--enable-large-files \
--enable-shared=yes \
--with-named-thread-libs="-lpthread -lmach -lexc -lc"
gnumake
```

If you get a problem with libtool, when compiling with shared libraries as above, when linking `mysql`, you should be able to get around this by issuing:

```
cd mysql
/bin/sh ../libtool --mode=link cxx -pthread  -O3 -DDBUG_OFF \
-O4 -ansi_alias -ansi_args -fast -inline speed \
-speculate all \ -arch host  -DUNDEF_HAVE_GETHOSTBYNAME_R \
```

```
-o mysql  mysql.o readline.o sql_string.o completion_hash.o \
../readline/libreadline.a -lcurses \
../libmysql/.libs/libmysqlclient.so  -lm
cd ..
gnumake
gnumake install
scripts/mysql_install_db
```

2.6.6.7 Alpha-DEC-OSF/1 Notes

If you have problems compiling and have DEC `CC` and `gcc` installed, try running `configure` like this:

```
CC=cc CFLAGS=-O CXX=gcc CXXFLAGS=-O3 \
./configure --prefix=/usr/local/mysql
```

If you get problems with the '`c_asm.h`' file, you can create and use a 'dummy' '`c_asm.h`' file with:

```
touch include/c_asm.h
CC=gcc CFLAGS=-I./include \
CXX=gcc CXXFLAGS=-O3 \
./configure --prefix=/usr/local/mysql
```

Note that the following problems with the `ld` program can be fixed by downloading the latest DEC (Compaq) patch kit from: `http://ftp.support.compaq.com/public/unix/`.

On OSF/1 V4.0D and compiler "DEC C V5.6-071 on Digital Unix V4.0 (Rev. 878)" the compiler had some strange behaviour (undefined `asm` symbols). `/bin/ld` also appears to be broken (problems with `_exit undefined` errors occurring while linking `mysqld`). On this system, we have managed to compile MySQL with the following `configure` line, after replacing `/bin/ld` with the version from OSF 4.0C:

```
CC=gcc CXX=gcc CXXFLAGS=-O3 ./configure --prefix=/usr/local/mysql
```

With the Digital compiler "C++ V6.1-029", the following should work:

```
CC=cc -pthread
CFLAGS=-O4 -ansi_alias -ansi_args -fast -inline speed -speculate all \
       -arch host
CXX=cxx -pthread
CXXFLAGS=-O4 -ansi_alias -ansi_args -fast -inline speed -speculate all \
          -arch host -noexceptions -nortti
export CC CFLAGS CXX CXXFLAGS
./configure --prefix=/usr/mysql/mysql --with-mysqld-ldflags=-all-static \
            --disable-shared --with-named-thread-libs="-lmach -lexc -lc"
```

In some versions of OSF/1, the `alloca()` function is broken. Fix this by removing the line in '`config.h`' that defines '`HAVE_ALLOCA`'.

The `alloca()` function also may have an incorrect prototype in `/usr/include/alloca.h`. This warning resulting from this can be ignored.

`configure` will use the following thread libraries automatically: `--with-named-thread-libs="-lpthread -lmach -lexc -lc"`.

When using `gcc`, you can also try running `configure` like this:

```
shell> CFLAGS=-D_PTHREAD_USE_D4 CXX=gcc CXXFLAGS=-O3 ./configure ...
```

If you have problems with signals (MySQL dies unexpectedly under high load), you may have found an OS bug with threads and signals. In this case you can tell MySQL not to use signals by configuring with:

```
shell> CFLAGS=-DDONT_USE_THR_ALARM \
       CXXFLAGS=-DDONT_USE_THR_ALARM \
       ./configure ...
```

This doesn't affect the performance of MySQL, but has the side effect that you can't kill clients that are "sleeping" on a connection with `mysqladmin kill` or `mysqladmin shutdown`. Instead, the client will die when it issues its next command.

With `gcc` 2.95.2, you will probably run into the following compile error:

```
sql_acl.cc:1456: Internal compiler error in 'scan_region', at except.c:2566
Please submit a full bug report.
```

To fix this you should change to the `sql` directory and do a "cut and paste" of the last `gcc` line, but change `-O3` to `-O0` (or add `-O0` immediately after `gcc` if you don't have any `-O` option on your compile line). After this is done you can just change back to the top-level directly and run `make` again.

2.6.6.8 SGI Irix Notes

If you are using Irix Version 6.5.3 or newer `mysqld` will only be able to create threads if you run it as a user with `CAP_SCHED_MGT` privileges (like `root`) or give the `mysqld` server this privilege with the following shell command:

```
shell> chcap "CAP_SCHED_MGT+epi" /opt/mysql/libexec/mysqld
```

You may have to undefine some things in '`config.h`' after running `configure` and before compiling.

In some Irix implementations, the `alloca()` function is broken. If the `mysqld` server dies on some `SELECT` statements, remove the lines from '`config.h`' that define `HAVE_ALLOC` and `HAVE_ALLOCA_H`. If `mysqladmin create` doesn't work, remove the line from '`config.h`' that defines `HAVE_READDIR_R`. You may have to remove the `HAVE_TERM_H` line as well.

SGI recommends that you install all of the patches on this page as a set: `http://support.sgi.com/surfzone/patches/patchset/6.2_indigo.rps.html`

At the very minimum, you should install the latest kernel rollup, the latest `rld` rollup, and the latest `libc` rollup.

You definitely need all the POSIX patches on this page, for pthreads support:

`http://support.sgi.com/surfzone/patches/patchset/6.2_posix.rps.html`

If you get the something like the following error when compiling '`mysql.cc`':

```
"/usr/include/curses.h", line 82: error(1084): invalid combination of type
```

Type the following in the top-level directory of your MySQL source tree:

```
shell> extra/replace bool curses_bool < /usr/include/curses.h \
> include/curses.h
shell> make
```

There have also been reports of scheduling problems. If only one thread is running, things go slow. Avoid this by starting another client. This may lead to a 2-to-10-fold increase in execution speed thereafter for the other thread. This is a poorly understood problem with Irix threads; you may have to improvise to find solutions until this can be fixed.

If you are compiling with `gcc`, you can use the following `configure` command:

```
CC=gcc CXX=gcc CXXFLAGS=-O3 \
./configure --prefix=/usr/local/mysql --enable-thread-safe-client \
--with-named-thread-libs=-lpthread
```

On Irix 6.5.11 with native Irix C and C++ compilers ver. 7.3.1.2, the following is reported to work

```
CC=cc CXX=CC CFLAGS='-O3 -n32 -TARG:platform=IP22 -I/usr/local/include \
-L/usr/local/lib' CXXFLAGS='-O3 -n32 -TARG:platform=IP22 \
-I/usr/local/include -L/usr/local/lib' ./configure \
--prefix=/usr/local/mysql --with-innodb --with-berkeley-db \
--with-libwrap=/usr/local \
--with-named-curses-libs=/usr/local/lib/libncurses.a
```

2.6.6.9 SCO Notes

The current port is tested only on "sco3.2v5.0.5", "sco3.2v5.0.6" and "sco3.2v5.0.7" systems. There has also been a lot of progress on a port to "sco 3.2v4.2".

For the moment the recommended compiler on OpenServer is gcc 2.95.2. With this you should be able to compile MySQL with just:

```
CC=gcc CXX=gcc ./configure ... (options)
```

1. For OpenServer 5.0.x you need to use gcc-2.95.2p1 or newer from the Skunkware. `http://www.sco.com/skunkware/` and choose browser OpenServer packages or by ftp to ftp2.caldera.com in the pub/skunkware/osr5/devtools/gcc directory.
2. You need the port of GCC 2.5.x for this product and the Development system. They are required on this version of SCO Unix. You cannot just use the GCC Dev system.
3. You should get the FSU Pthreads package and install it first. This can be found at `http://moss.csc.ncsu.edu/~mueller/ftp/pub/PART/pthreads.tar.gz`. You can also get a precompiled package from `http://www.mysql.com/Downloads/SCO/FSU-threads-3.5c.tar.gz`
4. FSU Pthreads can be compiled with SCO Unix 4.2 with tcpip. Or OpenServer 3.0 or Open Desktop 3.0 (OS 3.0 ODT 3.0), with the SCO Development System installed using a good port of GCC 2.5.x ODT or OS 3.0 you will need a good port of GCC 2.5.x There are a lot of problems without a good port. The port for this product requires the SCO Unix Development system. Without it, you are missing the libraries and the linker that is needed.
5. To build FSU Pthreads on your system, do the following:
   1. Run `./configure` in the '`threads/src`' directory and select the SCO OpenServer option. This command copies '`Makefile.SCO5`' to '`Makefile`'.
   2. Run `make`.
   3. To install in the default '`/usr/include`' directory, login as root, then `cd` to the '`thread/src`' directory, and run `make install`.

6. Remember to use GNU `make` when making MySQL.
7. If you don't start `mysqld_safe` as `root`, you probably will get only the default 110 open files per process. `mysqld` will write a note about this in the log file.
8. With SCO 3.2V5.0.5, you should use FSU Pthreads version 3.5c or newer. You should also use gcc 2.95.2 or newer!

   The following `configure` command should work:

   ```
   shell> ./configure --prefix=/usr/local/mysql --disable-shared
   ```
9. With SCO 3.2V4.2, you should use FSU Pthreads version 3.5c or newer. The following `configure` command should work:

   ```
   shell> CFLAGS="-D_XOPEN_XPG4" CXX=gcc CXXFLAGS="-D_XOPEN_XPG4" \
          ./configure \
              --prefix=/usr/local/mysql \
              --with-named-thread-libs="-lgthreads -lsocket -lgen -lgthreads" \
              --with-named-curses-libs="-lcurses"
   ```

   You may get some problems with some include files. In this case, you can find new SCO-specific include files at `http://www.mysql.com/Downloads/SCO/SCO-3.2v4.2-includes.tar.gz`. You should unpack this file in the '`include`' directory of your MySQL source tree.

SCO development notes:

- MySQL should automatically detect FSU Pthreads and link `mysqld` with `-lgthreads -lsocket -lgthreads`.
- The SCO development libraries are re-entrant in FSU Pthreads. SCO claim's that its libraries' functions are re-entrant, so they must be reentrant with FSU Pthreads. FSU Pthreads on OpenServer tries to use the SCO scheme to make re-entrant libraries.
- FSU Pthreads (at least the version at `http://www.mysql.com/`) comes linked with GNU `malloc`. If you encounter problems with memory usage, make sure that '`gmalloc.o`' is included in '`libgthreads.a`' and '`libgthreads.so`'.
- In FSU Pthreads, the following system calls are pthreads-aware: `read()`, `write()`, `getmsg()`, `connect()`, `accept()`, `select()`, and `wait()`.
- The CSSA-2001-SCO.35.2 (the patch is listed in custom as erg711905-dscr_remap security patch (version 2.0.0) breaks FSU threads and makes mysqld unstable. You have to remove this one if you want to run mysqld on an OpenServer 5.0.6 machine.
- SCO provides Operating Systems Patches at `ftp://ftp.sco.com/pub/openserver5` for OpenServer 5.0.x
- SCO provides secruity fixes and libsocket.so.2 at `ftp://ftp.sco.com/pub/security/OpenServer` and `ftp://ftp.sco.com/pub/security/sse` for OpenServer 5.0.x
- pre-OSR506 security fixes. Also, the telnetd fix at `ftp://stage.caldera.com/pub/security/openserver` or `ftp://stage.caldera.com/pub/security/openserver/CSSA-2001-SCO.10/` as both libsocket.so.2 and libresolv.so.1 with instructions for installing on pre-OSR506 systems.

  It's probably a good idea to install the above patches before trying to compile/use MySQL.

If you want to install DBI on SCO, you have to edit the '`Makefile`' in DBI-xxx and each subdirectory.

Note that the following assumes gcc 2.95.2 or newer:

```
OLD:                                    NEW:
CC = cc                                 CC = gcc
CCCDLFLAGS = -KPIC -W1,-Bexport         CCCDLFLAGS = -fpic
CCDLFLAGS = -wl,-Bexport                CCDLFLAGS =

LD = ld                                 LD = gcc -G -fpic
LDDLFLAGS = -G -L/usr/local/lib         LDDLFLAGS = -L/usr/local/lib
LDFLAGS = -belf -L/usr/local/lib        LDFLAGS = -L/usr/local/lib

LD = ld                                 LD = gcc -G -fpic
OPTIMISE = -Od                          OPTIMISE = -O1

OLD:
CCCFLAGS = -belf -dy -w0 -U M_XENIX -DPERL_SCO5 -I/usr/local/include

NEW:
CCFLAGS = -U M_XENIX -DPERL_SCO5 -I/usr/local/include
```

This is because the Perl dynaloader will not load the `DBI` modules if they were compiled with `icc` or `cc`.

Perl works best when compiled with `cc`.

2.6.6.10 SCO UnixWare Version 7.1.x Notes

You must use a version of MySQL at least as recent as Version 3.22.13 and of UnixWare 7.1.0 because these version fixes some portability and OS problems under UnixWare.

We have been able to compile MySQL with the following `configure` command on UnixWare Version 7.1.x:

```
CC=cc CXX=CC ./configure --prefix=/usr/local/mysql
```

If you want to use `gcc`, you must use `gcc` 2.95.2 or newer.

```
CC=gcc CXX=g++ ./configure --prefix=/usr/local/mysql
```

1. SCO provides Operating Systems Patches at `ftp://ftp.sco.com/pub/unixware7` for UnixWare 7.1.1 and 7.1.3 `ftp://ftp.sco.com/pub/openunix8` for OpenUNIX 8.0.0
2. SCO provides information about Security Fixes at `ftp://ftp.sco.com/pub/security/OpenUNIX` for OpenUNIX `ftp://ftp.sco.com/pub/security/UnixWare` for UnixWare

2.6.7 OS/2 Notes

MySQL uses quite a few open files. Because of this, you should add something like the following to your '`CONFIG.SYS`' file:

```
SET EMXOPT=-c -n -h1024
```

If you don't do this, you will probably run into the following error:

```
File 'xxxx' not found (Errcode: 24)
```

When using MySQL with OS/2 Warp 3, FixPack 29 or above is required. With OS/2 Warp 4, FixPack 4 or above is required. This is a requirement of the Pthreads library. MySQL must be installed in a partition that supports long filenames such as HPFS, FAT32, etc.

The '`INSTALL.CMD`' script must be run from OS/2's own '`CMD.EXE`' and may not work with replacement shells such as '`4OS2.EXE`'.

The '`scripts/mysql-install-db`' script has been renamed. It is now called '`install.cmd`' and is a REXX script, which will set up the default MySQL security settings and create the WorkPlace Shell icons for MySQL.

Dynamic module support is compiled in but not fully tested. Dynamic modules should be compiled using the Pthreads run-time library.

```
gcc -Zdll -Zmt -Zcrtdll=pthrdrtl -I../include -I../regex -I.. \
    -o example udf_example.cc -L../lib -lmysqlclient udf_example.def
mv example.dll example.udf
```

Note: Due to limitations in OS/2, UDF module name stems must not exceed 8 characters. Modules are stored in the '`/mysql2/udf`' directory; the `safe-mysqld.cmd` script will put this directory in the `BEGINLIBPATH` environment variable. When using UDF modules, specified extensions are ignored—it is assumed to be '`.udf`'. For example, in Unix, the shared module might be named '`example.so`' and you would load a function from it like this:

```
mysql> CREATE FUNCTION metaphon RETURNS STRING SONAME "example.so";
```

In OS/2, the module would be named '`example.udf`', but you would not specify the module extension:

```
mysql> CREATE FUNCTION metaphon RETURNS STRING SONAME "example";
```

2.6.8 Novell NetWare Notes

Porting `MySQL` to `NetWare` was an effort spearheaded by `Novell`. Novell customers will be pleased to note that NetWare 6.5 will ship with bundled MySQL binaries, complete with an automatic commercial use license for all servers running that version of NetWare.

See Section 2.1.4 [NetWare installation], page 69.

MySQL for NetWare is compiled using a combination of `Metrowerks Codewarrior for NetWare` and special cross-compilation versions of the GNU autotools. Check back here in the future for more information on building and optimising MySQL for NetWare.

2.6.9 BeOS Notes

We have in the past talked with some BeOS developers that have said that MySQL is 80% ported to BeOS, but we haven't heard from them in a while.

2.7 Perl Installation Comments

2.7.1 Installing Perl on Unix

Perl support for MySQL is provided by means of the `DBI/DBD` client interface. See Section 11.5 [Perl], page 816. The Perl `DBD/DBI` client code requires Perl Version 5.004 or later. The interface **will not work** if you have an older version of Perl.

MySQL Perl support also requires that you've installed MySQL client programming support. If you installed MySQL from RPM files, client programs are in the client RPM, but client programming support is in the developer RPM. Make sure you've installed the latter RPM.

As of Version 3.22.8, Perl support is distributed separately from the main MySQL distribution. If you want to install Perl support, the files you will need can be obtained from `http://www.mysql.com/downloads/api-dbi.html`.

The Perl distributions are provided as compressed `tar` archives and have names like '`MODULE-VERSION.tar.gz`', where `MODULE` is the module name and `VERSION` is the version number. You should get the `Data-Dumper`, `DBI`, and `DBD-mysql` distributions and install them in that order. The installation procedure is shown here. The example shown is for the `Data-Dumper` module, but the procedure is the same for all three distributions:

1. Unpack the distribution into the current directory:

   ```
   shell> gunzip < Data-Dumper-VERSION.tar.gz | tar xvf -
   ```

   This command creates a directory named '`Data-Dumper-VERSION`'.

2. Change into the top-level directory of the unpacked distribution:

   ```
   shell> cd Data-Dumper-VERSION
   ```

3. Build the distribution and compile everything:

   ```
   shell> perl Makefile.PL
   shell> make
   shell> make test
   shell> make install
   ```

The `make test` command is important because it verifies that the module is working. Note that when you run that command during the `DBD-mysql` installation to exercise the interface code, the MySQL server must be running or the test will fail.

It is a good idea to rebuild and reinstall the `DBD-mysql` distribution whenever you install a new release of MySQL, particularly if you notice symptoms such as all your `DBI` scripts dumping core after you upgrade MySQL.

If you don't have the right to install Perl modules in the system directory or if you to install local Perl modules, the following reference may help you:

```
http://servers.digitaldaze.com/extensions/perl/modules.html#modules
```

Look under the heading `Installing New Modules that Require Locally Installed Modules`.

2.7.2 Installing ActiveState Perl on Windows

To install the MySQL `DBD` module with ActiveState Perl on Windows, you should do the following:

- Get ActiveState Perl from `http://www.activestate.com/Products/ActivePerl/` and install it.
- Open a DOS shell.
- If required, set the HTTP_proxy variable. For example, you might try:

```
set HTTP_proxy=my.proxy.com:3128
```

- Start the PPM program:

```
C:\> c:\perl\bin\ppm.pl
```

- If you have not already done so, install `DBI`:

```
ppm> install DBI
```

- If this succeeds, run the following command:

```
install \
ftp://ftp.de.uu.net/pub/CPAN/authors/id/JWIED/DBD-mysql-1.2212.x86.ppd
```

The above should work at least with ActiveState Perl Version 5.6.

If you can't get the above to work, you should instead install the `MyODBC` driver and connect to MySQL server through ODBC:

```
use DBI;
$dbh= DBI->connect("DBI:ODBC:$dsn","$user","$password") ||
  die "Got error $DBI::errstr when connecting to $dsn\n";
```

2.7.3 Problems Using the Perl `DBI/DBD` Interface

If Perl reports that it can't find the '`../mysql/mysql.so`' module, then the problem is probably that Perl can't locate the shared library '`libmysqlclient.so`'.

You can fix this by any of the following methods:

- Compile the `DBD-mysql` distribution with `perl Makefile.PL -static -config` rather than `perl Makefile.PL`.
- Copy '`libmysqlclient.so`' to the directory where your other shared libraries are located (probably '`/usr/lib`' or '`/lib`').
- On Linux you can add the pathname of the directory where '`libmysqlclient.so`' is located to the '`/etc/ld.so.conf`' file.
- Add the pathname of the directory where '`libmysqlclient.so`' is located to the `LD_RUN_PATH` environment variable.

If you get the following errors from `DBD-mysql`, you are probably using `gcc` (or using an old binary compiled with `gcc`):

```
/usr/bin/perl: can't resolve symbol '__moddi3'
/usr/bin/perl: can't resolve symbol '__divdi3'
```

Add `-L/usr/lib/gcc-lib/... -lgcc` to the link command when the '`mysql.so`' library gets built (check the output from `make` for '`mysql.so`' when you compile the Perl client). The `-L` option should specify the pathname of the directory where '`libgcc.a`' is located on your system.

Another cause of this problem may be that Perl and MySQL aren't both compiled with `gcc`. In this case, you can solve the mismatch by compiling both with `gcc`.

If you get the following error from DBD-mysql when you run the tests:

```
t/00base.............install_driver(mysql) failed:
Can't load '../blib/arch/auto/DBD/mysql/mysql.so' for module DBD::mysql:
../blib/arch/auto/DBD/mysql/mysql.so: undefined symbol:
uncompress at /usr/lib/perl5/5.00503/i586-linux/DynaLoader.pm line 169.
```

it means that you need to include the compression library, -lz, to the link line. This can be doing the following change in the file 'lib/DBD/mysql/Install.pm':

```
$sysliblist .= " -lm";

to

$sysliblist .= " -lm -lz";
```

After this, you **must** run 'make realclean' and then proceed with the installation from the beginning.

If you want to use the Perl module on a system that doesn't support dynamic linking (like SCO) you can generate a static version of Perl that includes DBI and DBD-mysql. The way this works is that you generate a version of Perl with the DBI code linked in and install it on top of your current Perl. Then you use that to build a version of Perl that additionally has the DBD code linked in, and install that.

On SCO, you must have the following environment variables set:

```
shell> LD_LIBRARY_PATH=/lib:/usr/lib:/usr/local/lib:/usr/progressive/lib
or
shell> LD_LIBRARY_PATH=/usr/lib:/lib:/usr/local/lib:/usr/ccs/lib:\
/usr/progressive/lib:/usr/skunk/lib
shell> LIBPATH=/usr/lib:/lib:/usr/local/lib:/usr/ccs/lib:\
/usr/progressive/lib:/usr/skunk/lib
shell> MANPATH=scohelp:/usr/man:/usr/local1/man:/usr/local/man:\
/usr/skunk/man:
```

First, create a Perl that includes a statically linked DBI by running these commands in the directory where your DBI distribution is located:

```
shell> perl Makefile.PL -static -config
shell> make
shell> make install
shell> make perl
```

Then you must install the new Perl. The output of `make perl` will indicate the exact `make` command you will need to execute to perform the installation. On SCO, this is `make -f Makefile.aperl inst_perl MAP_TARGET=perl`.

Next, use the just-created Perl to create another Perl that also includes a statically-linked DBD::mysql by running these commands in the directory where your DBD-mysql distribution is located:

```
shell> perl Makefile.PL -static -config
shell> make
shell> make install
shell> make perl
```

Finally, you should install this new Perl. Again, the output of `make perl` indicates the command to use.

3 MySQL Tutorial

This chapter provides a tutorial introduction to MySQL by showing how to use the `mysql` client program to create and use a simple database. `mysql` (sometimes referred to as the "terminal monitor" or just "monitor") is an interactive program that allows you to connect to a MySQL server, run queries, and view the results. `mysql` may also be used in batch mode: you place your queries in a file beforehand, then tell `mysql` to execute the contents of the file. Both ways of using `mysql` are covered here.

To see a list of options provided by `mysql`, invoke it with the `--help` option:

```
shell> mysql --help
```

This chapter assumes that `mysql` is installed on your machine and that a MySQL server is available to which you can connect. If this is not true, contact your MySQL administrator. (If **you** are the administrator, you will need to consult other sections of this manual.)

This chapter describes the entire process of setting up and using a database. If you are interested only in accessing an already-existing database, you may want to skip over the sections that describe how to create the database and the tables it contains.

Because this chapter is tutorial in nature, many details are necessarily omitted. Consult the relevant sections of the manual for more information on the topics covered here.

3.1 Connecting to and Disconnecting from the Server

To connect to the server, you'll usually need to provide a MySQL user name when you invoke `mysql` and, most likely, a password. If the server runs on a machine other than the one where you log in, you'll also need to specify a hostname. Contact your administrator to find out what connection parameters you should use to connect (that is, what host, user name, and password to use). Once you know the proper parameters, you should be able to connect like this:

```
shell> mysql -h host -u user -p
Enter password: ********
```

The `********` represents your password; enter it when `mysql` displays the `Enter password:` prompt.

If that works, you should see some introductory information followed by a `mysql>` prompt:

```
shell> mysql -h host -u user -p
Enter password: ********
Welcome to the MySQL monitor.  Commands end with ; or \g.
Your MySQL connection id is 25338 to server version: 4.0.14-log

Type 'help;' or '\h' for help. Type '\c' to clear the buffer.

mysql>
```

The prompt tells you that `mysql` is ready for you to enter commands.

Some MySQL installations allow users to connect as the anonymous (unnamed) user to the server running on the local host. If this is the case on your machine, you should be able to connect to that server by invoking `mysql` without any options:

```
shell> mysql
```

After you have connected successfully, you can disconnect any time by typing `QUIT` (or `\q`) at the `mysql>` prompt:

```
mysql> QUIT
Bye
```

On Unix, you can also disconnect by pressing Control-D.

Most examples in the following sections assume you are connected to the server. They indicate this by the `mysql>` prompt.

3.2 Entering Queries

Make sure you are connected to the server, as discussed in the previous section. Doing so will not in itself select any database to work with, but that's okay. At this point, it's more important to find out a little about how to issue queries than to jump right in creating tables, loading data into them, and retrieving data from them. This section describes the basic principles of entering commands, using several queries you can try out to familiarise yourself with how `mysql` works.

Here's a simple command that asks the server to tell you its version number and the current date. Type it in as shown here following the `mysql>` prompt and press Enter:

```
mysql> SELECT VERSION(), CURRENT_DATE;
+--------------+--------------+
| VERSION()    | CURRENT_DATE |
+--------------+--------------+
| 3.22.20a-log | 1999-03-19   |
+--------------+--------------+
1 row in set (0.01 sec)
mysql>
```

This query illustrates several things about `mysql`:

- A command normally consists of an SQL statement followed by a semicolon. (There are some exceptions where a semicolon may be omitted. `QUIT`, mentioned earlier, is one of them. We'll get to others later.)
- When you issue a command, `mysql` sends it to the server for execution and displays the results, then prints another `mysql>` prompt to indicate that it is ready for another command.
- `mysql` displays query output in tabular form (rows and columns). The first row contains labels for the columns. The rows following are the query results. Normally, column labels are the names of the columns you fetch from database tables. If you're retrieving the value of an expression rather than a table column (as in the example just shown), `mysql` labels the column using the expression itself.
- `mysql` shows how many rows were returned and how long the query took to execute, which gives you a rough idea of server performance. These values are imprecise because they represent wall clock time (not CPU or machine time), and because they are affected by factors such as server load and network latency. (For brevity, the "rows in set" line is not shown in the remaining examples in this chapter.)

Keywords may be entered in any lettercase. The following queries are equivalent:

```
mysql> SELECT VERSION(), CURRENT_DATE;
mysql> select version(), current_date;
mysql> SeLeCt vErSiOn(), current_DATE;
```

Here's another query. It demonstrates that you can use `mysql` as a simple calculator:

```
mysql> SELECT SIN(PI()/4), (4+1)*5;
+-------------+---------+
| SIN(PI()/4) | (4+1)*5 |
+-------------+---------+
|    0.707107 |      25 |
+-------------+---------+
```

The queries shown thus far have been relatively short, single-line statements. You can even enter multiple statements on a single line. Just end each one with a semicolon:

```
mysql> SELECT VERSION(); SELECT NOW();
+--------------+
| VERSION()    |
+--------------+
| 3.22.20a-log |
+--------------+

+---------------------+
| NOW()               |
+---------------------+
| 1999-03-19 00:15:33 |
+---------------------+
```

A command need not be given all on a single line, so lengthy commands that require several lines are not a problem. `mysql` determines where your statement ends by looking for the terminating semicolon, not by looking for the end of the input line. (In other words, `mysql` accepts free-format input: it collects input lines but does not execute them until it sees the semicolon.)

Here's a simple multiple-line statement:

```
mysql> SELECT
    -> USER()
    -> ,
    -> CURRENT_DATE;
+--------------------+--------------+
| USER()             | CURRENT_DATE |
+--------------------+--------------+
| joesmith@localhost | 1999-03-18   |
+--------------------+--------------+
```

In this example, notice how the prompt changes from `mysql>` to `->` after you enter the first line of a multiple-line query. This is how `mysql` indicates that it hasn't seen a complete statement and is waiting for the rest. The prompt is your friend, because it provides valuable feedback. If you use that feedback, you will always be aware of what `mysql` is waiting for.

If you decide you don't want to execute a command that you are in the process of entering, cancel it by typing `\c`:

```
mysql> SELECT
    -> USER()
    -> \c
mysql>
```

Here, too, notice the prompt. It switches back to `mysql>` after you type `\c`, providing feedback to indicate that `mysql` is ready for a new command.

The following table shows each of the prompts you may see and summarises what they mean about the state that `mysql` is in:

Prompt	Meaning
`mysql>`	Ready for new command.
`->`	Waiting for next line of multiple-line command.
`'>`	Waiting for next line, collecting a string that begins with a single quote (“'”).
`">`	Waiting for next line, collecting a string that begins with a double quote (“"”).
`` `> ``	Waiting for next line, collecting an identifier that begins with a backtick (“`”).

Multiple-line statements commonly occur by accident when you intend to issue a command on a single line, but forget the terminating semicolon. In this case, `mysql` waits for more input:

```
mysql> SELECT USER()
    ->
```

If this happens to you (you think you've entered a statement but the only response is a `->` prompt), most likely `mysql` is waiting for the semicolon. If you don't notice what the prompt is telling you, you might sit there for a while before realising what you need to do. Enter a semicolon to complete the statement, and `mysql` will execute it:

```
mysql> SELECT USER()
    -> ;
+--------------------+
| USER()             |
+--------------------+
| joesmith@localhost |
+--------------------+
```

The `'>` and `">` prompts occur during string collection. In MySQL, you can write strings surrounded by either “'” or “"” characters (for example, `'hello'` or `"goodbye"`), and `mysql` lets you enter strings that span multiple lines. When you see a `'>` or `">` prompt, it means that you've entered a line containing a string that begins with a “'” or “"” quote character, but have not yet entered the matching quote that terminates the string. That's fine if you really are entering a multiple-line string, but how likely is that? Not very. More often, the `'>` and `">` prompts indicate that you've inadvertantly left out a quote character. For example:

```
mysql> SELECT * FROM my_table WHERE name = "Smith AND age < 30;
    ">
```

If you enter this `SELECT` statement, then press Enter and wait for the result, nothing will happen. Instead of wondering why this query takes so long, notice the clue provided by the `">` prompt. It tells you that `mysql` expects to see the rest of an unterminated string. (Do you see the error in the statement? The string `"Smith` is missing the second quote.)

At this point, what do you do? The simplest thing is to cancel the command. However, you cannot just type `\c` in this case, because `mysql` interprets it as part of the string that it is collecting! Instead, enter the closing quote character (so `mysql` knows you've finished the string), then type `\c`:

```
mysql> SELECT * FROM my_table WHERE name = "Smith AND age < 30;
    "> "\c
mysql>
```

The prompt changes back to `mysql>`, indicating that `mysql` is ready for a new command.

The `‘>` prompt is similar to th `’>` and `">` prompts, but indicates that you have begun but not completed a backtick-quoted identifier.

It's important to know what the `’>`, `">`, and `‘>` prompts signify, because if you mistakenly enter an unterminated string, any further lines you type will appear to be ignored by `mysql`—including a line containing `QUIT`! This can be quite confusing, especially if you don't know that you need to supply the terminating quote before you can cancel the current command.

3.3 Creating and Using a Database

Now that you know how to enter commands, it's time to access a database.

Suppose you have several pets in your home (your menagerie) and you'd like to keep track of various types of information about them. You can do so by creating tables to hold your data and loading them with the desired information. Then you can answer different sorts of questions about your animals by retrieving data from the tables. This section shows you how to:

- Create a database
- Create a table
- Load data into the table
- Retrieve data from the table in various ways
- Use multiple tables

The menagerie database will be simple (deliberately), but it is not difficult to think of real-world situations in which a similar type of database might be used. For example, a database like this could be used by a farmer to keep track of livestock, or by a veterinarian to keep track of patient records. A menagerie distribution containing some of the queries and sample data used in the following sections can be obtained from the MySQL web site. It's available in either compressed `tar` format (`http://www.mysql.com/Downloads/Contrib/Examples/menagerie.tar.gz`) or Zip format (`http://www.mysql.com/Downloads/Contrib/Examples/menagerie.zip`).

Use the `SHOW` statement to find out what databases currently exist on the server:

```
mysql> SHOW DATABASES;
+----------+
| Database |
+----------+
| mysql    |
| test     |
| tmp      |
+----------+
```

The list of databases is probably different on your machine, but the `mysql` and `test` databases are likely to be among them. The `mysql` database is required because it describes user access privileges. The `test` database is often provided as a workspace for users to try things out.

Note that you may not see all databases if you don't have the `SHOW DATABASES` privilege. See Section 4.4.1 [GRANT], page 239.

If the `test` database exists, try to access it:

```
mysql> USE test
Database changed
```

Note that `USE`, like `QUIT`, does not require a semicolon. (You can terminate such statements with a semicolon if you like; it does no harm.) The `USE` statement is special in another way, too: it must be given on a single line.

You can use the `test` database (if you have access to it) for the examples that follow, but anything you create in that database can be removed by anyone else with access to it. For this reason, you should probably ask your MySQL administrator for permission to use a database of your own. Suppose you want to call yours `menagerie`. The administrator needs to execute a command like this:

```
mysql> GRANT ALL ON menagerie.* TO 'your_mysql_name'@'your_client_host';
```

where `your_mysql_name` is the MySQL user name assigned to you and `your_client_host` is the host from which you connect to the server.

3.3.1 Creating and Selecting a Database

If the administrator creates your database for you when setting up your permissions, you can begin using it. Otherwise, you need to create it yourself:

```
mysql> CREATE DATABASE menagerie;
```

Under Unix, database names are case-sensitive (unlike SQL keywords), so you must always refer to your database as `menagerie`, not as `Menagerie`, `MENAGERIE`, or some other variant. This is also true for table names. (Under Windows, this restriction does not apply, although you must refer to databases and tables using the same lettercase throughout a given query.)

Creating a database does not select it for use; you must do that explicitly. To make `menagerie` the current database, use this command:

```
mysql> USE menagerie
Database changed
```

Your database needs to be created only once, but you must select it for use each time you begin a `mysql` session. You can do this by issuing a `USE` statement as shown in the example.

Alternatively, you can select the database on the command-line when you invoke `mysql`. Just specify its name after any connection parameters that you might need to provide. For example:

```
shell> mysql -h host -u user -p menagerie
Enter password: ********
```

Note that `menagerie` is not your password on the command just shown. If you want to supply your password on the command-line after the `-p` option, you must do so with no intervening space (for example, as `-pmypassword`, not as `-p mypassword`). However, putting your password on the command-line is not recommended, because doing so exposes it to snooping by other users logged in on your machine.

3.3.2 Creating a Table

Creating the database is the easy part, but at this point it's empty, as `SHOW TABLES` will tell you:

```
mysql> SHOW TABLES;
Empty set (0.00 sec)
```

The harder part is deciding what the structure of your database should be: what tables you will need and what columns will be in each of them.

You'll want a table that contains a record for each of your pets. This can be called the `pet` table, and it should contain, as a bare minimum, each animal's name. Because the name by itself is not very interesting, the table should contain other information. For example, if more than one person in your family keeps pets, you might want to list each animal's owner. You might also want to record some basic descriptive information such as species and sex.

How about age? That might be of interest, but it's not a good thing to store in a database. Age changes as time passes, which means you'd have to update your records often. Instead, it's better to store a fixed value such as date of birth. Then, whenever you need age, you can calculate it as the difference between the current date and the birth date. MySQL provides functions for doing date arithmetic, so this is not difficult. Storing birth date rather than age has other advantages, too:

- You can use the database for tasks such as generating reminders for upcoming pet birthdays. (If you think this type of query is somewhat silly, note that it is the same question you might ask in the context of a business database to identify clients to whom you'll soon need to send out birthday greetings, for that computer-assisted personal touch.)
- You can calculate age in relation to dates other than the current date. For example, if you store death date in the database, you can easily calculate how old a pet was when it died.

You can probably think of other types of information that would be useful in the `pet` table, but the ones identified so far are sufficient for now: name, owner, species, sex, birth, and death.

Use a `CREATE TABLE` statement to specify the layout of your table:

```
mysql> CREATE TABLE pet (name VARCHAR(20), owner VARCHAR(20),
    -> species VARCHAR(20), sex CHAR(1), birth DATE, death DATE);
```

VARCHAR is a good choice for the name, owner, and species columns because the column values will vary in length. The lengths of those columns need not all be the same, and need not be 20. You can pick any length from 1 to 255, whatever seems most reasonable to you. (If you make a poor choice and it turns out later that you need a longer field, MySQL provides an ALTER TABLE statement.)

Several types of values can be chosen to represent sex in animal records, such as "m" and "f", or perhaps "male" and "female". It's simplest to use the single characters "m" and "f".

The use of the DATE datatype for the birth and death columns is a fairly obvious choice.

Now that you have created a table, SHOW TABLES should produce some output:

```
mysql> SHOW TABLES;
+----------------------+
| Tables in menagerie |
+----------------------+
| pet                  |
+----------------------+
```

To verify that your table was created the way you expected, use a DESCRIBE statement:

```
mysql> DESCRIBE pet;
+---------+-------------+------+-----+---------+-------+
| Field   | Type        | Null | Key | Default | Extra |
+---------+-------------+------+-----+---------+-------+
| name    | varchar(20) | YES  |     | NULL    |       |
| owner   | varchar(20) | YES  |     | NULL    |       |
| species | varchar(20) | YES  |     | NULL    |       |
| sex     | char(1)     | YES  |     | NULL    |       |
| birth   | date        | YES  |     | NULL    |       |
| death   | date        | YES  |     | NULL    |       |
+---------+-------------+------+-----+---------+-------+
```

You can use DESCRIBE any time, for example, if you forget the names of the columns in your table or what types they have.

3.3.3 Loading Data into a Table

After creating your table, you need to populate it. The LOAD DATA and INSERT statements are useful for this.

Suppose your pet records can be described as shown here. (Observe that MySQL expects dates in 'YYYY-MM-DD' format; this may be different from what you are used to.)

name	owner	species	sex	birth	death
Fluffy	Harold	cat	f	1993-02-04	
Claws	Gwen	cat	m	1994-03-17	
Buffy	Harold	dog	f	1989-05-13	
Fang	Benny	dog	m	1990-08-27	

Bowser	Diane	dog	m	1979-08-31	1995-07-29
Chirpy	Gwen	bird	f	1998-09-11	
Whistler	Gwen	bird		1997-12-09	
Slim	Benny	snake	m	1996-04-29	

Because you are beginning with an empty table, an easy way to populate it is to create a text file containing a row for each of your animals, then load the contents of the file into the table with a single statement.

You could create a text file '`pet.txt`' containing one record per line, with values separated by tabs, and given in the order in which the columns were listed in the `CREATE TABLE` statement. For missing values (such as unknown sexes or death dates for animals that are still living), you can use `NULL` values. To represent these in your text file, use `\N` (backslash, capital-N). For example, the record for Whistler the bird would look like this (where the whitespace between values is a single tab character):

name	**owner**	**species**	**sex**	**birth**	**death**
`Whistler`	`Gwen`	`bird`	`\N`	`1997-12-09`	`\N`

To load the text file '`pet.txt`' into the `pet` table, use this command:

```
mysql> LOAD DATA LOCAL INFILE "pet.txt" INTO TABLE pet;
```

You can specify the column value separator and end of line marker explicitly in the `LOAD DATA` statement if you wish, but the defaults are tab and linefeed. These are sufficient for the statement to read the file '`pet.txt`' properly.

If the statement fails, it is likely that your MySQL installation does not have local file capability enabled by default. See Section 4.3.4 [`LOAD DATA LOCAL`], page 218 for information on how to change this.

When you want to add new records one at a time, the `INSERT` statement is useful. In its simplest form, you supply values for each column, in the order in which the columns were listed in the `CREATE TABLE` statement. Suppose Diane gets a new hamster named Puffball. You could add a new record using an `INSERT` statement like this:

```
mysql> INSERT INTO pet
    -> VALUES ('Puffball','Diane','hamster','f','1999-03-30',NULL);
```

Note that string and date values are specified as quoted strings here. Also, with `INSERT`, you can insert `NULL` directly to represent a missing value. You do not use `\N` like you do with `LOAD DATA`.

From this example, you should be able to see that there would be a lot more typing involved to load your records initially using several `INSERT` statements rather than a single `LOAD DATA` statement.

3.3.4 Retrieving Information from a Table

The `SELECT` statement is used to pull information from a table. The general form of the statement is:

```
SELECT what_to_select
FROM which_table
WHERE conditions_to_satisfy;
```

`what_to_select` indicates what you want to see. This can be a list of columns, or `*` to indicate "all columns." `which_table` indicates the table from which you want to retrieve data. The `WHERE` clause is optional. If it's present, `conditions_to_satisfy` specifies conditions that rows must satisfy to qualify for retrieval.

3.3.4.1 Selecting All Data

The simplest form of `SELECT` retrieves everything from a table:

```
mysql> SELECT * FROM pet;
+----------+--------+---------+------+------------+------------+
| name     | owner  | species | sex  | birth      | death      |
+----------+--------+---------+------+------------+------------+
| Fluffy   | Harold | cat     | f    | 1993-02-04 | NULL       |
| Claws    | Gwen   | cat     | m    | 1994-03-17 | NULL       |
| Buffy    | Harold | dog     | f    | 1989-05-13 | NULL       |
| Fang     | Benny  | dog     | m    | 1990-08-27 | NULL       |
| Bowser   | Diane  | dog     | m    | 1979-08-31 | 1995-07-29 |
| Chirpy   | Gwen   | bird    | f    | 1998-09-11 | NULL       |
| Whistler | Gwen   | bird    | NULL | 1997-12-09 | NULL       |
| Slim     | Benny  | snake   | m    | 1996-04-29 | NULL       |
| Puffball | Diane  | hamster | f    | 1999-03-30 | NULL       |
+----------+--------+---------+------+------------+------------+
```

This form of `SELECT` is useful if you want to review your entire table, for instance, after you've just loaded it with your initial dataset. For example, you may happen to think that the birth date for Bowser doesn't seem quite right. Consulting your original pedigree papers, you find that the correct birth year should be 1989, not 1979.

There are least a couple of ways to fix this:

- Edit the file '`pet.txt`' to correct the error, then empty the table and reload it using `DELETE` and `LOAD DATA`:

  ```
  mysql> DELETE FROM pet;
  mysql> LOAD DATA LOCAL INFILE "pet.txt" INTO TABLE pet;
  ```

  However, if you do this, you must also re-enter the record for Puffball.

- Fix only the erroneous record with an `UPDATE` statement:

  ```
  mysql> UPDATE pet SET birth = "1989-08-31" WHERE name = "Bowser";
  ```

  The `UPDATE` changes only the record in question and does not require you to reload the table.

3.3.4.2 Selecting Particular Rows

As shown in the preceding section, it is easy to retrieve an entire table. Just omit the `WHERE` clause from the `SELECT` statement. But typically you don't want to see the entire table, particularly when it becomes large. Instead, you're usually more interested in answering a particular question, in which case you specify some constraints on the information you want. Let's look at some selection queries in terms of questions about your pets that they answer.

You can select only particular rows from your table. For example, if you want to verify the change that you made to Bowser's birth date, select Bowser's record like this:

```
mysql> SELECT * FROM pet WHERE name = "Bowser";
+--------+-------+---------+------+------------+------------+
| name   | owner | species | sex  | birth      | death      |
+--------+-------+---------+------+------------+------------+
| Bowser | Diane | dog     | m    | 1989-08-31 | 1995-07-29 |
+--------+-------+---------+------+------------+------------+
```

The output confirms that the year is correctly recorded now as 1989, not 1979.

String comparisons normally are case-insensitive, so you can specify the name as `"bowser"`, `"BOWSER"`, etc. The query result will be the same.

You can specify conditions on any column, not just `name`. For example, if you want to know which animals were born after 1998, test the `birth` column:

```
mysql> SELECT * FROM pet WHERE birth >= "1998-1-1";
+----------+-------+---------+------+------------+-------+
| name     | owner | species | sex  | birth      | death |
+----------+-------+---------+------+------------+-------+
| Chirpy   | Gwen  | bird    | f    | 1998-09-11 | NULL  |
| Puffball | Diane | hamster | f    | 1999-03-30 | NULL  |
+----------+-------+---------+------+------------+-------+
```

You can combine conditions, for example, to locate female dogs:

```
mysql> SELECT * FROM pet WHERE species = "dog" AND sex = "f";
+-------+--------+---------+------+------------+-------+
| name  | owner  | species | sex  | birth      | death |
+-------+--------+---------+------+------------+-------+
| Buffy | Harold | dog     | f    | 1989-05-13 | NULL  |
+-------+--------+---------+------+------------+-------+
```

The preceding query uses the `AND` logical operator. There is also an `OR` operator:

```
mysql> SELECT * FROM pet WHERE species = "snake" OR species = "bird";
+----------+-------+---------+------+------------+-------+
| name     | owner | species | sex  | birth      | death |
+----------+-------+---------+------+------------+-------+
| Chirpy   | Gwen  | bird    | f    | 1998-09-11 | NULL  |
| Whistler | Gwen  | bird    | NULL | 1997-12-09 | NULL  |
| Slim     | Benny | snake   | m    | 1996-04-29 | NULL  |
+----------+-------+---------+------+------------+-------+
```

`AND` and `OR` may be intermixed, though `AND` has higher precedence than `OR`. If you use both operators, it's a good idea to use parentheses to indicate explicitly how conditions should be grouped:

```
mysql> SELECT * FROM pet WHERE (species = "cat" AND sex = "m")
    -> OR (species = "dog" AND sex = "f");
+-------+--------+---------+------+------------+-------+
| name  | owner  | species | sex  | birth      | death |
+-------+--------+---------+------+------------+-------+
```

```
| Claws | Gwen   | cat     | m    | 1994-03-17 | NULL  |
| Buffy | Harold | dog     | f    | 1989-05-13 | NULL  |
+-------+--------+---------+------+------------+-------+
```

3.3.4.3 Selecting Particular Columns

If you don't want to see entire rows from your table, just name the columns in which you're interested, separated by commas. For example, if you want to know when your animals were born, select the `name` and `birth` columns:

```
mysql> SELECT name, birth FROM pet;
+----------+------------+
| name     | birth      |
+----------+------------+
| Fluffy   | 1993-02-04 |
| Claws    | 1994-03-17 |
| Buffy    | 1989-05-13 |
| Fang     | 1990-08-27 |
| Bowser   | 1989-08-31 |
| Chirpy   | 1998-09-11 |
| Whistler | 1997-12-09 |
| Slim     | 1996-04-29 |
| Puffball | 1999-03-30 |
+----------+------------+
```

To find out who owns pets, use this query:

```
mysql> SELECT owner FROM pet;
+--------+
| owner  |
+--------+
| Harold |
| Gwen   |
| Harold |
| Benny  |
| Diane  |
| Gwen   |
| Gwen   |
| Benny  |
| Diane  |
+--------+
```

However, notice that the query simply retrieves the `owner` field from each record, and some of them appear more than once. To minimise the output, retrieve each unique output record just once by adding the keyword `DISTINCT`:

```
mysql> SELECT DISTINCT owner FROM pet;
+--------+
| owner  |
+--------+
```

```
| Benny  |
| Diane  |
| Gwen   |
| Harold |
+--------+
```

You can use a `WHERE` clause to combine row selection with column selection. For example, to get birth dates for dogs and cats only, use this query:

```
mysql> SELECT name, species, birth FROM pet
    -> WHERE species = "dog" OR species = "cat";
+--------+---------+------------+
| name   | species | birth      |
+--------+---------+------------+
| Fluffy | cat     | 1993-02-04 |
| Claws  | cat     | 1994-03-17 |
| Buffy  | dog     | 1989-05-13 |
| Fang   | dog     | 1990-08-27 |
| Bowser | dog     | 1989-08-31 |
+--------+---------+------------+
```

3.3.4.4 Sorting Rows

You may have noticed in the preceding examples that the result rows are displayed in no particular order. It's often easier to examine query output when the rows are sorted in some meaningful way. To sort a result, use an `ORDER BY` clause.

Here are animal birthdays, sorted by date:

```
mysql> SELECT name, birth FROM pet ORDER BY birth;
+----------+------------+
| name     | birth      |
+----------+------------+
| Buffy    | 1989-05-13 |
| Bowser   | 1989-08-31 |
| Fang     | 1990-08-27 |
| Fluffy   | 1993-02-04 |
| Claws    | 1994-03-17 |
| Slim     | 1996-04-29 |
| Whistler | 1997-12-09 |
| Chirpy   | 1998-09-11 |
| Puffball | 1999-03-30 |
+----------+------------+
```

On character type columns, sorting—like all other comparison operations—is normally performed in a case-insensitive fashion. This means that the order will be undefined for columns that are identical except for their case. You can force a case-sensitive sort for a column by using the `BINARY` cast: `ORDER BY BINARY col_name`.

The default sort order is ascending, with smallest values first. To sort in reverse (descending) order, add the `DESC` keyword to the name of the column you are sorting by:

```
mysql> SELECT name, birth FROM pet ORDER BY birth DESC;
+----------+------------+
| name     | birth      |
+----------+------------+
| Puffball | 1999-03-30 |
| Chirpy   | 1998-09-11 |
| Whistler | 1997-12-09 |
| Slim     | 1996-04-29 |
| Claws    | 1994-03-17 |
| Fluffy   | 1993-02-04 |
| Fang     | 1990-08-27 |
| Bowser   | 1989-08-31 |
| Buffy    | 1989-05-13 |
+----------+------------+
```

You can sort on multiple columns, and you can sort columns in different directions. For example, to sort by type of animal in ascending order, then by birth date within animal type in descending order (youngest animals first), use the following query:

```
mysql> SELECT name, species, birth FROM pet ORDER BY species, birth DESC;
+----------+---------+------------+
| name     | species | birth      |
+----------+---------+------------+
| Chirpy   | bird    | 1998-09-11 |
| Whistler | bird    | 1997-12-09 |
| Claws    | cat     | 1994-03-17 |
| Fluffy   | cat     | 1993-02-04 |
| Fang     | dog     | 1990-08-27 |
| Bowser   | dog     | 1989-08-31 |
| Buffy    | dog     | 1989-05-13 |
| Puffball | hamster | 1999-03-30 |
| Slim     | snake   | 1996-04-29 |
+----------+---------+------------+
```

Note that the `DESC` keyword applies only to the column name immediately preceding it (`birth`); it does not affect the `species` column sort order.

3.3.4.5 Date Calculations

MySQL provides several functions that you can use to perform calculations on dates, for example, to calculate ages or extract parts of dates.

To determine how many years old each of your pets is, compute the difference in the year part of the current date and the birth date, then subtract one if the current date occurs earlier in the calendar year than the birth date. The following query shows, for each pet, the birth date, the current date, and the age in years.

```
mysql> SELECT name, birth, CURDATE(),
    -> (YEAR(CURDATE())-YEAR(birth))
    -> - (RIGHT(CURDATE(),5)<RIGHT(birth,5))
```

```
    -> AS age
    -> FROM pet;
+----------+------------+------------+------+
| name     | birth      | CURDATE()  | age  |
+----------+------------+------------+------+
| Fluffy   | 1993-02-04 | 2003-08-19 |   10 |
| Claws    | 1994-03-17 | 2003-08-19 |    9 |
| Buffy    | 1989-05-13 | 2003-08-19 |   14 |
| Fang     | 1990-08-27 | 2003-08-19 |   12 |
| Bowser   | 1989-08-31 | 2003-08-19 |   13 |
| Chirpy   | 1998-09-11 | 2003-08-19 |    4 |
| Whistler | 1997-12-09 | 2003-08-19 |    5 |
| Slim     | 1996-04-29 | 2003-08-19 |    7 |
| Puffball | 1999-03-30 | 2003-08-19 |    4 |
+----------+------------+------------+------+
```

Here, `YEAR()` pulls out the year part of a date and `RIGHT()` pulls off the rightmost five characters that represent the `MM-DD` (calendar year) part of the date. The part of the expression that compares the `MM-DD` values evaluates to 1 or 0, which adjusts the year difference down a year if `CURDATE()` occurs earlier in the year than `birth`. The full expression is somewhat ungainly, so an alias (`age`) is used to make the output column label more meaningful.

The query works, but the result could be scanned more easily if the rows were presented in some order. This can be done by adding an `ORDER BY name` clause to sort the output by name:

```
mysql> SELECT name, birth, CURDATE(),
    -> (YEAR(CURDATE())-YEAR(birth))
    -> - (RIGHT(CURDATE(),5)<RIGHT(birth,5))
    -> AS age
    -> FROM pet ORDER BY name;
+----------+------------+------------+------+
| name     | birth      | CURDATE()  | age  |
+----------+------------+------------+------+
| Bowser   | 1989-08-31 | 2003-08-19 |   13 |
| Buffy    | 1989-05-13 | 2003-08-19 |   14 |
| Chirpy   | 1998-09-11 | 2003-08-19 |    4 |
| Claws    | 1994-03-17 | 2003-08-19 |    9 |
| Fang     | 1990-08-27 | 2003-08-19 |   12 |
| Fluffy   | 1993-02-04 | 2003-08-19 |   10 |
| Puffball | 1999-03-30 | 2003-08-19 |    4 |
| Slim     | 1996-04-29 | 2003-08-19 |    7 |
| Whistler | 1997-12-09 | 2003-08-19 |    5 |
+----------+------------+------------+------+
```

To sort the output by `age` rather than `name`, just use a different `ORDER BY` clause:

```
mysql> SELECT name, birth, CURDATE(),
    -> (YEAR(CURDATE())-YEAR(birth))
    -> - (RIGHT(CURDATE(),5)<RIGHT(birth,5))
    -> AS age
```

```
    -> FROM pet ORDER BY age;
+----------+------------+------------+------+
| name     | birth      | CURDATE()  | age  |
+----------+------------+------------+------+
| Chirpy   | 1998-09-11 | 2003-08-19 |    4 |
| Puffball | 1999-03-30 | 2003-08-19 |    4 |
| Whistler | 1997-12-09 | 2003-08-19 |    5 |
| Slim     | 1996-04-29 | 2003-08-19 |    7 |
| Claws    | 1994-03-17 | 2003-08-19 |    9 |
| Fluffy   | 1993-02-04 | 2003-08-19 |   10 |
| Fang     | 1990-08-27 | 2003-08-19 |   12 |
| Bowser   | 1989-08-31 | 2003-08-19 |   13 |
| Buffy    | 1989-05-13 | 2003-08-19 |   14 |
+----------+------------+------------+------+
```

A similar query can be used to determine age at death for animals that have died. You determine which animals these are by checking whether the `death` value is `NULL`. Then, for those with non-`NULL` values, compute the difference between the `death` and `birth` values:

```
mysql> SELECT name, birth, death,
    -> (YEAR(death)-YEAR(birth)) - (RIGHT(death,5)<RIGHT(birth,5))
    -> AS age
    -> FROM pet WHERE death IS NOT NULL ORDER BY age;
+--------+------------+------------+------+
| name   | birth      | death      | age  |
+--------+------------+------------+------+
| Bowser | 1989-08-31 | 1995-07-29 |    5 |
+--------+------------+------------+------+
```

The query uses `death IS NOT NULL` rather than `death <> NULL` because `NULL` is a special value that cannot be compared using the usual comparison operators. This is discussed later. See Section 3.3.4.6 [Working with NULL], page 173.

What if you want to know which animals have birthdays next month? For this type of calculation, year and day are irrelevant; you simply want to extract the month part of the `birth` column. MySQL provides several date-part extraction functions, such as `YEAR()`, `MONTH()`, and `DAYOFMONTH()`. `MONTH()` is the appropriate function here. To see how it works, run a simple query that displays the value of both `birth` and `MONTH(birth)`:

```
mysql> SELECT name, birth, MONTH(birth) FROM pet;
+----------+------------+--------------+
| name     | birth      | MONTH(birth) |
+----------+------------+--------------+
| Fluffy   | 1993-02-04 |            2 |
| Claws    | 1994-03-17 |            3 |
| Buffy    | 1989-05-13 |            5 |
| Fang     | 1990-08-27 |            8 |
| Bowser   | 1989-08-31 |            8 |
| Chirpy   | 1998-09-11 |            9 |
| Whistler | 1997-12-09 |           12 |
| Slim     | 1996-04-29 |            4 |
```

```
| Puffball | 1999-03-30 |            3 |
+----------+------------+--------------+
```

Finding animals with birthdays in the upcoming month is easy, too. Suppose the current month is April. Then the month value is `4` and you look for animals born in May (month `5`) like this:

```
mysql> SELECT name, birth FROM pet WHERE MONTH(birth) = 5;
+-------+------------+
| name  | birth      |
+-------+------------+
| Buffy | 1989-05-13 |
+-------+------------+
```

There is a small complication if the current month is December, of course. You don't just add one to the month number (`12`) and look for animals born in month `13`, because there is no such month. Instead, you look for animals born in January (month `1`).

You can even write the query so that it works no matter what the current month is. That way you don't have to use a particular month number in the query. `DATE_ADD()` allows you to add a time interval to a given date. If you add a month to the value of `CURDATE()`, then extract the month part with `MONTH()`, the result produces the month in which to look for birthdays:

```
mysql> SELECT name, birth FROM pet
    -> WHERE MONTH(birth) = MONTH(DATE_ADD(CURDATE(), INTERVAL 1 MONTH));
```

A different way to accomplish the same task is to add `1` to get the next month after the current one (after using the modulo function (`MOD`) to wrap around the month value to `0` if it is currently `12`):

```
mysql> SELECT name, birth FROM pet
    -> WHERE MONTH(birth) = MOD(MONTH(CURDATE()), 12) + 1;
```

Note that `MONTH` returns a number between `1` and `12`. And `MOD(something,12)` returns a number between `0` and `11`. So the addition has to be after the `MOD()`, otherwise we would go from November (`11`) to January (`1`).

3.3.4.6 Working with `NULL` Values

The `NULL` value can be surprising until you get used to it. Conceptually, `NULL` means missing value or unknown value and it is treated somewhat differently than other values. To test for `NULL`, you cannot use the arithmetic comparison operators such as `=`, `<`, or `<>`. To demonstrate this for yourself, try the following query:

```
mysql> SELECT 1 = NULL, 1 <> NULL, 1 < NULL, 1 > NULL;
+----------+-----------+----------+----------+
| 1 = NULL | 1 <> NULL | 1 < NULL | 1 > NULL |
+----------+-----------+----------+----------+
|     NULL |      NULL |     NULL |     NULL |
+----------+-----------+----------+----------+
```

Clearly you get no meaningful results from these comparisons. Use the `IS NULL` and `IS NOT NULL` operators instead:

```
mysql> SELECT 1 IS NULL, 1 IS NOT NULL;
+-----------+---------------+
| 1 IS NULL | 1 IS NOT NULL |
+-----------+---------------+
|         0 |             1 |
+-----------+---------------+
```

Note that in MySQL, `0` or `NULL` means false and anything else means true. The default truth value from a boolean operation is `1`.

This special treatment of `NULL` is why, in the previous section, it was necessary to determine which animals are no longer alive using `death IS NOT NULL` instead of `death <> NULL`.

Two `NULL` values are regarded as equal in a `GROUP BY`.

When doing an `ORDER BY`, `NULL` values are presented first if you do `ORDER BY ... ASC` and last if you do `ORDER BY ... DESC`.

Note that MySQL 4.0.2 to 4.0.10 incorrectly always sorts `NULL` values first regardless of the sort direction.

3.3.4.7 Pattern Matching

MySQL provides standard SQL pattern matching as well as a form of pattern matching based on extended regular expressions similar to those used by Unix utilities such as `vi`, `grep`, and `sed`.

SQL pattern matching allows you to use '`_`' to match any single character and '`%`' to match an arbitrary number of characters (including zero characters). In MySQL, SQL patterns are case-insensitive by default. Some examples are shown here. Note that you do not use `=` or `<>` when you use SQL patterns; use the `LIKE` or `NOT LIKE` comparison operators instead.

To find names beginning with '`b`':

```
mysql> SELECT * FROM pet WHERE name LIKE "b%";
+--------+--------+---------+------+------------+------------+
| name   | owner  | species | sex  | birth      | death      |
+--------+--------+---------+------+------------+------------+
| Buffy  | Harold | dog     | f    | 1989-05-13 | NULL       |
| Bowser | Diane  | dog     | m    | 1989-08-31 | 1995-07-29 |
+--------+--------+---------+------+------------+------------+
```

To find names ending with '`fy`':

```
mysql> SELECT * FROM pet WHERE name LIKE "%fy";
+--------+--------+---------+------+------------+-------+
| name   | owner  | species | sex  | birth      | death |
+--------+--------+---------+------+------------+-------+
| Fluffy | Harold | cat     | f    | 1993-02-04 | NULL  |
| Buffy  | Harold | dog     | f    | 1989-05-13 | NULL  |
+--------+--------+---------+------+------------+-------+
```

To find names containing a '`w`':

```
mysql> SELECT * FROM pet WHERE name LIKE "%w%";
+----------+-------+---------+------+------------+------------+
```

```
| name     | owner | species | sex  | birth      | death      |
+----------+-------+---------+------+------------+------------+
| Claws    | Gwen  | cat     | m    | 1994-03-17 | NULL       |
| Bowser   | Diane | dog     | m    | 1989-08-31 | 1995-07-29 |
| Whistler | Gwen  | bird    | NULL | 1997-12-09 | NULL       |
+----------+-------+---------+------+------------+------------+
```

To find names containing exactly five characters, use fives instances of the '`_`' pattern character:

```
mysql> SELECT * FROM pet WHERE name LIKE "_____";
+-------+--------+---------+------+------------+-------+
| name  | owner  | species | sex  | birth      | death |
+-------+--------+---------+------+------------+-------+
| Claws | Gwen   | cat     | m    | 1994-03-17 | NULL  |
| Buffy | Harold | dog     | f    | 1989-05-13 | NULL  |
+-------+--------+---------+------+------------+-------+
```

The other type of pattern matching provided by MySQL uses extended regular expressions. When you test for a match for this type of pattern, use the `REGEXP` and `NOT REGEXP` operators (or `RLIKE` and `NOT RLIKE`, which are synonyms).

Some characteristics of extended regular expressions are:

- '`.`' matches any single character.
- A character class '`[...]`' matches any character within the brackets. For example, '`[abc]`' matches '`a`', '`b`', or '`c`'. To name a range of characters, use a dash. '`[a-z]`' matches any letter, whereas '`[0-9]`' matches any digit.
- '`*`' matches zero or more instances of the thing preceding it. For example, '`x*`' matches any number of '`x`' characters, '`[0-9]*`' matches any number of digits, and '`.*`' matches any number of anything.
- A `REGEXP` pattern match succeed if the pattern matches anywhere in the value being tested. (This differs from a `LIKE` pattern match, which succeeds only if the pattern matches the entire value.)
- To anchor a pattern so that it must match the beginning or end of the value being tested, use '`^`' at the beginning or '`$`' at the end of the pattern.

To demonstrate how extended regular expressions work, the `LIKE` queries shown previously are rewritten here to use `REGEXP`.

To find names beginning with '`b`', use '`^`' to match the beginning of the name:

```
mysql> SELECT * FROM pet WHERE name REGEXP "^b";
+--------+--------+---------+------+------------+------------+
| name   | owner  | species | sex  | birth      | death      |
+--------+--------+---------+------+------------+------------+
| Buffy  | Harold | dog     | f    | 1989-05-13 | NULL       |
| Bowser | Diane  | dog     | m    | 1989-08-31 | 1995-07-29 |
+--------+--------+---------+------+------------+------------+
```

Prior to MySQL Version 3.23.4, `REGEXP` is case-sensitive, and the previous query will return no rows. In this case, to match either lowercase or uppercase '`b`', use this query instead:

```
mysql> SELECT * FROM pet WHERE name REGEXP "^[bB]";
```

From MySQL 3.23.4 on, if you really want to force a `REGEXP` comparison to be case-sensitive, use the `BINARY` keyword to make one of the strings a binary string. This query will match only lowercase '`b`' at the beginning of a name:

```
mysql> SELECT * FROM pet WHERE name REGEXP BINARY "^b";
```

To find names ending with '`fy`', use '`$`' to match the end of the name:

```
mysql> SELECT * FROM pet WHERE name REGEXP "fy$";
+--------+--------+---------+------+------------+-------+
| name   | owner  | species | sex  | birth      | death |
+--------+--------+---------+------+------------+-------+
| Fluffy | Harold | cat     | f    | 1993-02-04 | NULL  |
| Buffy  | Harold | dog     | f    | 1989-05-13 | NULL  |
+--------+--------+---------+------+------------+-------+
```

To find names containing a '`w`', use this query:

```
mysql> SELECT * FROM pet WHERE name REGEXP "w";
+----------+-------+---------+------+------------+------------+
| name     | owner | species | sex  | birth      | death      |
+----------+-------+---------+------+------------+------------+
| Claws    | Gwen  | cat     | m    | 1994-03-17 | NULL       |
| Bowser   | Diane | dog     | m    | 1989-08-31 | 1995-07-29 |
| Whistler | Gwen  | bird    | NULL | 1997-12-09 | NULL       |
+----------+-------+---------+------+------------+------------+
```

Because a regular expression pattern matches if it occurs anywhere in the value, it is not necessary in the previous query to put a wildcard on either side of the pattern to get it to match the entire value like it would be if you used an SQL pattern.

To find names containing exactly five characters, use '`^`' and '`$`' to match the beginning and end of the name, and five instances of '`.`' in between:

```
mysql> SELECT * FROM pet WHERE name REGEXP "^.....$";
+-------+--------+---------+------+------------+-------+
| name  | owner  | species | sex  | birth      | death |
+-------+--------+---------+------+------------+-------+
| Claws | Gwen   | cat     | m    | 1994-03-17 | NULL  |
| Buffy | Harold | dog     | f    | 1989-05-13 | NULL  |
+-------+--------+---------+------+------------+-------+
```

You could also write the previous query using the '`{n}`' "repeat-`n`-times" operator:

```
mysql> SELECT * FROM pet WHERE name REGEXP "^.{5}$";
+-------+--------+---------+------+------------+-------+
| name  | owner  | species | sex  | birth      | death |
+-------+--------+---------+------+------------+-------+
| Claws | Gwen   | cat     | m    | 1994-03-17 | NULL  |
| Buffy | Harold | dog     | f    | 1989-05-13 | NULL  |
+-------+--------+---------+------+------------+-------+
```

3.3.4.8 Counting Rows

Databases are often used to answer the question, "How often does a certain type of data occur in a table?" For example, you might want to know how many pets you have, or how many pets each owner has, or you might want to perform various kinds of census operations on your animals.

Counting the total number of animals you have is the same question as "How many rows are in the `pet` table?" because there is one record per pet. `COUNT(*)` counts the number of rows, so the query to count your animals looks like this:

```
mysql> SELECT COUNT(*) FROM pet;
+----------+
| COUNT(*) |
+----------+
|        9 |
+----------+
```

Earlier, you retrieved the names of the people who owned pets. You can use `COUNT()` if you want to find out how many pets each owner has:

```
mysql> SELECT owner, COUNT(*) FROM pet GROUP BY owner;
+--------+----------+
| owner  | COUNT(*) |
+--------+----------+
| Benny  |        2 |
| Diane  |        2 |
| Gwen   |        3 |
| Harold |        2 |
+--------+----------+
```

Note the use of `GROUP BY` to group together all records for each `owner`. Without it, all you get is an error message:

```
mysql> SELECT owner, COUNT(*) FROM pet;
ERROR 1140: Mixing of GROUP columns (MIN(),MAX(),COUNT()...)
with no GROUP columns is illegal if there is no GROUP BY clause
```

`COUNT()` and `GROUP BY` are useful for characterising your data in various ways. The following examples show different ways to perform animal census operations.

Number of animals per species:

```
mysql> SELECT species, COUNT(*) FROM pet GROUP BY species;
+---------+----------+
| species | COUNT(*) |
+---------+----------+
| bird    |        2 |
| cat     |        2 |
| dog     |        3 |
| hamster |        1 |
| snake   |        1 |
+---------+----------+
```

Number of animals per sex:

```
mysql> SELECT sex, COUNT(*) FROM pet GROUP BY sex;
+------+----------+
| sex  | COUNT(*) |
+------+----------+
| NULL |        1 |
| f    |        4 |
| m    |        4 |
+------+----------+
```

(In this output, `NULL` indicates that the sex is unknown.)

Number of animals per combination of species and sex:

```
mysql> SELECT species, sex, COUNT(*) FROM pet GROUP BY species, sex;
+---------+------+----------+
| species | sex  | COUNT(*) |
+---------+------+----------+
| bird    | NULL |        1 |
| bird    | f    |        1 |
| cat     | f    |        1 |
| cat     | m    |        1 |
| dog     | f    |        1 |
| dog     | m    |        2 |
| hamster | f    |        1 |
| snake   | m    |        1 |
+---------+------+----------+
```

You need not retrieve an entire table when you use `COUNT()`. For example, the previous query, when performed just on dogs and cats, looks like this:

```
mysql> SELECT species, sex, COUNT(*) FROM pet
    -> WHERE species = "dog" OR species = "cat"
    -> GROUP BY species, sex;
+---------+------+----------+
| species | sex  | COUNT(*) |
+---------+------+----------+
| cat     | f    |        1 |
| cat     | m    |        1 |
| dog     | f    |        1 |
| dog     | m    |        2 |
+---------+------+----------+
```

Or, if you wanted the number of animals per sex only for known-sex animals:

```
mysql> SELECT species, sex, COUNT(*) FROM pet
    -> WHERE sex IS NOT NULL
    -> GROUP BY species, sex;
+---------+------+----------+
| species | sex  | COUNT(*) |
+---------+------+----------+
| bird    | f    |        1 |
| cat     | f    |        1 |
```

```
| cat     | m    |        1 |
| dog     | f    |        1 |
| dog     | m    |        2 |
| hamster | f    |        1 |
| snake   | m    |        1 |
+---------+------+----------+
```

3.3.4.9 Using More Than one Table

The `pet` table keeps track of which pets you have. If you want to record other information about them, such as events in their lives like visits to the vet or when litters are born, you need another table. What should this table look like? It needs:

- To contain the pet name so you know which animal each event pertains to.
- A date so you know when the event occurred.
- A field to describe the event.
- An event type field, if you want to be able to categorise events.

Given these considerations, the `CREATE TABLE` statement for the `event` table might look like this:

```
mysql> CREATE TABLE event (name VARCHAR(20), date DATE,
    -> type VARCHAR(15), remark VARCHAR(255));
```

As with the `pet` table, it's easiest to load the initial records by creating a tab-delimited text file containing the information:

name	date	type	remark
Fluffy	1995-05-15	litter	4 kittens, 3 female, 1 male
Buffy	1993-06-23	litter	5 puppies, 2 female, 3 male
Buffy	1994-06-19	litter	3 puppies, 3 female
Chirpy	1999-03-21	vet	needed beak straightened
Slim	1997-08-03	vet	broken rib
Bowser	1991-10-12	kennel	
Fang	1991-10-12	kennel	
Fang	1998-08-28	birthday	Gave him a new chew toy
Claws	1998-03-17	birthday	Gave him a new flea collar
Whistler	1998-12-09	birthday	First birthday

Load the records like this:

```
mysql> LOAD DATA LOCAL INFILE "event.txt" INTO TABLE event;
```

Based on what you've learned from the queries you've run on the `pet` table, you should be able to perform retrievals on the records in the `event` table; the principles are the same. But when is the `event` table by itself insufficient to answer questions you might ask?

Suppose you want to find out the ages at which each pet had its litters. We saw earlier how to calculate ages from two dates. The litter date of the mother is in the `event` table, but to calculate her age on that date you need her birth date, which is stored in the `pet` table. This means the query requires both tables:

```
mysql> SELECT pet.name,
```

```
    -> (YEAR(date)-YEAR(birth)) - (RIGHT(date,5)<RIGHT(birth,5)) AS age,
    -> remark
    -> FROM pet, event
    -> WHERE pet.name = event.name AND type = "litter";
+--------+------+-----------------------------+
| name   | age  | remark                      |
+--------+------+-----------------------------+
| Fluffy |    2 | 4 kittens, 3 female, 1 male |
| Buffy  |    4 | 5 puppies, 2 female, 3 male |
| Buffy  |    5 | 3 puppies, 3 female         |
+--------+------+-----------------------------+
```

There are several things to note about this query:

- The `FROM` clause lists two tables because the query needs to pull information from both of them.
- When combining (joining) information from multiple tables, you need to specify how records in one table can be matched to records in the other. This is easy because they both have a `name` column. The query uses `WHERE` clause to match up records in the two tables based on the `name` values.
- Because the `name` column occurs in both tables, you must be specific about which table you mean when referring to the column. This is done by prepending the table name to the column name.

You need not have two different tables to perform a join. Sometimes it is useful to join a table to itself, if you want to compare records in a table to other records in that same table. For example, to find breeding pairs among your pets, you can join the `pet` table with itself to produce candidate pairs of males and females of like species:

```
mysql> SELECT p1.name, p1.sex, p2.name, p2.sex, p1.species
    -> FROM pet AS p1, pet AS p2
    -> WHERE p1.species = p2.species AND p1.sex = "f" AND p2.sex = "m";
+--------+------+--------+------+---------+
| name   | sex  | name   | sex  | species |
+--------+------+--------+------+---------+
| Fluffy | f    | Claws  | m    | cat     |
| Buffy  | f    | Fang   | m    | dog     |
| Buffy  | f    | Bowser | m    | dog     |
+--------+------+--------+------+---------+
```

In this query, we specify aliases for the table name in order to refer to the columns and keep straight which instance of the table each column reference is associated with.

3.4 Getting Information About Databases and Tables

What if you forget the name of a database or table, or what the structure of a given table is (for example, what its columns are called)? MySQL addresses this problem through several statements that provide information about the databases and tables it supports.

You have already seen `SHOW DATABASES`, which lists the databases managed by the server. To find out which database is currently selected, use the `DATABASE()` function:

```
mysql> SELECT DATABASE();
+------------+
| DATABASE() |
+------------+
| menagerie  |
+------------+
```

If you haven't selected any database yet, the result is `NULL` (or the empty string before MySQL 4.1.1).

To find out what tables the current database contains (for example, when you're not sure about the name of a table), use this command:

```
mysql> SHOW TABLES;
+----------------------+
| Tables in menagerie |
+----------------------+
| event                |
| pet                  |
+----------------------+
```

If you want to find out about the structure of a table, the `DESCRIBE` command is useful; it displays information about each of a table's columns:

```
mysql> DESCRIBE pet;
+---------+-------------+------+-----+---------+-------+
| Field   | Type        | Null | Key | Default | Extra |
+---------+-------------+------+-----+---------+-------+
| name    | varchar(20) | YES  |     | NULL    |       |
| owner   | varchar(20) | YES  |     | NULL    |       |
| species | varchar(20) | YES  |     | NULL    |       |
| sex     | char(1)     | YES  |     | NULL    |       |
| birth   | date        | YES  |     | NULL    |       |
| death   | date        | YES  |     | NULL    |       |
+---------+-------------+------+-----+---------+-------+
```

`Field` indicates the column name, `Type` is the datatype for the column, `NULL` indicates whether the column can contain `NULL` values, `Key` indicates whether the column is indexed, and `Default` specifies the column's default value.

If you have indexes on a table, `SHOW INDEX FROM tbl_name` produces information about them.

3.5 Using `mysql` in Batch Mode

In the previous sections, you used `mysql` interactively to enter queries and view the results. You can also run `mysql` in batch mode. To do this, put the commands you want to run in a file, then tell `mysql` to read its input from the file:

```
shell> mysql < batch-file
```

If you are running `mysql` under Windows and have some special characters in the file that cause problems, you can do this:

```
dos> mysql -e "source batch-file"
```

If you need to specify connection parameters on the command line, the command might look like this:

```
shell> mysql -h host -u user -p < batch-file
Enter password: ********
```

When you use `mysql` this way, you are creating a script file, then executing the script.

If you want the script to continue even if some of the statements in it produce errors, you should use the `--force` command-line option.

Why use a script? Here are a few reasons:

- If you run a query repeatedly (say, every day or every week), making it a script allows you to avoid retyping it each time you execute it.
- You can generate new queries from existing ones that are similar by copying and editing script files.
- Batch mode can also be useful while you're developing a query, particularly for multiple-line commands or multiple-statement sequences of commands. If you make a mistake, you don't have to retype everything. Just edit your script to correct the error, then tell `mysql` to execute it again.
- If you have a query that produces a lot of output, you can run the output through a pager rather than watching it scroll off the top of your screen:

  ```
  shell> mysql < batch-file | more
  ```

- You can catch the output in a file for further processing:

  ```
  shell> mysql < batch-file > mysql.out
  ```

- You can distribute your script to other people so they can run the commands, too.
- Some situations do not allow for interactive use, for example, when you run a query from a `cron` job. In this case, you must use batch mode.

The default output format is different (more concise) when you run `mysql` in batch mode than when you use it interactively. For example, the output of `SELECT DISTINCT species FROM pet` looks like this when `mysql` is run interactively:

```
+---------+
| species |
+---------+
| bird    |
| cat     |
| dog     |
| hamster |
| snake   |
+---------+
```

In batch mode, the output looks like this instead:

```
species
bird
cat
dog
hamster
```

```
snake
```

If you want to get the interactive output format in batch mode, use `mysql -t`. To echo to the output the commands that are executed, use `mysql -vvv`.

You can also use scripts from the `mysql` prompt by using the `source` command:

```
mysql> source filename;
```

3.6 Examples of Common Queries

Here are examples of how to solve some common problems with MySQL.

Some of the examples use the table `shop` to hold the price of each article (item number) for certain traders (dealers). Supposing that each trader has a single fixed price per article, then (`article`, `dealer`) is a primary key for the records.

Start the command-line tool `mysql` and select a database:

```
shell> mysql your-database-name
```

(In most MySQL installations, you can use the database name `test`).

You can create and populate the example table with these statements:

```
mysql> CREATE TABLE shop (
    -> article INT(4) UNSIGNED ZEROFILL DEFAULT '0000' NOT NULL,
    -> dealer  CHAR(20)                 DEFAULT ''     NOT NULL,
    -> price   DOUBLE(16,2)             DEFAULT '0.00' NOT NULL,
    -> PRIMARY KEY(article, dealer));
mysql> INSERT INTO shop VALUES
    -> (1,'A',3.45),(1,'B',3.99),(2,'A',10.99),(3,'B',1.45),(3,'C',1.69),
    -> (3,'D',1.25),(4,'D',19.95);
```

After issuing the statements, the table should have the following contents:

```
mysql> SELECT * FROM shop;
+---------+--------+-------+
| article | dealer | price |
+---------+--------+-------+
|    0001 | A      |  3.45 |
|    0001 | B      |  3.99 |
|    0002 | A      | 10.99 |
|    0003 | B      |  1.45 |
|    0003 | C      |  1.69 |
|    0003 | D      |  1.25 |
|    0004 | D      | 19.95 |
+---------+--------+-------+
```

3.6.1 The Maximum Value for a Column

"What's the highest item number?"

```
SELECT MAX(article) AS article FROM shop;
```

```
+---------+
| article |
+---------+
|       4 |
+---------+
```

3.6.2 The Row Holding the Maximum of a Certain Column

"Find number, dealer, and price of the most expensive article."

In SQL-99 (and MySQL Version 4.1) this is easily done with a subquery:

```
SELECT article, dealer, price
FROM   shop
WHERE  price=(SELECT MAX(price) FROM shop);
```

In MySQL versions prior to 4.1, just do it in two steps:

1. Get the maximum price value from the table with a `SELECT` statement.

   ```
   mysql> SELECT MAX(price) FROM shop;
   +------------+
   | MAX(price) |
   +------------+
   |      19.95 |
   +------------+
   ```

2. Using the value 19.95 shown by the previous query to be the maximum article price, write a query to locate and display the corresponding record:

   ```
   mysql> SELECT article, dealer, price
       -> FROM   shop
       -> WHERE  price=19.95;
   +---------+--------+-------+
   | article | dealer | price |
   +---------+--------+-------+
   |    0004 | D      | 19.95 |
   +---------+--------+-------+
   ```

Another solution is to sort all rows descending by price and only get the first row using the MySQL-specific `LIMIT` clause:

```
SELECT article, dealer, price
FROM   shop
ORDER BY price DESC
LIMIT 1;
```

NOTE: If there were several most expensive articles, each with a price of 19.95, the `LIMIT` solution would show only one of them!

3.6.3 Maximum of Column per Group

"What's the highest price per article?"

```
SELECT article, MAX(price) AS price
FROM   shop
GROUP BY article

+---------+-------+
| article | price |
+---------+-------+
|    0001 |  3.99 |
|    0002 | 10.99 |
|    0003 |  1.69 |
|    0004 | 19.95 |
+---------+-------+
```

3.6.4 The Rows Holding the Group-wise Maximum of a Certain Field

"For each article, find the dealer(s) with the most expensive price."

In SQL-99 (and MySQL Version 4.1 or greater), the problem can be solved with a subquery like this:

```
SELECT article, dealer, price
FROM   shop s1
WHERE  price=(SELECT MAX(s2.price)
              FROM shop s2
              WHERE s1.article = s2.article);
```

In MySQL versions prior to 4.1, it's best do it in several steps:

1. Get the list of (article,maxprice) pairs.
2. For each article, get the corresponding rows that have the stored maximum price.

This can easily be done with a temporary table and a join:

```
CREATE TEMPORARY TABLE tmp (
        article INT(4) UNSIGNED ZEROFILL DEFAULT '0000' NOT NULL,
        price   DOUBLE(16,2)             DEFAULT '0.00' NOT NULL);

LOCK TABLES shop READ;

INSERT INTO tmp SELECT article, MAX(price) FROM shop GROUP BY article;

SELECT shop.article, dealer, shop.price FROM shop, tmp
WHERE shop.article=tmp.article AND shop.price=tmp.price;

UNLOCK TABLES;

DROP TABLE tmp;
```

If you don't use a `TEMPORARY` table, you must also lock the `tmp` table.

"Can it be done with a single query?"

Yes, but only by using a quite inefficient trick called the "MAX-CONCAT trick":

```
SELECT article,
       SUBSTRING( MAX( CONCAT(LPAD(price,6,'0'),dealer) ), 7) AS dealer,
  0.00+LEFT(      MAX( CONCAT(LPAD(price,6,'0'),dealer) ), 6) AS price
FROM   shop
GROUP BY article;

+---------+--------+-------+
| article | dealer | price |
+---------+--------+-------+
|    0001 | B      |  3.99 |
|    0002 | A      | 10.99 |
|    0003 | C      |  1.69 |
|    0004 | D      | 19.95 |
+---------+--------+-------+
```

The last example can, of course, be made a bit more efficient by doing the splitting of the concatenated column in the client.

3.6.5 Using User Variables

You can use MySQL user variables to remember results without having to store them in temporary variables in the client. See Section 6.1.4 [Variables], page 446.

For example, to find the articles with the highest and lowest price you can do this:

```
mysql> SELECT @min_price:=MIN(price),@max_price:=MAX(price) FROM shop;
mysql> SELECT * FROM shop WHERE price=@min_price OR price=@max_price;
+---------+--------+-------+
| article | dealer | price |
+---------+--------+-------+
|    0003 | D      |  1.25 |
|    0004 | D      | 19.95 |
+---------+--------+-------+
```

3.6.6 Using Foreign Keys

In MySQL 3.23.44 and up, `InnoDB` tables support checking of foreign key constraints. See Section 7.5 [InnoDB], page 606. See also Section 1.7.4.5 [ANSI diff Foreign Keys], page 40.

You don't actually need foreign keys to join 2 tables. For table types other than `InnoDB`), the only things MySQL currently doesn't do are 1) `CHECK` to make sure that the keys you use really exist in the table or tables you're referencing and 2) automatically delete rows from a table with a foreign key definition. Using your keys to join tables will work just fine:

```
CREATE TABLE person (
    id SMALLINT UNSIGNED NOT NULL AUTO_INCREMENT,
    name CHAR(60) NOT NULL,
    PRIMARY KEY (id)
);
```

```
CREATE TABLE shirt (
    id SMALLINT UNSIGNED NOT NULL AUTO_INCREMENT,
    style ENUM('t-shirt', 'polo', 'dress') NOT NULL,
    colour ENUM('red', 'blue', 'orange', 'white', 'black') NOT NULL,
    owner SMALLINT UNSIGNED NOT NULL REFERENCES person(id),
    PRIMARY KEY (id)
);


INSERT INTO person VALUES (NULL, 'Antonio Paz');

INSERT INTO shirt VALUES
(NULL, 'polo', 'blue', LAST_INSERT_ID()),
(NULL, 'dress', 'white', LAST_INSERT_ID()),
(NULL, 't-shirt', 'blue', LAST_INSERT_ID());


INSERT INTO person VALUES (NULL, 'Lilliana Angelovska');

INSERT INTO shirt VALUES
(NULL, 'dress', 'orange', LAST_INSERT_ID()),
(NULL, 'polo', 'red', LAST_INSERT_ID()),
(NULL, 'dress', 'blue', LAST_INSERT_ID()),
(NULL, 't-shirt', 'white', LAST_INSERT_ID());


SELECT * FROM person;
+----+--------------------+
| id | name               |
+----+--------------------+
|  1 | Antonio Paz        |
|  2 | Lilliana Angelovska |
+----+--------------------+

SELECT * FROM shirt;
+----+---------+--------+-------+
| id | style   | colour | owner |
+----+---------+--------+-------+
|  1 | polo    | blue   |     1 |
|  2 | dress   | white  |     1 |
|  3 | t-shirt | blue   |     1 |
|  4 | dress   | orange |     2 |
|  5 | polo    | red    |     2 |
|  6 | dress   | blue   |     2 |
|  7 | t-shirt | white  |     2 |
+----+---------+--------+-------+
```

```
SELECT s.* FROM person p, shirt s
 WHERE p.name LIKE 'Lilliana%'
   AND s.owner = p.id
   AND s.colour <> 'white';

+----+-------+--------+-------+
| id | style | colour | owner |
+----+-------+--------+-------+
|  4 | dress | orange |     2 |
|  5 | polo  | red    |     2 |
|  6 | dress | blue   |     2 |
+----+-------+--------+-------+
```

3.6.7 Searching on Two Keys

MySQL doesn't yet optimise when you search on two different keys combined with `OR` (searching on one key with different `OR` parts is optimised quite well):

```
SELECT field1_index, field2_index FROM test_table
WHERE field1_index = '1' OR  field2_index = '1'
```

The reason is that we haven't yet had time to come up with an efficient way to handle this in the general case. (The `AND` handling is, in comparison, now completely general and works very well.)

In MySQL 4.0 and up, you can solve this problem efficiently by using a `UNION` that combines the output of two separate `SELECT` statements. See Section 6.4.1.2 [UNION], page 537. Each `SELECT` searches only one key and can be optimised:

```
SELECT field1_index, field2_index FROM test_table WHERE field1_index = '1'
UNION
SELECT field1_index, field2_index FROM test_table WHERE field2_index = '1';
```

Prior to MySQL 4.0, you can achieve the same effect by using a `TEMPORARY` table and separate `SELECT` statements. This type of optimisation is also very good if you are using very complicated queries where the SQL server does the optimisations in the wrong order.

```
CREATE TEMPORARY TABLE tmp
SELECT field1_index, field2_index FROM test_table WHERE field1_index = '1';
INSERT INTO tmp
SELECT field1_index, field2_index FROM test_table WHERE field2_index = '1';
SELECT * from tmp;
DROP TABLE tmp;
```

The above way to solve this query is in effect a `UNION` of two queries.

3.6.8 Calculating Visits Per Day

The following example shows how you can use the bit group functions to calculate the number of days per month a user has visited a web page.

```
CREATE TABLE t1 (year YEAR(4), month INT(2) UNSIGNED ZEROFILL,
             day INT(2) UNSIGNED ZEROFILL);
INSERT INTO t1 VALUES(2000,1,1),(2000,1,20),(2000,1,30),(2000,2,2),
            (2000,2,23),(2000,2,23);
```

The example table contains year-month-day values representing visits by users to the page. To determine how many different days in each month these visits occur, use this query:

```
SELECT year,month,BIT_COUNT(BIT_OR(1<<day)) AS days FROM t1
       GROUP BY year,month;
```

Which returns:

```
+------+-------+------+
| year | month | days |
+------+-------+------+
| 2000 |    01 |    3 |
| 2000 |    02 |    2 |
+------+-------+------+
```

The query calculates how many different days appear in the table for each year/month combination, with automatic removal of duplicate entries.

3.6.9 Using AUTO_INCREMENT

The AUTO_INCREMENT attribute can be used to generate a unique identity for new rows:

```
CREATE TABLE animals (
             id MEDIUMINT NOT NULL AUTO_INCREMENT,
             name CHAR(30) NOT NULL,
             PRIMARY KEY (id)
             );
INSERT INTO animals (name) VALUES ("dog"),("cat"),("penguin"),
                                  ("lax"),("whale"),("ostrich");
SELECT * FROM animals;
```

Which returns:

```
+----+---------+
| id | name    |
+----+---------+
|  1 | dog     |
|  2 | cat     |
|  3 | penguin |
|  4 | lax     |
|  5 | whale   |
|  6 | ostrich |
+----+---------+
```

You can retrieve the most recent AUTO_INCREMENT value with the LAST_INSERT_ID() SQL function or the mysql_insert_id() C API function. Note: For a multiple-row insert, LAST_INSERT_ID()/mysql_insert_id() will actually return the AUTO_INCREMENT key from the **first** of the inserted rows. This allows multiple-row inserts to be reproduced correctly on other servers in a replication setup.

For MyISAM and BDB tables you can specify AUTO_INCREMENT on a secondary column in a multiple-column index. In this case, the generated value for the AUTO_INCREMENT column is calculated as MAX(auto_increment_column)+1) WHERE prefix=given-prefix. This is useful when you want to put data into ordered groups.

```
CREATE TABLE animals (
             grp ENUM('fish','mammal','bird') NOT NULL,
             id MEDIUMINT NOT NULL AUTO_INCREMENT,
             name CHAR(30) NOT NULL,
             PRIMARY KEY (grp,id)
             );
INSERT INTO animals (grp,name) VALUES("mammal","dog"),("mammal","cat"),
                   ("bird","penguin"),("fish","lax"),("mammal","whale"),
                   ("bird","ostrich");
SELECT * FROM animals ORDER BY grp,id;
```

Which returns:

```
+--------+----+---------+
| grp    | id | name    |
+--------+----+---------+
| fish   |  1 | lax     |
| mammal |  1 | dog     |
| mammal |  2 | cat     |
| mammal |  3 | whale   |
| bird   |  1 | penguin |
| bird   |  2 | ostrich |
+--------+----+---------+
```

Note that in this case (when the AUTO_INCREMENT column is part of a multiple-column index), AUTO_INCREMENT values will be reused if you delete the row with the biggest AUTO_INCREMENT value in any group. This happens even for MyISAM tables, for which AUTO_INCREMENT values normally are not reused.)

3.7 Queries from the Twin Project

At Analytikerna and Lentus, we have been doing the systems and field work for a big research project. This project is a collaboration between the Institute of Environmental Medicine at Karolinska Institutet Stockholm and the Section on Clinical Research in Aging and Psychology at the University of Southern California.

The project involves a screening part where all twins in Sweden older than 65 years are interviewed by telephone. Twins who meet certain criteria are passed on to the next stage. In this latter stage, twins who want to participate are visited by a doctor/nurse team. Some of the examinations include physical and neuropsychological examination, laboratory testing, neuroimaging, psychological status assessment, and family history collection. In addition, data are collected on medical and environmental risk factors.

More information about Twin studies can be found at: http://www.mep.ki.se/twinreg/index_en.html

The latter part of the project is administered with a web interface written using Perl and MySQL.

Each night all data from the interviews is moved into a MySQL database.

3.7.1 Find All Non-distributed Twins

The following query is used to determine who goes into the second part of the project:

```
SELECT
        CONCAT(p1.id, p1.tvab) + 0 AS tvid,
        CONCAT(p1.christian_name, " ", p1.surname) AS Name,
        p1.postal_code AS Code,
        p1.city AS City,
        pg.abrev AS Area,
        IF(td.participation = "Aborted", "A", " ") AS A,
        p1.dead AS dead1,
        l.event AS event1,
        td.suspect AS tsuspect1,
        id.suspect AS isuspect1,
        td.severe AS tsevere1,
        id.severe AS isevere1,
        p2.dead AS dead2,
        l2.event AS event2,
        h2.nurse AS nurse2,
        h2.doctor AS doctor2,
        td2.suspect AS tsuspect2,
        id2.suspect AS isuspect2,
        td2.severe AS tsevere2,
        id2.severe AS isevere2,
        l.finish_date
FROM
        twin_project AS tp
        /* For Twin 1 */
        LEFT JOIN twin_data AS td ON tp.id = td.id
                  AND tp.tvab = td.tvab
        LEFT JOIN informant_data AS id ON tp.id = id.id
                  AND tp.tvab = id.tvab
        LEFT JOIN harmony AS h ON tp.id = h.id
                  AND tp.tvab = h.tvab
        LEFT JOIN lentus AS l ON tp.id = l.id
                  AND tp.tvab = l.tvab
        /* For Twin 2 */
        LEFT JOIN twin_data AS td2 ON p2.id = td2.id
                  AND p2.tvab = td2.tvab
        LEFT JOIN informant_data AS id2 ON p2.id = id2.id
                  AND p2.tvab = id2.tvab
        LEFT JOIN harmony AS h2 ON p2.id = h2.id
```

```
                AND p2.tvab = h2.tvab
        LEFT JOIN lentus AS l2 ON p2.id = l2.id
                AND p2.tvab = l2.tvab,
        person_data AS p1,
        person_data AS p2,
        postal_groups AS pg
WHERE
        /* p1 gets main twin and p2 gets his/her twin. */
        /* ptvab is a field inverted from tvab */
        p1.id = tp.id AND p1.tvab = tp.tvab AND
        p2.id = p1.id AND p2.ptvab = p1.tvab AND
        /* Just the sceening survey */
        tp.survey_no = 5 AND
        /* Skip if partner died before 65 but allow emigration (dead=9) */
        (p2.dead = 0 OR p2.dead = 9 OR
         (p2.dead = 1 AND
          (p2.death_date = 0 OR
           (((TO_DAYS(p2.death_date) - TO_DAYS(p2.birthday)) / 365)
            >= 65))))
        AND
        (
        /* Twin is suspect */
        (td.future_contact = 'Yes' AND td.suspect = 2) OR
        /* Twin is suspect - Informant is Blessed */
        (td.future_contact = 'Yes' AND td.suspect = 1
                                   AND id.suspect = 1) OR
        /* No twin - Informant is Blessed */
        (ISNULL(td.suspect) AND id.suspect = 1
                            AND id.future_contact = 'Yes') OR
        /* Twin broken off - Informant is Blessed */
        (td.participation = 'Aborted'
         AND id.suspect = 1 AND id.future_contact = 'Yes') OR
        /* Twin broken off - No inform - Have partner */
        (td.participation = 'Aborted' AND ISNULL(id.suspect)
                                      AND p2.dead = 0))
        AND
        l.event = 'Finished'
        /* Get at area code */
        AND SUBSTRING(p1.postal_code, 1, 2) = pg.code
        /* Not already distributed */
        AND (h.nurse IS NULL OR h.nurse=00 OR h.doctor=00)
        /* Has not refused or been aborted */
        AND NOT (h.status = 'Refused' OR h.status = 'Aborted'
        OR h.status = 'Died' OR h.status = 'Other')
ORDER BY
        tvid;
```

Some explanations:

`CONCAT(p1.id, p1.tvab) + 0 AS tvid`
: We want to sort on the concatenated `id` and `tvab` in numerical order. Adding `0` to the result causes MySQL to treat the result as a number.

column `id`
: This identifies a pair of twins. It is a key in all tables.

column `tvab`
: This identifies a twin in a pair. It has a value of `1` or `2`.

column `ptvab`
: This is an inverse of `tvab`. When `tvab` is `1` this is `2`, and vice versa. It exists to save typing and to make it easier for MySQL to optimise the query.

This query demonstrates, among other things, how to do lookups on a table from the same table with a join (`p1` and `p2`). In the example, this is used to check whether a twin's partner died before the age of 65. If so, the row is not returned.

All of the above exist in all tables with twin-related information. We have a key on both `id,tvab` (all tables), and `id,ptvab` (`person_data`) to make queries faster.

On our production machine (A 200MHz UltraSPARC), this query returns about 150-200 rows and takes less than one second.

The current number of records in the tables used above:

Table	**Rows**
`person_data`	71074
`lentus`	5291
`twin_project`	5286
`twin_data`	2012
`informant_data`	663
`harmony`	381
`postal_groups`	100

3.7.2 Show a Table of Twin Pair Status

Each interview ends with a status code called `event`. The query shown here is used to display a table over all twin pairs combined by event. This indicates in how many pairs both twins are finished, in how many pairs one twin is finished and the other refused, and so on.

```
SELECT
        t1.event,
        t2.event,
        COUNT(*)
FROM
        lentus AS t1,
        lentus AS t2,
        twin_project AS tp
WHERE
        /* We are looking at one pair at a time */
```

```
        t1.id = tp.id
        AND t1.tvab=tp.tvab
        AND t1.id = t2.id
        /* Just the sceening survey */
        AND tp.survey_no = 5
        /* This makes each pair only appear once */
        AND t1.tvab='1' AND t2.tvab='2'
GROUP BY
        t1.event, t2.event;
```

3.8 Using MySQL with Apache

There are programs that let you authenticate your users from a MySQL database and also let you write your log files into a MySQL table.

You can change the Apache logging format to be easily readable by MySQL by putting the following into the Apache configuration file:

```
LogFormat \
        "\"%h\",%{%Y%m%d%H%M%S}t,%>s,\"%b\",\"%{Content-Type}o\",  \
        \"%U\",\"%{Referer}i\",\"%{User-Agent}i\""
```

To load a log file in that format into MySQL, you can use a statement something like this:

```
LOAD DATA INFILE '/local/access_log' INTO TABLE table_name
FIELDS TERMINATED BY ',' OPTIONALLY ENCLOSED BY '"' ESCAPED BY '\\'
```

The named table should be created to have columns that correspond to those that the `LogFormat` line writes to the log file.

4 Database Administration

4.1 Configuring MySQL

4.1.1 `mysqld` Command-line Options

In most cases you should manage `mysqld` options through option files. See Section 4.1.2 [Option files], page 203.

`mysqld` and `mysqld.server` read options from the `mysqld` and `server` groups. `mysqld_safe` read options from the `mysqld`, `server`, `mysqld_safe` and `safe_mysqld` groups. An embedded MySQL server usually reads options from the `server`, `embedded` and `xxxxx_SERVER`, where `xxxxx` is the name of the application.

`mysqld` accepts a lot of command-line options. Here follows some of the most common ones. For a full list execute `mysqld --help`. Options used for replication are listed in a separate section, see Section 4.11.6 [Replication Options], page 369.

`--ansi`
: Use SQL-99 syntax instead of MySQL syntax. See Section 1.7.2 [ANSI mode], page 33.

`-b, --basedir=path`
: Path to installation directory. All paths are usually resolved relative to this.

`--big-tables`
: Allow big result sets by saving all temporary sets on file. It solves most 'table full' errors, but also slows down the queries where in-memory tables would suffice. Since Version 3.23.2, MySQL is able to solve it automatically by using memory for small temporary tables and switching to disk tables where necessary.

`--bind-address=IP`
: IP address to bind to.

`--console`
: Write the error log messages to stderr/stdout even if `--log-error` is specified. On Windows, `mysqld` will not close the console screen if this option is used.

`--character-sets-dir=path`
: Directory where character sets are. See Section 4.7.1 [Character sets], page 306.

`--chroot=path`
: Put `mysqld` daemon in chroot environment at startup. Recommended security measure since MySQL 4.0 (MySQL 3.23 is not able to provide 100% closed chroot jail). It somewhat limits `LOAD DATA INFILE` and `SELECT ... INTO OUTFILE` though.

`--core-file`
: Write a core file if `mysqld` dies. For some systems you must also specify `--core-file-size` to `mysqld_safe`. See Section 4.8.2 [`mysqld_safe`], page 312. Note that on some systems, like Solaris, you will not get a core file if you are also using the `--user` option.

`-h, --datadir=path`
: Path to the database root.

`--debug[...]=`
: If MySQL is configured with `--with-debug`, you can use this option to get a trace file of what `mysqld` is doing. See Section E.1.2 [Making trace files], page 1008.

`--default-character-set=charset`
: Set the default character set. See Section 4.7.1 [Character sets], page 306.

`--default-table-type=type`
: Set the default table type for tables. See Chapter 7 [Table types], page 594.

`--delay-key-write[= OFF | ON | ALL]`
: How MyISAM `DELAYED KEYS` should be used. See Section 5.5.2 [Server parameters], page 427.

`--delay-key-write-for-all-tables; In MySQL 4.0.3 you should use --delay-key-write=ALL instead.`
: Don't flush key buffers between writes for any `MyISAM` table. See Section 5.5.2 [Server parameters], page 427.

`--des-key-file=filename`
: Read the default keys used by `DES_ENCRYPT()` and `DES_DECRYPT()` from this file.

`--enable-external-locking (was --enable-locking)`
: Enable system locking. Note that if you use this option on a system on which `lockd` does not fully work (as on Linux), you will easily get mysqld to deadlock.

`--enable-named-pipe`
: Enable support for named pipes (only on NT/Win2000/XP).

`-T, --exit-info`
: This is a bit mask of different flags one can use for debugging the mysqld server; one should not use this option if one doesn't know exactly what it does!

`--flush`
: Flush all changes to disk after each SQL command. Normally MySQL only does a write of all changes to disk after each SQL command and lets the operating system handle the syncing to disk. See Section A.4.1 [Crashing], page 859.

`-?, --help`
: Display short help and exit.

`--init-file=file`
: Read SQL commands from this file at startup.

`-L, --language=...`
: Client error messages in given language. May be given as a full path. See Section 4.7.2 [Languages], page 307.

`-l, --log[=file]`
: Log connections and queries to file. See Section 4.10.2 [Query log], page 350.

`--log-bin=[file]`
: Log all queries that change data to the file. Used for backup and replication. See Section 4.10.4 [Binary log], page 351.

`--log-bin-index[=file]`
: Index file for binary log file names. See Section 4.10.4 [Binary log], page 351.

`--log-error[=file]`
: Log errors and startup messages to this file. See Section 4.10.1 [Error log], page 350.

`--log-isam[=file]`
: Log all ISAM/MyISAM changes to file (only used when debugging ISAM/MyISAM).

`--log-long-format`
: Log some extra information to the logfiles (update log, binary update log, and slow queries log, whatever log has been activated). For example, username and timestamp are logged for queries. If you are using `--log-slow-queries` and `--log-long-format`, then also queries that are not using indexes are logged to the slow query log. Note that `--log-long-format` is deprecated as of MySQL version 4.1, when `--log-short-format` was introduced (the long log format is the default setting since version 4.1). Also note that starting with MySQL 4.1 the `--log-queries-not-using-indexes` option is available for the purpose of logging queries that do not use indexes to the slow queries log.

`--log-queries-not-using-indexes`
: If you are using this option with `--log-slow-queries`, then also queries that are not using indexes are logged to the slow query log. This option is available as of MySQL 4.1. See Section 4.10.5 [Slow query log], page 354.

`--log-short-format`
: Log less information to the logfiles (update log, binary update log, and slow queries log, whatever log has been activated). For example, username and timestamp are not logged for queries. This options was introduced in MySQL 4.1.

`--log-slow-queries[=file]`
: Log all queries that have taken more than `long_query_time` seconds to execute to file. Note that the default for the amount of information logged has changed in MySQL 4.1. See the `--log-long-format` and `--log-long-format` options for details. See Section 4.10.5 [Slow query log], page 354.

`--log-update[=file]`
: Log updates to `file.#` where `#` is a unique number if not given. See Section 4.10.3 [Update log], page 351. The update log is deprecated and will be removed in MySQL 5.0; you should use the binary log instead (`--log-bin`). See Section 4.10.4 [Binary log], page 351. Starting from version 5.0, using `--log-update` will just turn on the binlog instead.

`--low-priority-updates`
: Table-modifying operations (`INSERT`/`DELETE`/`UPDATE`) will have lower priority than selects. It can also be done via `{INSERT | REPLACE | UPDATE | DELETE}`

`LOW_PRIORITY ...` to lower the priority of only one query, or by `SET LOW_PRIORITY_UPDATES=1` to change the priority in one thread. See Section 5.3.2 [Table locking], page 419.

`--memlock`

Lock the `mysqld` process in memory. This works only if your system supports the `mlockall()` system call (like Solaris). This may help if you have a problem where the operating system is causing `mysqld` to swap on disk. Note that use of this option requires that you run the server as `root`, which is normally not a good idea for security reasons.

`--myisam-recover [=option[,option...]]]`

Option is any combination of `DEFAULT`, `BACKUP`, `FORCE` or `QUICK`. You can also set this explicitly to `""` if you want to disable this option. If this option is used, `mysqld` will on open check if the table is marked as crashed or if the table wasn't closed properly. (The last option only works if you are running with `--skip-external-locking`.) If this is the case `mysqld` will run check on the table. If the table was corrupted, `mysqld` will attempt to repair it.

The following options affects how the repair works.

Option	Description
DEFAULT	The same as not giving any option to `--myisam-recover`.
BACKUP	If the data table was changed during recover, save a backup of the '`table_name.MYD`' datafile as '`table_name-datetime.BAK`'.
FORCE	Run recover even if we will lose more than one row from the .MYD file.
QUICK	Don't check the rows in the table if there aren't any delete blocks.

Before a table is automatically repaired, MySQL will add a note about this in the error log. If you want to be able to recover from most things without user intervention, you should use the options `BACKUP,FORCE`. This will force a repair of a table even if some rows would be deleted, but it will keep the old datafile as a backup so that you can later examine what happened.

`--new` From version 4.0.12, the `--new` option can be used to make the server behave as 4.1 in certain aspects, easing a 4.0 to 4.1 upgrade:

- `TIMESTAMP` is returned as a string with the format `'YYYY-MM-DD HH:MM:SS'`. See Section 6.2 [Column types], page 453.

`--pid-file=path`

Path to pid file used by `mysqld_safe`.

`-P, --port=...`

Port number to listen for TCP/IP connections.

`-o, --old-protocol`

Use the 3.20 protocol for compatibility with some very old clients. See Section 2.5.5 [Upgrading-from-3.20], page 118.

`--one-thread`

Only use one thread (for debugging under Linux). See Section E.1 [Debugging server], page 1007.

`--open-files-limit=`
: To change the number of file descriptors available to `mysqld`. If this is not set or set to 0, then `mysqld` will use this value to reserve file descriptors to use with `setrlimit()`. If this value is 0 then `mysqld` will reserve `max_connections*5` or `max_connections + table_cache*2` (whichever is larger) number of files. You should try increasing this if `mysqld` gives you the error 'Too many open files'.

`-O, --set-variable var=option`
: Give a variable a value. `--help` lists variables. You can find a full description for all variables in the `SHOW VARIABLES` section in this manual. See Section 4.6.8.4 [SHOW VARIABLES], page 290. The tuning server parameters section includes information of how to optimise these. Please note that `--set-variable` is deprecated since MySQL 4.0, just use `--var=option` on its own. See Section 5.5.2 [Server parameters], page 427.

  In MySQL 4.0.2 one can set a variable directly with `--variable-name=option` and `set-variable` is no longer needed in option files.

  If you want to restrict the maximum value a startup option can be set to with `SET`, you can define this by using the `--maximum-variable-name` command line option. See Section 5.5.6 [SET OPTION], page 432.

  Note that when setting a variable to a value, MySQL may automatically correct it to stay within a given range and also adjusts the value a little to fix for the used algorithm.

`--safe-mode`
: Skip some optimise stages.

`--safe-show-database`
: With this option, the `SHOW DATABASES` command returns only those databases for which the user has some kind of privilege. From version 4.0.2 this option is deprecated and doesn't do anything (the option is enabled by default) as we now have the `SHOW DATABASES` privilege. See Section 4.4.1 [GRANT], page 239.

`--safe-user-create`
: If this is enabled, a user can't create new users with the GRANT command, if the user doesn't have `INSERT` privilege to the `mysql.user` table or any column in this table.

`--skip-bdb`
: Disable usage of BDB tables. This will save memory and may speed up some things.

`--skip-concurrent-insert`
: Turn off the ability to select and insert at the same time on `MyISAM` tables. (This is only to be used if you think you have found a bug in this feature.)

`--skip-delay-key-write`
: In MySQL 4.0.3 you should use –delay-key-write=OFF instead. Ignore the `DELAY_KEY_WRITE` option for all tables. See Section 5.5.2 [Server parameters], page 427.

`--skip-grant-tables`
: This option causes the server not to use the privilege system at all. This gives everyone **full access** to all databases! (You can tell a running server to start using the grant tables again by executing `mysqladmin flush-privileges` or `mysqladmin reload`.)

`--skip-host-cache`
: Never use host name cache for faster name-ip resolution, but query DNS server on every connect instead. See Section 5.5.5 [DNS], page 432.

`--skip-innodb`
: Disable usage of Innodb tables. This will save memory and disk space and speed up some things.

`--skip-external-locking (was --skip-locking)`
: Don't use system locking. To use `isamchk` or `myisamchk` you must shut down the server. See Section 1.2.3 [Stability], page 8. Note that in MySQL Version 3.23 you can use `REPAIR` and `CHECK` to repair/check `MyISAM` tables.

`--skip-name-resolve`
: Hostnames are not resolved. All `Host` column values in the grant tables must be IP numbers or `localhost`. See Section 5.5.5 [DNS], page 432.

`--skip-networking`
: Don't listen for TCP/IP connections at all. All interaction with `mysqld` must be made via named pipes or Unix sockets. This option is highly recommended for systems where only local requests are allowed. See Section 5.5.5 [DNS], page 432.

`--skip-new`
: Don't use new, possibly wrong routines.

`--skip-symlink`
: Deprecated option in 4.0.13; use `--skip-symbolic-links` instead.

`--symbolic-links, --skip-symbolic-links`
: Enable or disable symbolic link support. This option has different effects on Windows and Unix.

  On Windows, enabling symbolic links allows you to establish a symbolic link to a database directory by creating a `directory.sym` file that contains the path to the real directory. See Section 2.6.1.2 [Windows symbolic links], page 122.

  On Unix, enabling symbolic links means that you can link a `MyISAM` index file or datafile to another directory with the `INDEX DIRECTORY` or `DATA DIRECTORY` options of the `CREATE TABLE` statement. If you delete or rename the table, the files that its symbolic links point to also will be deleted or renamed.

`--skip-safemalloc`
: If MySQL is configured with `--with-debug=full`, all programs check memory for overruns for every memory allocation and memory freeing operations. This checking is very slow, so for the server you can avoid it when you don't need it by using the `--skip-safemalloc` option.

`--skip-show-database`
: Don't allow the `SHOW DATABASES` command, unless the user has the `SHOW DATABASES` privilege.

`--skip-stack-trace`
: Don't write stack traces. This option is useful when you are running `mysqld` under a debugger. On some systems, you also must use this option to get a core file. See Section E.1 [Debugging server], page 1007.

`--skip-thread-priority`
: Disable using thread priorities for faster response time.

`--socket=path`
: On Unix, the socket file to use for local connections (default '`/tmp/mysql.sock`'). On Windows, the pipe name to use for local connections that use a named pipe (default `MySQL`).

`--sql-mode=value[,value[,value...]]`
: The option values can be any combination of: `REAL_AS_FLOAT`, `PIPES_AS_CONCAT`, `ANSI_QUOTES`, `IGNORE_SPACE`, `ONLY_FULL_GROUP_BY`, `NO_UNSIGNED_SUBTRACTION`, `NO_AUTO_VALUE_ON_ZERO`, `NO_TABLE_OPTIONS`, `NO_FIELD_OPTIONS`, `NO_KEY_OPTIONS`, `NO_DIR_IN_CREATE`, `MYSQL323`, `MYSQL40`, `DB2`, `MAXDB`, `MSSQL`, `ORACLE`, `POSTGRESQL`, or `ANSI`. The value also can be empty (`--sql-mode=""`) if you want to reset it.

  `NO_AUTO_VALUE_ON_ZERO` affects handling of `AUTO_INCREMENT` columns. Normally, you generate the next sequence number for the column by inserting either `NULL` or `0` into it. `NO_AUTO_VALUE_ON_ZERO` suppresses this behaviour for `0` so that only `NULL` generates the next sequence number. This mode can be useful if `0` has been stored in a table's `AUTO_INCREMENT` column (this is not recommended, by the way). For example, if you dump the table with `mysqldump` and then reload it, normally MySQL will generate new sequence numbers when it encounters the `0` values, resulting in a table with different contents than the one that was dumped. Enabling `NO_AUTO_VALUE_ON_ZERO` before reloading the dump file solves this problem. (As of MySQL 4.1.1, when this option value became available, `mysqldump` automatically includes dump output to enable `NO_AUTO_VALUE_ON_ZERO`.)

  Several of the option values are used for compatibility with other servers. If specified, they cause the server to omit from the output of `SHOW CREATE TABLE` those parts of the statement that are not understood by earlier versions of MySQL or other database servers. Using these option values results in `CREATE TABLE` statements that are more portable for use with other servers:

  - The `NO_TABLE_OPTIONS`, `NO_FIELD_OPTIONS`, `NO_DIR_IN_CREATE`, and `NO_KEY_OPTIONS` values cause omission of table options, or options pertaining to column or index definitions.
  - The values `MYSQL323` and `MYSQL40` are for compatibility with MySQL 3.23 and MySQL 4.0.
  - The values used for compatibility with other servers are `DB2`, `MAXDB`, `MSSQL`, `ORACLE`, and `POSTGRESQL`.

These options also affect the output of `mysqldump`, because that program uses `SHOW CREATE TABLE` to obtain the table-creation statements that it includes in its own output.

Several of the option values have a complex effect because they are shorthand for a group or set of values. For example, you can tell the server to run in ANSI mode by using the `--sql-mode=ANSI` (or `--ansi`) option, which is equivalent to specifying both of the following command-line options:

```
--sql-mode=REAL_AS_FLOAT,PIPES_AS_CONCAT,ANSI_QUOTES,IGNORE_SPACE,ONLY_FULL_
--transaction-isolation=SERIALIZABLE
```

Note that specifying ANSI mode in this way also has the effect of setting the transaction isolation level. For more information about running the server in ANSI mode, see Section 1.7.2 [ANSI mode], page 33.

Other "group" values are `DB2`, `MAXDB`, `MSSQL`, `ORACLE`, and `POSTGRESQL`. Specifying any of them turns on the `PIPES_AS_CONCAT`, `ANSI_QUOTES`, `IGNORE_SPACE`, `NO_TABLE_OPTIONS`, `NO_FIELD_OPTIONS`, and `NO_KEY_OPTIONS` values.

The `--sql-mode` option was added in MySQL 3.23.41. The `NO_UNSIGNED_SUBTRACTION` value was added in 4.0.0. `NO_DIR_IN_CREATE` was added in 4.0.15. `NO_AUTO_VALUE_ON_ZERO`, `NO_TABLE_OPTIONS`, `NO_FIELD_OPTIONS`, `NO_KEY_OPTIONS`, `MYSQL323`, `MYSQL40`, `DB2`, `MAXDB`, `MSSQL`, `ORACLE`, `POSTGRESQL`, and `ANSI` were added in 4.1.1.

`--temp-pool`

Using this option will cause most temporary files created by the server to use a small set of names, rather than a unique name for each new file. This is to work around a problem in the Linux kernel dealing with creating many new files with different names. With the old behaviour, Linux seems to "leak" memory, as it's being allocated to the directory entry cache rather than to the disk cache.

`--transaction-isolation={ READ-UNCOMMITTED | READ-COMMITTED | REPEATABLE-READ | SERIALIZABLE }`

Sets the default transaction isolation level. See Section 6.7.6 [`SET TRANSACTION`], page 583.

`-t, --tmpdir=path`

Path of the directory to use for creating temporary files. It may be useful if your default `/tmp` directory resides on a partition that is too small to hold temporary tables. Starting from MySQL 4.1, this option accepts several paths that are used in round-robin fashion. Paths should be separated by colon characters (':') on Unix and semicolon characters (';') on Windows. It is possible to set `tmpdir` to point to a memory-based filesystem, except if the MySQL server is a slave. If it is a slave, it needs some of its temporary files (for replication of temporary tables or of `LOAD DATA INFILE`) to survive a machine's reboot, so a memory-based `tmpdir` which is cleared when the machine reboots is not suitable; a disk-based `tmpdir` is necessary.

`-u, --user={user_name | user_id}`

Run the `mysqld` server as the user having the name `user_name` or numeric user ID `user_id`. ("User" in this context refers to a system login account, not a MySQL user listed in the grant tables.)

This option is **mandatory** when starting `mysqld` as `root`. The server will change its user ID during its startup sequence, causing it to run as that particular user rather than as `root`. See Section 4.3.2 [Security], page 215.

Starting from MySQL 3.23.56 and 4.0.12: To avoid a possible security hole where a user adds a `--user=root` option to some '`my.cnf`' file (thus causing the server to run as `root`), `mysqld` uses only the first `--user` option specified and produces a warning if there are multiple `--user` options. Options in '`/etc/my.cnf`' and '`datadir/my.cnf`' are processed before command-line options, so it is recommended that you put a `--user` option in '`/etc/my.cnf`' and specify a value other than `root`. The option in '`/etc/my.cnf`' will be found before any other `--user` options, which ensures that the server runs as a user other than `root`, and that a warning results if any other `--user` option is found.

`-V, --version`
Display version information and exit.

`-W, --log-warnings`
Print out warnings like `Aborted connection...` to the '`.err`' file. Enabling this option is recommended, for example, if you use replication (you will get more information about what is happening, such as messages about network failures and reconnections). See Section A.2.10 [Communication errors], page 853.

This option used to be called `--warnings`.

You can change most values for a running server with the `SET` command. See Section 5.5.6 [`SET OPTION`], page 432.

4.1.2 '`my.cnf`' Option Files

MySQL can, since Version 3.22, read default startup options for the server and for clients from option files.

On Windows, MySQL reads default options from the following files:

Filename	Purpose
`windows-directory\my.ini`	Global options
`C:\my.cnf`	Global options

`windows-directory` is the location of your Windows directory.

On Unix, MySQL reads default options from the following files:

Filename	Purpose
`/etc/my.cnf`	Global options
`DATADIR/my.cnf`	Server-specific options
`defaults-extra-file`	The file specified with `--defaults-extra-file=path`
`~/.my.cnf`	User-specific options

`DATADIR` is the MySQL data directory (typically '`/usr/local/mysql/data`' for a binary installation or '`/usr/local/var`' for a source installation). Note that this is the directory that was specified at configuration time, not the one specified with `--datadir` when `mysqld` starts up! (`--datadir` has no effect on where the server looks for option files, because the server looks for files before it processes any command-line arguments.)

Note that on Windows you should specify all paths in option files with '/' instead of '\'. If you use '\', you need to specify it twice, because '\' is the escape character in MySQL.

MySQL tries to read option files in the order listed above. If multiple option files exist, an option specified in a file read later takes precedence over the same option specified in a file read earlier. Options specified on the command-line take precedence over options specified in any option file. Some options can be specified using environment variables. Options specified on the command-line or in option files take precedence over environment variable values. See Appendix F [Environment variables], page 1019.

The following programs support option files: `mysql`, `mysqladmin`, `mysqld`, `mysqld_safe`, `mysql.server`, `mysqldump`, `mysqlimport`, `mysqlshow`, `mysqlcheck`, `myisamchk`, and `myisampack`.

Since Version 4.0.2, you can use the `loose` prefix for command-line options (or options in my.cnf). If an option is prefixed by `loose`, the program reading it will not exit with an error if an option is unknown, but will rather only issue a warning:

```
shell> mysql --loose-no-such-option
```

Any long option that may be given on the command-line when running a MySQL program can be given in an option file as well (without the leading double dash). Run the program with the `--help` option to get a list of available options.

An option file can contain lines of the following forms:

`#comment` Comment lines start with '`#`' or '`;`'. Comment can start from a middle of a line too. Empty lines are ignored.

`[group]` `group` is the name of the program or group for which you want to set options. After a group line, any `option` or `set-variable` lines apply to the named group until the end of the option file or another group line is given.

`option` This is equivalent to `--option` on the command-line.

`option=value`
This is equivalent to `--option=value` on the command-line. Please note that you must quote an argument using double quotes, if the argument for an option contains a comment character.

`set-variable = variable=value`
This is equivalent to `--set-variable variable=value` on the command-line. Please note that `--set-variable` is deprecated since MySQL 4.0; as of that version, program variable names can be used as option names. On the command line, just use `--variable=value`. In an option file, use `variable=value`.

The `[client]` group allows you to specify options that apply to all MySQL clients (not `mysqld`). This is the perfect group to use to specify the password that you use to connect to the server. (But make sure the option file is readable and writable only by yourself.)

If you want to create options that should only be read by one specific `mysqld` server version you can do this with `[mysqld-4.0]`, `[mysqld-4.1]` etc:

```
[mysqld-4.0]
new
```

The above new option will only be used with MySQL server versions 4.0.x.

Note that for options and values, all leading and trailing blanks are automatically deleted. You may use the escape sequences '`\b`', '`\t`', '`\n`', '`\r`', '`\\`', and '`\s`' in your value string ('`\s`' == blank).

Here is a typical global option file:

```
[client]
port=3306
socket=/tmp/mysql.sock

[mysqld]
port=3306
socket=/tmp/mysql.sock
set-variable = key_buffer_size=16M
set-variable = max_allowed_packet=1M

[mysqldump]
quick
```

Here is typical user option file:

```
[client]
# The following password will be sent to all standard MySQL clients
password="my_password"

[mysql]
no-auto-rehash
set-variable = connect_timeout=2

[mysqlhotcopy]
interactive-timeout
```

If you have a source distribution, you will find sample configuration files named '`my-xxxx.cnf`' in the '`support-files`' directory. If you have a binary distribution, look in the '`DIR/support-files`' directory, where `DIR` is the pathname to the MySQL installation directory (typically '`C:\mysql`' or '`/usr/local/mysql`'). Currently there are sample configuration files for small, medium, large, and very large systems. You can copy '`my-xxxx.cnf`' to your home directory (rename the copy to '`.my.cnf`') to experiment with this.

All MySQL programs that support option files support the following options:

Option	Description
`--no-defaults`	Don't read any option files.
`--print-defaults`	Print the program name and all options that it will get.
`--defaults-file=full-path-to-default-file`	Only use the given configuration file.
`--defaults-extra-file=full-path-to-default-file`	Read this configuration file after the global configuration file but before the user configuration file.

Note that the options just shown must be first on the command line to work, with the exception that `--print-defaults` may be used immediately after `--defaults-file` or `--defaults-extra-file`.

Note for developers: Option file handling is implemented simply by processing all matching options (that is, options in the appropriate group) before any command-line arguments. This works nicely for programs that use the last instance of an option that is specified multiple times. If you have an old program that handles multiply specified options this way but doesn't read option files, you need add only two lines to give it that capability. Check the source code of any of the standard MySQL clients to see how to do this.

In shell scripts, you can use the `my_print_defaults` command to parse the option files. The following example shows the output that `my_print_defaults` might produce when asked to show the options found in the `[client]` and `[mysql]` groups:

```
shell> my_print_defaults client mysql
--port=3306
--socket=/tmp/mysql.sock
--no-auto-rehash
```

4.2 Running Multiple MySQL Servers on the Same Machine

In some cases you might want to run multiple `mysqld` servers on the same machine. You might want to test a new MySQL release while leaving your existing production setup undisturbed. Or you may want to give different users access to different `mysqld` servers that they manage themselves. (For example, you might be an Internet service provider that wants to provide independent MySQL installations for different customers.)

To run multiple servers on a single machine, each server must have unique values for several operating parameters. These can be set on the command line or in option files. See Section 4.1.1 [Command-line options], page 195, and Section 4.1.2 [Option files], page 203.

At least the following options must be different for each server:

- `--port=port_num`
- `--socket=path`
- `--shared-memory-base-name=name` (Windows only; new in MySQL 4.1)
- `--pid-file=path` (Unix only)

`--port` controls the port number for TCP/IP connections. `--socket` controls the socket file path on Unix and the name of the named pipe on Windows. (It's necessary to specify distinct pipe names on Windows only for those servers that support named pipe connections.) `--shared-memory-base-name` designates the shared memory name used by a Windows server to allow clients to connect via shared memory. `--pid-file` indicates the name of the file in which a Unix server writes its process ID.

If you use the following options, they must be different for each server:

- `--log=path`
- `--log-bin=path`
- `--log-update=path`

- `--log-error=path`
- `--log-isam=path`
- `--bdb-logdir=path`

If you want more performance, you can also specify the following options differently for each server, to spread load between several physical disks:

- `--tmpdir=path`
- `--bdb-tmpdir=path`

Having different temporary directories like above is also recommended because it will be easier for you in case you want to know to which MySQL server a certain temporary file belongs.

Generally, each server should also use a different data directory, which is specified using the `--datadir=path` option.

Warning: Normally you should never have two servers that update data in the same databases! This may lead to unpleasant surprises if your operating system doesn't support fault-free system locking! If (despite this warning) you run multiple servers using the same data directory and they have logging enabled, you must use the appropriate options to specify log file names that are unique to each server. Otherwise, the servers will try to log to the same files.

This warning against sharing a data directory among servers also applies in an NFS environment. Allowing multiple MySQL servers to access a common data directory over NFS is a **bad idea**!

- The primary problem is that NFS will become the speed bottleneck. It is not meant for such use.
- Another risk with NFS is that you will have to come up with a way to make sure that two or more servers do not interfere with each other. Usually NFS file locking is handled by the `lockd` daemon, but at the moment there is no platform that will perform locking 100% reliably in every situation.

Make it easy for yourself: Forget about sharing a data directory among servers over NFS. A better solution is to have one computer that contains several CPUs and use an operating system that handles threads efficiently.

If you have multiple MySQL installations in different locations, normally you can specify the base installation directory for each server with the `--basedir=path` option to cause each server to use a different data directory, log files, and PID file. (The defaults for all these values are determined relative to the base directory.) In that case, the only other options you need to specify are the `--socket` and `--port` options. For example, suppose you install different versions of MySQL using '`.tar`' file binary distributions. These will install in different locations, so you can start the server for each installation using the command `./bin/mysqld_safe` under its corresponding base directory. `mysqld_safe` will determine the proper `--basedir` option to pass to `mysqld`, and you need specify only the `--socket` and `--port` options to `mysqld_safe`.

As discussed in the following sections, it is possible to start additional servers by setting environment variables or by specifying appropriate command-line options. However, if you need to run multiple servers on a more permanent basis, it will be more convenient to use option files to specify for each server those option values that must be unique to it.

4.2.1 Running Multiple Servers on Windows

You can run multiple servers on Windows by starting them manually from the command line, each with appropriate operating parameters. On Windows NT-based systems, you also have the option of installing several servers as Windows services and running them that way. General instructions for running MySQL servers from the command line or as services are given in Section 2.6.1 [Windows], page 122. This section describes how to make sure you start each server with different values for those startup options that must be unique per server, such as the data directory. (These options are described in Section 4.2 [Multiple servers], page 206.)

4.2.1.1 Starting Multiple Windows Servers at the Command Line

To start multiple servers manually from the command line, you can specify the appropriate options on the command line or in an option file. It's more convenient to place the options in an option file, but it's necessary to make sure that each server gets its own set of options. To do this, create an option file for each server and tell the server the filename with a `--defaults-file` option when you run it.

Suppose you want to run `mysqld` on port 3307 with a data directory of '`C:\mydata1`', and `mysqld-max` on port 3308 with a data directory of '`C:\mydata2`'. To accomplish this, create two option files. For example, create one file named '`C:\my-opts1.cnf`' that looks like this:

```
[mysqld]
datadir = C:/mydata1
port = 3307
```

Create a second file named '`C:\my-opts2.cnf`' that looks like this:

```
[mysqld]
datadir = C:/mydata2
port = 3308
```

Then start each server with its own option file:

```
shell> mysqld --defaults-file=C:\my-opts1.cnf
shell> mysqld-max --defaults-file=C:\my-opts2.cnf
```

(On NT, the servers will start in the foreground, so you'll need to issue those two commands in separate console windows.)

To shut down the servers, you must connect to the appropriate port number:

```
shell> mysqladmin --port=3307 shutdown
shell> mysqladmin --port=3308 shutdown
```

Servers configured as just described will allow clients to connect over TCP/IP. If you also want to allow named pipe connections, use the `mysqld-nt` or `mysqld-max-nt` servers and specify options that enable the named pipe and specify its name. (Each server that supports named pipe connections must use a unique pipe name.) For example, the '`C:\my-opts1.cnf`' file might be written like this:

```
[mysqld]
datadir = C:/mydata1
port = 3307
```

```
enable-named-pipe
socket = mypipe1
```

Then start the server this way:

```
shell> mysqld-nt --defaults-file=C:\my-opts1.cnf
```

'`C:\my-opts2.cnf`' would be modified similarly for use by the second server.

4.2.1.2 Starting Multiple Windows Servers as Services

On NT-based systems, a MySQL server can be run as a Windows service. The procedures for installing, controlling, and removing a single MySQL service are described in Section 2.1.1.7 [NT start], page 61.

As of MySQL 4.0.2, you can install multiple servers as services. In this case, you must make sure that each server uses a different service name in addition to all the other parameters that must be unique per server.

For the following instructions, assume that you want to run the `mysqld-nt` server from two different versions of MySQL that are installed at '`C:\mysql-4.0.8`' and '`C:\mysql-4.0.17`', respectively. (This might be the case if you're running 4.0.8 as your production server, but want to test 4.0.17 before upgrading to it.)

The following principles are relevant when installing a MySQL service with the `--install` option:

- If you specify no service name, the server uses the default service name of `MySQL` and the server reads options from the `[mysqld]` group in the standard option files.
- If you specify a service name after the `--install` option, the server ignores the `[mysqld]` option group and instead reads options from the group that has the same name as the service. The server reads options from the standard option files.
- If you specify a `--defaults-file` option after the service name, the server ignores the standard option files and reads options only from the `[mysqld]` group of the named file.

These principles also apply if you install a server using the `--install-manual` option.

Based on the preceding information, you have several ways to set up multiple services. The following instructions describe some examples. Before trying any of them, be sure you shut down and remove any existing MySQL services first.

- Specify the options for all services in one of the standard option files. To do this, use a different service name for each server. Suppose you want to run the 4.0.8 `mysqld-nt` using the service name of `mysqld1` and the 4.0.17 `mysqld-nt` using the service name `mysqld2`. In this case, you can use the `[mysqld1]` group for 4.0.8 and the `[mysqld2]` group for 4.0.17. For example, you can set up '`C:\my.cnf`' like this:

  ```
  # options for mysqld1 service
  [mysqld1]
  basedir = C:/mysql-4.0.8
  port = 3307
  enable-named-pipe
  socket = mypipe1
  ```

```
# options for mysqld2 service
[mysqld2]
basedir = C:/mysql-4.0.17
port = 3308
enable-named-pipe
socket = mypipe2
```

Install the services as follows, using the full server pathnames to ensure that Windows registers the correct executable program for each service:

```
shell> C:\mysql-4.0.8\bin\mysqld-nt --install mysqld1
shell> C:\mysql-4.0.17\bin\mysqld-nt --install mysqld2
```

To start the services, use the services manager, or use `NET START` with the appropriate service names:

```
shell> NET START mysqld1
shell> NET START mysqld2
```

To stop the services, use the services manager, or use `NET STOP` with the appropriate service names:

```
shell> NET STOP mysqld1
shell> NET STOP mysqld2
```

Note: Before MySQL 4.0.17, only a server installed using the default service name (`MySQL`) or one installed explicitly with a service name of `mysqld` will read the `[mysqld]` group in the standard option files. As of 4.0.17, all servers read the `[mysqld` group if they read the standard option files, even if they are installed using another service name. This allows you to use the `[mysqld]` group for options that should be used by all MySQL services, and an option group named after each service for use by the server installed with that service name.

- Specify options for each server in separate files and use `--defaults-file` when you install the services to tell each server what file to use. In this case, each file should list options using a `[mysqld]` group.

  With this approach, to specify options for the 4.0.8 `mysqld-nt`, create a file '`C:\my-opts1.cnf`' that looks like this:

  ```
  [mysqld]
  basedir = C:/mysql-4.0.8
  port = 3307
  enable-named-pipe
  socket = mypipe1
  ```

  For the 4.0.17 `mysqld-nt`, create a file '`C:\my-opts2.cnf`' that looks like this:

  ```
  [mysqld]
  basedir = C:/mysql-4.0.17
  port = 3308
  enable-named-pipe
  socket = mypipe2
  ```

  Install the services as follows (enter each command on a single line):

  ```
  shell> C:\mysql-4.0.8\bin\mysqld-nt --install mysqld1
  ```

```
            --defaults-file=C:\my-opts1.cnf
shell> C:\mysql-4.0.17\bin\mysqld-nt --install mysqld2
            --defaults-file=C:\my-opts2.cnf
```

To use a `--defaults-file` option when you install a MySQL server as a service, you must precede the option with the service name.

After installing the services, start and stop them the same way as in the preceding example.

To remove multiple services, use `mysqld --remove` for each one, specifying a service name following the `--remove` option if the service to remove has a name different than the default.

4.2.2 Running Multiple Servers on Unix

The easiest way is to run multiple servers on Unix is to compile them with different TCP/IP ports and socket files so that each one is listening on different network interfaces. Also, by compiling in different base directories for each installation, that automatically results in different compiled-in data directory, log file, and PID file locations for each of your servers.

Assume an existing server is configured for the default port number and socket file. To configure a new server to have different operating parameters, use a `configure` command something like this:

```
shell> ./configure --with-tcp-port=port_number \
            --with-unix-socket-path=file_name \
            --prefix=/usr/local/mysql-4.0.17
```

Here `port_number` and `file_name` should be different from the default port number and socket file pathname, and the `--prefix` value should specify an installation directory different than the one under which the existing MySQL installation is located.

If you have a MySQL server listening on a given port number, you can use the following command to find out what operating parameters it is using for several important configurable variables, including the base directory and socket name:

```
shell> mysqladmin --host=host_name --port=port_number variables
```

With the information displayed by that command, you can tell what option values **not** to use when configuring an additional server.

Note that if you specify "`localhost`" as a hostname, `mysqladmin` will default to using a Unix socket connection rather than TCP/IP. In MySQL 4.1, you can explicitly specify the connection protocol to use by using the `--protocol={TCP | SOCKET | PIPE | MEMORY}` option.

You don't have to compile a new MySQL server just to start with a different socket file and TCP/IP port number. It is also possible to specify those values at runtime. One way to do so is by using command-line options:

```
shell> /path/to/mysqld_safe --socket=file_name --port=port_number
```

To use another database directory for the second server, pass a `--datadir=path` option to `mysqld_safe`.

Another way to achieve a similar effect is to use environment variables to set the socket name and port number:

```
shell> MYSQL_UNIX_PORT=/tmp/mysqld-new.sock
shell> MYSQL_TCP_PORT=3307
shell> export MYSQL_UNIX_PORT MYSQL_TCP_PORT
shell> scripts/mysql_install_db
shell> bin/mysqld_safe &
```

This is a quick way of starting a second server to use for testing. The nice thing about this method is that the environment variable settings will apply to any client programs that you invoke from the above shell. Thus, connections for those clients automatically will be directed to the second server!

Appendix F [Environment variables], page 1019 includes a list of other environment variables you can use to affect `mysqld`.

For automatic server execution, your startup script that is executed at boot time should execute the following command once for each server with an appropriate option file path for each command:

```
mysqld_safe --defaults-file=path-to-option-file
```

Each option file should contain option values specific to a given server.

On Unix, the `mysqld_multi` script is another way to start multiple servers. See Section 4.8.3 [`mysqld_multi`], page 313.

4.2.3 Using Client Programs in a Multiple-Server Environment

When you want to connect with a client program to a MySQL server that is listening to different network interfaces than those compiled into your client, you can use one of the following methods:

- Start the client with `--host=host_name --port=port_number` to connect via TCP/IP to a remote host, or with `--host=localhost --socket=file_name` to connect to a local host via a Unix socket or a Windows named pipe.
- As of MySQL 4.1, start the client with `--protocol=tcp` to connect via TCP/IP, `--protocol=socket` to connect via a Unix socket, `--protocol=pipe` to connect via a named pipe, or `--protocol=memory` to connect via shared memory. For TCP/IP connections, you may also need to specify `--host` and `--port` options. For the other types of connections, you may need to specify a `--socket` option to specify a socket or named pipe name, or a `--shared-memory-base-name` option to specify the shared memory name.
- On Unix, set the `MYSQL_UNIX_PORT` and `MYSQL_TCP_PORT` environment variables to point to the Unix socket and TCP/IP port before you start your clients. If you normally use a specific socket or port, you can place commands to set these environment variables in your '`.login`' file so that they apply each time you log in. See Appendix F [Environment variables], page 1019.
- Specify the default socket and TCP/IP port in the `[client]` group of an option file. Foe example, you can use '`C:\my.cnf`' on Windows, or the '`.my.cnf`' file in your home directory on Unix. See Section 4.1.2 [Option files], page 203.
- In a C program, you can specify the port or socket arguments in the `mysql_real_connect()` call. You can also have the program read option files by calling `mysql_options()`. See Section 11.1.3 [C API functions], page 723.

- If you are using the Perl `DBD::mysql` module, you can read the options from the MySQL option files. For example:

```
$dsn = "DBI:mysql:test;mysql_read_default_group=client;"
        . "mysql_read_default_file=/usr/local/mysql/data/my.cnf";
$dbh = DBI->connect($dsn, $user, $password);
```

  See Section 11.5.2 [Perl DBI Class], page 817.

4.3 General Security Issues and the MySQL Access Privilege System

MySQL has an advanced but non-standard security/privilege system. This section describes how it works.

4.3.1 General Security Guidelines

Anyone using MySQL on a computer connected to the Internet should read this section to avoid the most common security mistakes.

In discussing security, we emphasise the necessity of fully protecting the entire server host (not simply the MySQL server) against all types of applicable attacks: eavesdropping, altering, playback, and denial of service. We do not cover all aspects of availability and fault tolerance here.

MySQL uses security based on Access Control Lists (ACLs) for all connections, queries, and other operations that a user may attempt to perform. There is also some support for SSL-encrypted connections between MySQL clients and servers. Many of the concepts discussed here are not specific to MySQL at all; the same general ideas apply to almost all applications.

When running MySQL, follow these guidelines whenever possible:

- **Do not ever give anyone (except the mysql `root` user) access to the `user` table in the `mysql` database!** This is critical. **The encrypted password is the real password in MySQL.** Anyone who knows the password which is listed in the `user` table and has access to the host listed for the account **can easily log in as that user**.
- Learn the MySQL access privilege system. The `GRANT` and `REVOKE` commands are used for controlling access to MySQL. Do not grant any more privileges than necessary. Never grant privileges to all hosts.

  Checklist:

  - Try `mysql -u root`. If you are able to connect successfully to the server without being asked for a password, you have problems. Anyone can connect to your MySQL server as the MySQL `root` user with full privileges! Review the MySQL installation instructions, paying particular attention to the item about setting a `root` password.
  - Use the command `SHOW GRANTS` and check to see who has access to what. Remove those privileges that are not necessary using the `REVOKE` command.

- Do not keep any plain-text passwords in your database. When your computer becomes compromised, the intruder can take the full list of passwords and use them. Instead use `MD5()`, `SHA1()` or another one-way hashing function.
- Do not choose passwords from dictionaries. There are special programs to break them. Even passwords like "xfish98" are very bad. Much better is "duag98" which contains the same word "fish" but typed one key to the left on a standard QWERTY keyboard. Another method is to use "Mhall" which is taken from the first characters of each word in the sentence "Mary had a little lamb." This is easy to remember and type, but difficult to guess for someone who does not know it.
- Invest in a firewall. This protects you from at least 50% of all types of exploits in any software. Put MySQL behind the firewall or in a demilitarised zone (DMZ).

  Checklist:

  – Try to scan your ports from the Internet using a tool such as `nmap`. MySQL uses port 3306 by default. This port should be inaccessible from untrusted hosts. Another simple way to check whether or not your MySQL port is open is to try the following command from some remote machine, where `server_host` is the hostname of your MySQL server:

    ```
    shell> telnet server_host 3306
    ```

    If you get a connection and some garbage characters, the port is open, and should be closed on your firewall or router, unless you really have a good reason to keep it open. If `telnet` just hangs or the connection is refused, everything is OK; the port is blocked.
- Do not trust any data entered by your users. They can try to trick your code by entering special or escaped character sequences in web forms, URLs, or whatever application you have built. Be sure that your application remains secure if a user enters something like "`; DROP DATABASE mysql;`". This is an extreme example, but large security leaks and data loss may occur as a result of hackers using similar techniques, if you do not prepare for them.

  Also remember to check numeric data. A common mistake is to protect only strings. Sometimes people think that if a database contains only publicly available data that it need not be protected. This is incorrect. At least denial-of-service type attacks can be performed on such databases. The simplest way to protect from this type of attack is to use apostrophes around the numeric constants: `SELECT * FROM table WHERE ID='234'` rather than `SELECT * FROM table WHERE ID=234`. MySQL automatically converts this string to a number and strips all non-numeric symbols from it.

  Checklist:

  – All web applications:

    - Try to enter '`'`' and '`"`' in all your web forms. If you get any kind of MySQL error, investigate the problem right away.
    - Try to modify any dynamic URLs by adding `%22` ('`"`'), `%23` ('`#`'), and `%27` ('`'`') in the URL.
    - Try to modify datatypes in dynamic URLs from numeric ones to character ones containing characters from previous examples. Your application should be safe against this and similar attacks.

    - Try to enter characters, spaces, and special symbols instead of numbers in numeric fields. Your application should remove them before passing them to MySQL or your application should generate an error. Passing unchecked values to MySQL is very dangerous!
    - Check data sizes before passing them to MySQL.
    - Consider having your application connect to the database using a different user name than the one you use for administrative purposes. Do not give your applications any more access privileges than they need.
  - Users of PHP:
    - Check out the `addslashes()` function. As of PHP 4.0.3, a `mysql_escape_string()` function is available that is based on the function of the same name in the MySQL C API.
  - Users of MySQL C API:
    - Check out the `mysql_real_escape_string()` API call.
  - Users of MySQL++:
    - Check out the `escape` and `quote` modifiers for query streams.
  - Users of Perl DBI:
    - Check out the `quote()` method or use placeholders.
  - Users of Java JDBC:
    - Use a `PreparedStatement` object and placeholders.
- Do not transmit plain (unencrypted) data over the Internet. These data are accessible to everyone who has the time and ability to intercept it and use it for their own purposes. Instead, use an encrypted protocol such as SSL or SSH. MySQL supports internal SSL connections as of Version 4.0.0. SSH port-forwarding can be used to create an encrypted (and compressed) tunnel for the communication.
- Learn to use the `tcpdump` and `strings` utilities. For most cases, you can check whether MySQL data streams are unencrypted by issuing a command like the following:

  ```
  shell> tcpdump -l -i eth0 -w - src or dst port 3306 | strings
  ```

  (This works under Linux and should work with small modifications under other systems.) Warning: If you do not see data this doesn't always actually mean that it is encrypted. If you need high security, you should consult with a security expert.

4.3.2 How to Make MySQL Secure Against Crackers

When you connect to a MySQL server, you normally should use a password. The password is not transmitted in clear text over the connection, however the encryption algorithm is not very strong, and with some effort a clever attacker can crack the password if he is able to sniff the traffic between the client and the server. If the connection between the client and the server goes through an untrusted network, you should use an SSH tunnel to encrypt the communication.

All other information is transferred as text that can be read by anyone who is able to watch the connection. If you are concerned about this, you can use the compressed protocol (in MySQL Version 3.22 and above) to make things much harder. To make

things even more secure you should use `ssh`. You can find an `Open Source ssh` client at `http://www.openssh.org/`, and a commercial `ssh` client at `http://www.ssh.com/`. With this, you can get an encrypted TCP/IP connection between a MySQL server and a MySQL client.

If you are using MySQL 4.0, you can also use internal OpenSSL support. See Section 4.4.10 [Secure connections], page 252.

To make a MySQL system secure, you should strongly consider the following suggestions:

- Use passwords for all MySQL users. Remember that anyone can log in as any other person as simply as `mysql -u other_user db_name` if `other_user` has no password. It is common behaviour with client/server applications that the client may specify any user name. You can change the password of all users by editing the `mysql_install_db` script before you run it, or only the password for the MySQL `root` user like this:

  ```
  shell> mysql -u root mysql
  mysql> UPDATE user SET Password=PASSWORD('new_password')
      ->             WHERE user='root';
  mysql> FLUSH PRIVILEGES;
  ```

- Don't run the MySQL daemon as the Unix `root` user. This is very dangerous, because any user with the `FILE` privilege will be able to create files as `root` (for example, `~root/.bashrc`). To prevent this, `mysqld` will refuse to run as `root` unless it is specified directly using a `--user=root` option.

  `mysqld` can be run as an ordinary unprivileged user instead. You can also create a new Unix user `mysql` to make everything even more secure. If you run `mysqld` as another Unix user, you don't need to change the `root` user name in the `user` table, because MySQL user names have nothing to do with Unix user names. To start `mysqld` as another Unix user, add a `user` line that specifies the user name to the `[mysqld]` group of the '`/etc/my.cnf`' option file or the '`my.cnf`' option file in the server's data directory. For example:

  ```
  [mysqld]
  user=mysql
  ```

  This will cause the server to start as the designated user whether you start it manually or by using `mysqld_safe` or `mysql.server`. For more details, see Section A.3.2 [Changing MySQL user], page 858.

- Don't support symlinks to tables (this can be disabled with the `--skip-symlink` option). This is especially important if you run `mysqld` as root as anyone that has write access to the mysqld data directories could then delete any file in the system! See Section 5.6.1.2 [Symbolic links to tables], page 439.

- Check that the Unix user that `mysqld` runs as is the only user with read/write privileges in the database directories.

- Don't give the `PROCESS` privilege to all users. The output of `mysqladmin processlist` shows the text of the currently executing queries, so any user who is allowed to execute that command might be able to see if another user issues an `UPDATE user SET password=PASSWORD('not_secure')` query.

  `mysqld` reserves an extra connection for users who have the `PROCESS` privilege, so that a MySQL `root` user can log in and check things even if all normal connections are in use.

- Don't give the `FILE` privilege to all users. Any user that has this privilege can write a file anywhere in the filesystem with the privileges of the `mysqld` daemon! To make this a bit safer, all files generated with `SELECT ... INTO OUTFILE` are writeable by everyone, and you cannot overwrite existing files.

  The `FILE` privilege may also be used to read any world readable file that is accessible to the Unix user that the server runs as. One can also read any file to the current database (which the user need some privilege for). This could be abused, for example, by using `LOAD DATA` to load '`/etc/passwd`' into a table, which can then be read with `SELECT`.
- If you don't trust your DNS, you should use IP numbers instead of hostnames in the grant tables. In any case, you should be very careful about creating grant table entries using hostname values that contain wildcards!
- If you want to restrict the number of connections for a single user, you can do this by setting the `max_user_connections` variable in `mysqld`.

4.3.3 Startup Options for `mysqld` Concerning Security

The following `mysqld` options affect security:

`--local-infile[=(0|1)]`
: If one uses `--local-infile=0` then one can't use `LOAD DATA LOCAL INFILE`.

`--safe-show-database`
: With this option, the `SHOW DATABASES` command returns only those databases for which the user has some kind of privilege. From version 4.0.2 this option is deprecated and doesn't do anything (the option is enabled by default) as we now have the `SHOW DATABASES` privilege. See Section 4.4.1 [GRANT], page 239.

`--safe-user-create`
: If this is enabled, an user can't create new users with the `GRANT` command, if the user doesn't have the `INSERT` privilege for the `mysql.user` table. If you want to give a user access to just create new users with those privileges that the user has right to grant, you should give the user the following privilege:

  ```
  mysql> GRANT INSERT(user) ON mysql.user TO 'user'@'hostname';
  ```

  This will ensure that the user can't change any privilege columns directly, but has to use the `GRANT` command to give privileges to other users.

`--skip-grant-tables`
: This option causes the server not to use the privilege system at all. This gives everyone **full access** to all databases! (You can tell a running server to start using the grant tables again by executing `mysqladmin flush-privileges` or `mysqladmin reload`.)

`--skip-name-resolve`
: Hostnames are not resolved. All `Host` column values in the grant tables must be IP numbers or `localhost`.

`--skip-networking`
: Don't allow TCP/IP connections over the network. All connections to `mysqld` must be made via Unix sockets. This option is unsuitable when using a MySQL

version prior to 3.23.27 with the MIT-pthreads package, because Unix sockets were not supported by MIT-pthreads at that time.

`--skip-show-database`
: Don't allow `SHOW DATABASES` command, unless the user has the `SHOW DATABASES` privilege. From version 4.0.2 you should no longer need this option, since access can now be granted specifically with the `SHOW DATABASES` privilege.

4.3.4 Security issues with `LOAD DATA LOCAL`

In MySQL 3.23.49 and MySQL 4.0.2, we added some new options to deal with possible security issues when it comes to `LOAD DATA LOCAL`.

There are two possible problems with supporting this command:

As the reading of the file is initiated from the server, one could theoretically create a patched MySQL server that could read any file on the client machine that the current user has read access to, when the client issues a query against the table.

In a web environment where the clients are connecting from a web server, a user could use `LOAD DATA LOCAL` to read any files that the web server process has read access to (assuming a user could run any command against the SQL server).

There are two separate fixes for this:

If you don't configure MySQL with `--enable-local-infile`, then `LOAD DATA LOCAL` will be disabled by all clients, unless one calls `mysql_options(... MYSQL_OPT_LOCAL_INFILE, 0)` in the client. See Section 11.1.3.39 [`mysql_options()`], page 748.

For the `mysql` command-line client, `LOAD DATA LOCAL` can be enabled by specifying the option `--local-infile[=1]`, or disabled with `--local-infile=0`.

By default, all MySQL clients and libraries are compiled with `--enable-local-infile`, to be compatible with MySQL 3.23.48 and before.

One can disable all `LOAD DATA LOCAL` commands in the MySQL server by starting `mysqld` with `--local-infile=0`.

In the case that `LOAD DATA LOCAL INFILE` is disabled in the server or the client, you will get the error message (1148):

```
The used command is not allowed with this MySQL version
```

4.3.5 What the Privilege System Does

The primary function of the MySQL privilege system is to authenticate a user connecting from a given host, and to associate that user with privileges on a database such as `SELECT`, `INSERT`, `UPDATE` and `DELETE`.

Additional functionality includes the ability to have an anonymous user and to grant privileges for MySQL-specific functions such as `LOAD DATA INFILE` and administrative operations.

4.3.6 How the Privilege System Works

The MySQL privilege system ensures that all users may do exactly the things that they are supposed to be allowed to do. When you connect to a MySQL server, your identity is determined by **the host from which you connect** and **the user name you specify**. The system grants privileges according to your identity and **what you want to do**.

MySQL considers both your hostname and user name in identifying you because there is little reason to assume that a given user name belongs to the same person everywhere on the Internet. For example, the user `joe` who connects from `office.com` need not be the same person as the user `joe` who connects from `elsewhere.com`. MySQL handles this by allowing you to distinguish users on different hosts that happen to have the same name: you can grant `joe` one set of privileges for connections from `office.com`, and a different set of privileges for connections from `elsewhere.com`.

MySQL access control involves two stages:

- Stage 1: The server checks whether you are even allowed to connect.
- Stage 2: Assuming you can connect, the server checks each request you issue to see whether you have sufficient privileges to perform it. For example, if you try to select rows from a table in a database or drop a table from the database, the server makes sure you have the `SELECT` privilege for the table or the `DROP` privilege for the database.

Note that if your privileges are changed (either by yourself or someone else) while you are connected, those changes will not necessarily take effect with your next query or queries. See Section 4.4.3 [Privilege changes], page 244 for details.

The server uses the `user`, `db`, and `host` tables in the `mysql` database at both stages of access control. The fields in these grant tables are shown here:

Table name	**user**	**db**	**host**
Scope fields	`Host`	`Host`	`Host`
	`User`	`Db`	`Db`
	`Password`	`User`	
Privilege fields	`Select_priv`	`Select_priv`	`Select_priv`
	`Insert_priv`	`Insert_priv`	`Insert_priv`
	`Update_priv`	`Update_priv`	`Update_priv`
	`Delete_priv`	`Delete_priv`	`Delete_priv`
	`Index_priv`	`Index_priv`	`Index_priv`
	`Alter_priv`	`Alter_priv`	`Alter_priv`
	`Create_priv`	`Create_priv`	`Create_priv`
	`Drop_priv`	`Drop_priv`	`Drop_priv`
	`Grant_priv`	`Grant_priv`	`Grant_priv`
	`References_priv`	`References_priv`	`References_priv`
	`Reload_priv`		
	`Shutdown_priv`		
	`Process_priv`		
	`File_priv`		

Show_db_priv		
Super_priv		
Create_tmp_table_priv	Create_tmp_table_priv	Create_tmp_table_priv
Lock_tables_priv	Lock_tables_priv	Lock_tables_priv
Execute_priv		
Repl_slave_priv		
Repl_client_priv		
ssl_type		
ssl_cypher		
x509_issuer		
x509_cubject		
max_questions		
max_updates		
max_connections		

For the second stage of access control (request verification), the server may, if the request involves tables, additionally consult the `tables_priv` and `columns_priv` tables. The fields in these tables are shown here:

Table name	**tables_priv**	**columns_priv**
Scope fields	Host	Host
	Db	Db
	User	User
	Table_name	Table_name
		Column_name
Privilege fields	Table_priv	Column_priv
	Column_priv	
Other fields	Timestamp	Timestamp
	Grantor	

Each grant table contains scope fields and privilege fields.

Scope fields determine the scope of each entry in the tables, that is, the context in which the entry applies. For example, a `user` table entry with `Host` and `User` values of `'thomas.loc.gov'` and `'bob'` would be used for authenticating connections made to the server by `bob` from the host `thomas.loc.gov`. Similarly, a `db` table entry with `Host`, `User`, and `Db` fields of `'thomas.loc.gov'`, `'bob'` and `'reports'` would be used when `bob` connects from the host `thomas.loc.gov` to access the `reports` database. The `tables_priv` and `columns_priv` tables contain scope fields indicating tables or table/column combinations to which each entry applies.

For access-checking purposes, comparisons of `Host` values are case-insensitive. `User`, `Password`, `Db`, and `Table_name` values are case-sensitive. `Column_name` values are case-insensitive in MySQL Version 3.22.12 or later.

Privilege fields indicate the privileges granted by a table entry, that is, what operations can be performed. The server combines the information in the various grant tables to form a complete description of a user's privileges. The rules used to do this are described in Section 4.3.10 [Request access], page 228.

Scope fields are strings, declared as shown here; the default value for each is the empty string:

Field name	Type	Notes
`Host`	`CHAR(60)`	
`User`	`CHAR(16)`	
`Password`	`CHAR(16)`	
`Db`	`CHAR(64)`	(`CHAR(60)` for the `tables_priv` and `columns_priv` tables)
`Table_name`	`CHAR(60)`	
`Column_name`	`CHAR(60)`	

In the `user`, `db` and `host` tables, all privilege fields are declared as `ENUM('N','Y')`—each can have a value of `'N'` or `'Y'`, and the default value is `'N'`.

In the `tables_priv` and `columns_priv` tables, the privilege fields are declared as `SET` fields:

Table name	Field name	Possible set elements
`tables_priv`	`Table_priv`	`'Select', 'Insert', 'Update', 'Delete', 'Create', 'Drop', 'Grant', 'References', 'Index', 'Alter'`
`tables_priv`	`Column_priv`	`'Select', 'Insert', 'Update', 'References'`
`columns_priv`	`Column_priv`	`'Select', 'Insert', 'Update', 'References'`

Briefly, the server uses the grant tables like this:

- The `user` table scope fields determine whether to allow or reject incoming connections. For allowed connections, any privileges granted in the `user` table indicate the user's global (superuser) privileges. These privileges apply to **all** databases on the server.
- The `db` and `host` tables are used together:
  - The `db` table scope fields determine which users can access which databases from which hosts. The privilege fields determine which operations are allowed.
  - The `host` table is used as an extension of the `db` table when you want a given `db` table entry to apply to several hosts. For example, if you want a user to be able to use a database from several hosts in your network, leave the `Host` value empty in the user's `db` table entry, then populate the `host` table with an entry for each of those hosts. This mechanism is described more detail in Section 4.3.10 [Request access], page 228.
- The `tables_priv` and `columns_priv` tables are similar to the `db` table, but are more fine-grained: they apply at the table and column levels rather than at the database level.

Note that administrative privileges (`RELOAD`, `SHUTDOWN`, etc.) are specified only in the `user` table. This is because administrative operations are operations on the server itself and are not database-specific, so there is no reason to list such privileges in the other grant tables.

In fact, only the `user` table need be consulted to determine whether you can perform an administrative operation.

The `FILE` privilege is specified only in the `user` table, too. It is not an administrative privilege as such, but your ability to read or write files on the server host is independent of the database you are accessing.

The `mysqld` server reads the contents of the grant tables once, when it starts up. Changes to the grant tables take effect as indicated in Section 4.4.3 [Privilege changes], page 244.

When you modify the contents of the grant tables, it is a good idea to make sure that your changes set up privileges the way you want. For help in diagnosing problems, see Section 4.3.12 [Access denied], page 235. For advice on security issues, see Section 4.3.2 [Security], page 215.

A useful diagnostic tool is the `mysqlaccess` script, which Yves Carlier has provided for the MySQL distribution. Invoke `mysqlaccess` with the `--help` option to find out how it works. Note that `mysqlaccess` checks access using only the `user`, `db` and `host` tables. It does not check table- or column-level privileges.

4.3.7 Privileges Provided by MySQL

Information about user privileges is stored in the `user`, `db`, `host`, `tables_priv`, and `columns_priv` tables in the `mysql` database (that is, in the database named `mysql`). The MySQL server reads the contents of these tables when it starts up and under the circumstances indicated in Section 4.4.3 [Privilege changes], page 244.

The names used in this manual to refer to the privileges provided by MySQL version 4.0.2 are shown here, along with the table column name associated with each privilege in the grant tables and the context in which the privilege applies. Further information about the meaning of each privilege may be found at Section 4.4.1 [`GRANT`], page 239.

Privilege	**Column**	**Context**
`ALTER`	`Alter_priv`	tables
`DELETE`	`Delete_priv`	tables
`INDEX`	`Index_priv`	tables
`INSERT`	`Insert_priv`	tables
`SELECT`	`Select_priv`	tables
`UPDATE`	`Update_priv`	tables
`CREATE`	`Create_priv`	databases, tables, or indexes
`DROP`	`Drop_priv`	databases or tables
`GRANT`	`Grant_priv`	databases or tables
`REFERENCES`	`References_priv`	databases or tables
`CREATE TEMPORARY TABLES`	`Create_tmp_table_priv`	server administration
`EXECUTE`	`Execute_priv`	server administration
`FILE`	`File_priv`	file access on server
`LOCK TABLES`	`Lock_tables_priv`	server administration
`PROCESS`	`Process_priv`	server administration

RELOAD	Reload_priv	server administration
REPLICATION CLIENT	Repl_client_priv	server administration
REPLICATION SLAVE	Repl_slave_priv	server administration
SHOW DATABASES	Show_db_priv	server administration
SHUTDOWN	Shutdown_priv	server administration
SUPER	Super_priv	server administration

The `SELECT`, `INSERT`, `UPDATE`, and `DELETE` privileges allow you to perform operations on rows in existing tables in a database.

`SELECT` statements require the `SELECT` privilege only if they actually retrieve rows from a table. You can execute certain `SELECT` statements even without permission to access any of the databases on the server. For example, you could use the `mysql` client as a simple calculator:

```
mysql> SELECT 1+1;
mysql> SELECT PI()*2;
```

The `INDEX` privilege allows you to create or drop (remove) indexes.

The `ALTER` privilege allows you to use `ALTER TABLE`.

The `CREATE` and `DROP` privileges allow you to create new databases and tables, or to drop (remove) existing databases and tables.

Note that if you grant the `DROP` privilege for the `mysql` database to a user, that user can drop the database in which the MySQL access privileges are stored!

The `GRANT` privilege allows you to give to other users those privileges you yourself possess.

The `FILE` privilege gives you permission to read and write files on the server using the `LOAD DATA INFILE` and `SELECT ... INTO OUTFILE` statements. Any user to whom this privilege is granted can read any world readable file accessable by the MySQL server and create a new world readable file in any directory where the MySQL server can write. The user can also read any file in the current database directory. The user can however not change any existing file.

The remaining privileges are used for administrative operations, which are performed using the `mysqladmin` program. The table here shows which `mysqladmin` commands each administrative privilege allows you to execute:

Privilege	**Commands permitted to privilege holders**
RELOAD	`reload`, `refresh`, `flush-privileges`, `flush-hosts`, `flush-logs`, and `flush-tables`
SHUTDOWN	`shutdown`
PROCESS	`processlist`
SUPER	`kill`

The `reload` command tells the server to re-read the grant tables. The `refresh` command flushes all tables and opens and closes the log files. `flush-privileges` is a synonym for `reload`. The other `flush-*` commands perform functions similar to `refresh` but are more limited in scope, and may be preferable in some instances. For example, if you want to flush just the log files, `flush-logs` is a better choice than `refresh`.

The `shutdown` command shuts down the server.

The `processlist` command displays information about the threads executing within the server. The `kill` command kills server threads. You can always display or kill your own threads, but you need the `PROCESS` privilege to display and `SUPER` privilege to kill threads initiated by other users. See Section 4.6.7 [KILL], page 284.

It is a good idea in general to grant privileges only to those users who need them, but you should exercise particular caution in granting certain privileges:

- The `GRANT` privilege allows users to give away their privileges to other users. Two users with different privileges and with the `GRANT` privilege are able to combine privileges.
- The `ALTER` privilege may be used to subvert the privilege system by renaming tables.
- The `FILE` privilege can be abused to read any world-readable file on the server or any file in the current database directory on the server into a database table, the contents of which can then be accessed using `SELECT`.
- The `SHUTDOWN` privilege can be abused to deny service to other users entirely, by terminating the server.
- The `PROCESS` privilege can be used to view the plain text of currently executing queries, including queries that set or change passwords.
- Privileges on the `mysql` database can be used to change passwords and other access privilege information. (Passwords are stored encrypted, so a malicious user cannot simply read them to know the plain text password.) If they can access the `mysql.user` password column, they can use it to log into the MySQL server for the given user. (With sufficient privileges, the same user can replace a password with a different one.)

There are some things that you cannot do with the MySQL privilege system:

- You cannot explicitly specify that a given user should be denied access. That is, you cannot explicitly match a user and then refuse the connection.
- You cannot specify that a user has privileges to create or drop tables in a database but not to create or drop the database itself.

4.3.8 Connecting to the MySQL Server

MySQL client programs generally require that you specify connection parameters when you want to access a MySQL server: the host you want to connect to, your user name, and your password. For example, the `mysql` client can be started like this (optional arguments are enclosed between '`[`' and '`]`'):

```
shell> mysql [-h host_name] [-u user_name] [-pyour_pass]
```

Alternate forms of the `-h`, `-u`, and `-p` options are `--host=host_name`, `--user=user_name`, and `--password=your_pass`. Note that there is *no space* between `-p` or `--password=` and the password following it.

Note: Specifying a password on the command-line is not secure! Any user on your system may then find out your password by typing a command like: `ps auxww`. See Section 4.1.2 [Option files], page 203.

`mysql` uses default values for connection parameters that are missing from the command-line:

- The default hostname is `localhost`.
- The default user name is your Unix login name.
- No password is supplied if `-p` is missing.

Thus, for a Unix user `joe`, the following commands are equivalent:

```
shell> mysql -h localhost -u joe
shell> mysql -h localhost
shell> mysql -u joe
shell> mysql
```

Other MySQL clients behave similarly.

On Unix systems, you can specify different default values to be used when you make a connection, so that you need not enter them on the command-line each time you invoke a client program. This can be done in a couple of ways:

- You can specify connection parameters in the `[client]` section of the '`.my.cnf`' configuration file in your home directory. The relevant section of the file might look like this:

  ```
  [client]
  host=host_name
  user=user_name
  password=your_pass
  ```

  See Section 4.1.2 [Option files], page 203.
- You can specify connection parameters using environment variables. The host can be specified for `mysql` using `MYSQL_HOST`. The MySQL user name can be specified using `USER` (this is for Windows only). The password can be specified using `MYSQL_PWD` (but this is insecure; see the next section). See Appendix F [Environment variables], page 1019.

4.3.9 Access Control, Stage 1: Connection Verification

When you attempt to connect to a MySQL server, the server accepts or rejects the connection based on your identity and whether you can verify your identity by supplying the correct password. If not, the server denies access to you completely. Otherwise, the server accepts the connection, then enters Stage 2 and waits for requests.

Your identity is based on two pieces of information:

- The host from which you connect
- Your MySQL user name

Identity checking is performed using the three `user` table scope fields (`Host`, `User`, and `Password`). The server accepts the connection only if a `user` table entry matches your hostname and user name, and you supply the correct password.

Values in the `user` table scope fields may be specified as follows:

- A `Host` value may be a hostname or an IP number, or `'localhost'` to indicate the local host.
- You can use the wildcard characters '`%`' and '`_`' in the `Host` field.

- A `Host` value of `'%'` matches any hostname.
- A blank `Host` value means that the privilege should be anded with the entry in the `host` table that matches the given host name. You can find more information about this in the next chapter.
- As of MySQL Version 3.23, for `Host` values specified as IP numbers, you can specify a netmask indicating how many address bits to use for the network number. For example:

```
mysql> GRANT ALL PRIVILEGES ON db.*
    -> TO david@'192.58.197.0/255.255.255.0';
```

  This will allow everyone to connect from an IP where the following is true:

```
user_ip & netmask = host_ip.
```

  In the above example all IP:s in the interval 192.58.197.0 - 192.58.197.255 can connect to the MySQL server.
- Wildcard characters are not allowed in the `User` field, but you can specify a blank value, which matches any name. If the `user` table entry that matches an incoming connection has a blank user name, the user is considered to be the anonymous user (the user with no name), rather than the name that the client actually specified. This means that a blank user name is used for all further access checking for the duration of the connection (that is, during Stage 2).
- The `Password` field can be blank. This does not mean that any password matches, it means the user must connect without specifying a password.

Non-blank `Password` values represent encrypted passwords. MySQL does not store passwords in plaintext form for anyone to see. Rather, the password supplied by a user who is attempting to connect is encrypted (using the `PASSWORD()` function). The encrypted password is then used when the client/server is checking if the password is correct. (This is done without the encrypted password ever traveling over the connection.) Note that from MySQL's point of view the encrypted password is the REAL password, so you should not give anyone access to it! In particular, don't give normal users read access to the tables in the `mysql` database! From version 4.1, MySQL employs a different password and login mechanism that is secure even if TCP/IP packets are sniffed and/or the mysql database is captured.

The examples here show how various combinations of `Host` and `User` values in `user` table entries apply to incoming connections:

`Host` value	`User` value	Connections matched by entry
`'thomas.loc.gov'`	`'fred'`	`fred`, connecting from `thomas.loc.gov`
`'thomas.loc.gov'`	`''`	Any user, connecting from `thomas.loc.gov`
`'%'`	`'fred'`	`fred`, connecting from any host
`'%'`	`''`	Any user, connecting from any host
`'%.loc.gov'`	`'fred'`	`fred`, connecting from any host in the `loc.gov` domain
`'x.y.%'`	`'fred'`	`fred`, connecting from `x.y.net`, `x.y.com`,`x.y.edu`, etc. (this is probably not useful)
`'144.155.166.177'`	`'fred'`	`fred`, connecting from the host with IP address `144.155.166.177`

'144.155.166.%'	'fred'	fred, connecting from any host in the 144.155.166 class C subnet
'144.155.166.0/255.255.255.0"	'fred'	Same as previous example

Because you can use IP wildcard values in the Host field (for example, '144.155.166.%' to match every host on a subnet), there is the possibility that someone might try to exploit this capability by naming a host 144.155.166.somewhere.com. To foil such attempts, MySQL disallows matching on hostnames that start with digits and a dot. Thus, if you have a host named something like 1.2.foo.com, its name will never match the Host column of the grant tables. Only an IP number can match an IP wildcard value.

An incoming connection may be matched by more than one entry in the user table. For example, a connection from thomas.loc.gov by fred would be matched by several of the entries shown in the preceding table. How does the server choose which entry to use if more than one matches? The server resolves this question by sorting the user table after reading it at startup time, then looking through the entries in sorted order when a user attempts to connect. The first matching entry is the one that is used.

user table sorting works as follows. Suppose the user table looks like this:

```
+-----------+----------+-
| Host      | User     | ...
+-----------+----------+-
| %         | root     | ...
| %         | jeffrey  | ...
| localhost | root     | ...
| localhost |          | ...
+-----------+----------+-
```

When the server reads in the table, it orders the entries with the most-specific Host values first ('%' in the Host column means "any host" and is least specific). Entries with the same Host value are ordered with the most-specific User values first (a blank User value means "any user" and is least specific). The resulting sorted user table looks like this:

```
+-----------+----------+-
| Host      | User     | ...
+-----------+----------+-
| localhost | root     | ...
| localhost |          | ...
| %         | jeffrey  | ...
| %         | root     | ...
+-----------+----------+-
```

When a connection is attempted, the server looks through the sorted entries and uses the first match found. For a connection from localhost by jeffrey, the entries with 'localhost' in the Host column match first. Of those, the entry with the blank user name matches both the connecting hostname and user name. (The '%'/'jeffrey' entry would have matched, too, but it is not the first match in the table.)

Here is another example. Suppose the user table looks like this:

```
+---------------+----------+-
| Host          | User     | ...
+---------------+----------+-
```

```
| %              | jeffrey  | ...
| thomas.loc.gov |          | ...
+----------------+----------+-
```

The sorted table looks like this:

```
+----------------+----------+-
| Host           | User     | ...
+----------------+----------+-
| thomas.loc.gov |          | ...
| %              | jeffrey  | ...
+----------------+----------+-
```

A connection from `thomas.loc.gov` by `jeffrey` is matched by the first entry, whereas a connection from `whitehouse.gov` by `jeffrey` is matched by the second.

A common misconception is to think that for a given user name, all entries that explicitly name that user will be used first when the server attempts to find a match for the connection. This is simply not true. The previous example illustrates this, where a connection from `thomas.loc.gov` by `jeffrey` is first matched not by the entry containing `'jeffrey'` as the `User` field value, but by the entry with no user name!

If you have problems connecting to the server, print out the `user` table and sort it by hand to see where the first match is being made. If connection was successful, but your privileges are not what you expected you may use `CURRENT_USER()` function (new in version 4.0.6) to see what user/host combination your connection actually matched. See Section 6.3.6.2 [CURRENT_USER()], page 515.

4.3.10 Access Control, Stage 2: Request Verification

Once you establish a connection, the server enters Stage 2. For each request that comes in on the connection, the server checks whether you have sufficient privileges to perform it, based on the type of operation you wish to perform. This is where the privilege fields in the grant tables come into play. These privileges can come from any of the `user`, `db`, `host`, `tables_priv`, or `columns_priv` tables. The grant tables are manipulated with `GRANT` and `REVOKE` commands. See Section 4.4.1 [GRANT], page 239. (You may find it helpful to refer to Section 4.3.6 [Privileges], page 219, which lists the fields present in each of the grant tables.)

The `user` table grants privileges that are assigned to you on a global basis and that apply no matter what the current database is. For example, if the `user` table grants you the `DELETE` privilege, you can delete rows from any database on the server host! In other words, `user` table privileges are superuser privileges. It is wise to grant privileges in the `user` table only to superusers such as server or database administrators. For other users, you should leave the privileges in the `user` table set to `'N'` and grant privileges on a database-specific basis only, using the `db` and `host` tables.

The `db` and `host` tables grant database-specific privileges. Values in the scope fields may be specified as follows:

- The wildcard characters '`%`' and '`_`' can be used in the `Host` and `Db` fields of either table. If you wish to use for instance a '`_`' character as part of a database name, specify it as '`\_`' in the `GRANT` command.

- A '%' Host value in the db table means "any host." A blank Host value in the db table means "consult the host table for further information."
- A '%' or blank Host value in the host table means "any host."
- A '%' or blank Db value in either table means "any database."
- A blank User value in either table matches the anonymous user.

The db and host tables are read in and sorted when the server starts up (at the same time that it reads the user table). The db table is sorted on the Host, Db, and User scope fields, and the host table is sorted on the Host and Db scope fields. As with the user table, sorting puts the most-specific values first and least-specific values last, and when the server looks for matching entries, it uses the first match that it finds.

The tables_priv and columns_priv tables grant table- and column-specific privileges. Values in the scope fields may be specified as follows:

- The wildcard characters '%' and '_' can be used in the Host field of either table.
- A '%' or blank Host value in either table means "any host."
- The Db, Table_name and Column_name fields cannot contain wildcards or be blank in either table.

The tables_priv and columns_priv tables are sorted on the Host, Db, and User fields. This is similar to db table sorting, although the sorting is simpler because only the Host field may contain wildcards.

The request verification process is described here. (If you are familiar with the access-checking source code, you will notice that the description here differs slightly from the algorithm used in the code. The description is equivalent to what the code actually does; it differs only to make the explanation simpler.)

For administrative requests (SHUTDOWN, RELOAD, etc.), the server checks only the user table entry, because that is the only table that specifies administrative privileges. Access is granted if the entry allows the requested operation and denied otherwise. For example, if you want to execute mysqladmin shutdown but your user table entry doesn't grant the SHUTDOWN privilege to you, access is denied without even checking the db or host tables. (They contain no Shutdown_priv column, so there is no need to do so.)

For database-related requests (INSERT, UPDATE, etc.), the server first checks the user's global (superuser) privileges by looking in the user table entry. If the entry allows the requested operation, access is granted. If the global privileges in the user table are insufficient, the server determines the user's database-specific privileges by checking the db and host tables:

1. The server looks in the db table for a match on the Host, Db, and User fields. The Host and User fields are matched to the connecting user's hostname and MySQL user name. The Db field is matched to the database the user wants to access. If there is no entry for the Host and User, access is denied.
2. If there is a matching db table entry and its Host field is not blank, that entry defines the user's database-specific privileges.
3. If the matching db table entry's Host field is blank, it signifies that the host table enumerates which hosts should be allowed access to the database. In this case, a further lookup is done in the host table to find a match on the Host and Db fields. If

no `host` table entry matches, access is denied. If there is a match, the user's database-specific privileges are computed as the intersection (**not** the union!) of the privileges in the `db` and `host` table entries, that is, the privileges that are `'Y'` in both entries. (This way you can grant general privileges in the `db` table entry and then selectively restrict them on a host-by-host basis using the `host` table entries.)

After determining the database-specific privileges granted by the `db` and `host` table entries, the server adds them to the global privileges granted by the `user` table. If the result allows the requested operation, access is granted. Otherwise, the server checks the user's table and column privileges in the `tables_priv` and `columns_priv` tables and adds those to the user's privileges. Access is allowed or denied based on the result.

Expressed in boolean terms, the preceding description of how a user's privileges are calculated may be summarised like this:

```
global privileges
OR (database privileges AND host privileges)
OR table privileges
OR column privileges
```

It may not be apparent why, if the global `user` entry privileges are initially found to be insufficient for the requested operation, the server adds those privileges to the database-, table-, and column-specific privileges later. The reason is that a request might require more than one type of privilege. For example, if you execute an `INSERT ... SELECT` statement, you need both `INSERT` and `SELECT` privileges. Your privileges might be such that the `user` table entry grants one privilege and the `db` table entry grants the other. In this case, you have the necessary privileges to perform the request, but the server cannot tell that from either table by itself; the privileges granted by the entries in both tables must be combined.

The `host` table can be used to maintain a list of secure servers.

At TcX, the `host` table contains a list of all machines on the local network. These are granted all privileges.

You can also use the `host` table to indicate hosts that are **not** secure. Suppose you have a machine `public.your.domain` that is located in a public area that you do not consider secure. You can allow access to all hosts on your network except that machine by using `host` table entries like this:

```
+--------------------+----+-
| Host               | Db | ...
+--------------------+----+-
| public.your.domain | %  | ... (all privileges set to 'N')
| %.your.domain      | %  | ... (all privileges set to 'Y')
+--------------------+----+-
```

Naturally, you should always test your entries in the grant tables (for example, using `mysqlaccess`) to make sure your access privileges are actually set up the way you think they are.

4.3.11 Password Hashing in MySQL 4.1

MySQL user accounts are listed in the `user` table of the `mysql` database. Each MySQL account is assigned a password, although what is stored in the `Password` column of the

`user` table is not the plaintext version of the password, but a hash value computed from it. Password hash values are computed by the `PASSWORD()` function.

MySQL uses passwords in two phases of client/server communication:

- First, when a client attempts to connect to the server, there is an initial authentication step in which the client must present a password that matches the hash value stored in the user table for the account that the client wants to use.
- Second, after the client connects, it may set or change the password hashes for accounts listed in the user table (if it has sufficient privileges). The client may do this by using the PASSWORD() function to generate a password hash, or by using the GRANT or SET PASSWORD statements.

In other words, the server *uses* hash values during authentication when a client first attempts to connect. The server *generates* hash values if a connected client invokes the `PASSWORD()` function or uses a `GRANT` or `SET PASSWORD` statement to set or change a password.

The password hashing mechanism was updated in MySQL 4.1 to provide better security and to reduce the risk of passwords being stolen. However, this new mechanism is understood only by the 4.1 server and 4.1 clients, which can result in some compatibility problems. A 4.1 client can connect to a pre-4.1 server, because the client understands both the old and new password hashing mechanisms. However, a pre-4.1 client that attempts to connect to a 4.1 server may run into difficulties. For example, a 4.0 `mysql` client that attempts to connect to a 4.1 server may fail with the following error message:

```
shell> mysql
Client does not support authentication protocol requested
by server; consider upgrading MySQL client
```

The following discussion describes the differences between the old and new password mechanisms, and what you should do if you upgrade your server to 4.1 but need to maintain backward compatibility with pre-4.1 clients.

Note: This discussion contrasts 4.1 behaviour with pre-4.1 behaviour, but the 4.1 behaviour described here actually begins with 4.1.1. MySQL 4.1.0 is an "odd" release because it has a slightly different mechanism than that implemented in 4.1.1 and up. Differences between 4.1.0 and more recent versions are described later.

Prior to MySQL 4.1, password hashes computed by the `PASSWORD()` function are 16 bytes long. Such hashes look like this:

```
mysql> SELECT PASSWORD('mypass');
+--------------------+
| PASSWORD('mypass') |
+--------------------+
| 6f8c114b58f2ce9e   |
+--------------------+
```

The `Password` column of the `user` table (in which these hashes are stored) also is 16 bytes long before MySQL 4.1.

As of MySQL 4.1, the `PASSWORD()` function has been modified to produce a longer 41-byte hash value:

```
mysql> SELECT PASSWORD('mypass');
+-------------------------------------------+
```

```
| PASSWORD('mypass')                          |
+---------------------------------------------+
| *43c8aa34cdc98eddd3de1fe9a9c2c2a9f92bb2098d75 |
+---------------------------------------------+
```

Accordingly, the `Password` column in the `user` table also must be 41 bytes long to store these values:

- If you perform a new installation of MySQL 4.1, the `Password` column will be made 41 bytes long automatically.
- If you upgrade an older installation to 4.1, you should run the `mysql_fix_privilege_tables` script to update the length of the `Password` column from 16 to 41 bytes. (The script does not change existing password values, which remain 16 bytes long.)

A widened `Password` column can store password hashes in both the old and new formats. The format of any given password hash value can be determined two ways:

- The obvious difference is the length (16 bytes versus 41 bytes)
- A second difference is that password hashes in the new format always begin with a '`*`' character, whereas passwords in the old format never do

The longer password hash format has better cryptographic properties, and client authentication based on long hashes is more secure than that based on the older short hashes.

The differences between short and long password hashes are relevant both for how the server uses passwords during authentication and for how it generates password hashes for connected clients that perform password-changing operations.

The way in which the server uses password hashes during authentication is affected by the width of the Password column:

- If the column is narrow, only short-hash authentication is used.
- If the column is wide, it can hold either short or long hashes, and the server can use either format:
  - Pre-4.1 clients can connect, though because they know only about the old hashing mechanism, they can authenticate only for accounts that have short hashes.
  - 4.1 clients can authenticate for accounts that have short or long hashes.

For short-hash accounts, the authentication process is actually a bit more secure for 4.1 clients than for older clients. In terms of security, the gradient from least to most secure is:

- Pre-4.1 client authenticating for account with short password hash
- 4.1 client authenticating for account with short password hash
- 4.1 client authenticating for account with long password hash

The way in which the server generates password hashes for connected clients is affected by the width of the `Password` column and by the `--old-passwords` option. A 4.1 server generates long hashes only if certain conditions are met: The `Password` column must be wide enough to hold long values and the `--old-passwords` option must not be given. These conditions apply as follows:

- The `Password` column must be wide enough to hold long hashes (41 bytes). If the column has not been updated and still has the pre-4.1 width (16 bytes), the server notices that long hashes cannot fit into it and generates only short hashes when a client

performs password-changing operations using `PASSWORD()`, `GRANT`, or `SET PASSWORD`. (This behaviour occurs if you have upgraded to 4.1 but have not run the `mysql_fix_privilege_tables` script to widen the `Password` column.)

- If the `Password` column is wide, it can store either short or long password hashes. In this case, `PASSWORD()`, `GRANT`, and `SET PASSWORD` will generate long hashes unless the server was started with the `--old-passwords` option. This option forces the server to generate short passsword hashes instead.

The purpose of the `--old-passwords` option is to allow you to maintain backward compatibility with pre-4.1 clients under circumstances where the server would otherwise generate long password hashes. It doesn't affect authentication (4.1 clients can still use accounts that have long password hashes), but it does prevent creation of a long password hash in the `user` table as the result of a password-changing operation. Were that to occur, the account no longer could be used by pre-4.1 clients. Without the `--old-passwords` option, the following scenario is possible:

- An old client connects to an account that has a short password hash.
- The client changes the account's password. Without `--old-passwords`, this results in the account having a long password hash.
- The next time the old client attempts to connect to the account, it cannot, because the account now requires the new hashing mechanism during authentication. (Once an account has a long password hash in the user table, only 4.1 clients can authenticate for it, because pre-4.1 clients do not understand long hashes.)

This scenario illustrates that it is dangerous to run a 4.1 server without using the `--old-passwords` option if you must support older pre-4.1 clients. By running the server with `--old-passwords`, password-changing operations will not generate long password hashes and thus do not cause accounts to become inaccessible to older clients. (Those clients cannot inadvertently lock themselves out by changing their password and ending up with a long password hash.)

The downside of the `--old-passwords` option is that any passwords you create or change will use short hashes, even for 4.1 clients. Thus, you lose the additional security provided by long password hashes. If you want to create an account that has a long hash (for example, for use by 4.1 clients), you must do so while running the server without `--old-passwords`.

The following scenarios are possible for running a 4.1 server:

Scenario 1) Narrow `Password` column in user table

- Only short hashes can be stored in the `Password` column.
- The server uses only short hashes during client authentication.
- For connected clients, password hash-generating operations involving `PASSWORD()`, `GRANT`, or `SET PASSWORD` use short hashes exclusively. Any change to an account's password results in that account having a short password hash.
- The `--old-passwords` option can be used but is superfluous because with a narrow `Password` column, the server will be generating short password hashes anyway.

Scenario 2) Long `Password` column; server not started with `--old-passwords` option

- Short or long hashes can be stored in the `Password` column.
- 4.1 clients can authenticate for accounts that have short or long hashes.

- Pre-4.1 clients can authenticate only for accounts that have short hashes.
- For connected clients, password hash-generating operations involving `PASSWORD()`, `GRANT`, or `SET PASSWORD` use long hashes exclusively. Any change to an account's password results in that account having a long password hash.
- `OLD_PASSWORD()` may be used to explicitly generate a short hash. For example, to assign an account a short password, use `UPDATE` as follows:

```
mysql> UPDATE user SET Password = OLD_PASSWORD('mypass')
    -> WHERE Host = 'some_host' AND User = 'some_user';
mysql> FLUSH PRIVILEGES;
```

As indicated earlier, a danger in this scenario is that it is possible for accounts that have a short password hash to become inaccessible to pre-4.1 clients. Any change to such an account's password made via `GRANT`, `SET PASSWORD`, or `PASSWORD()` results in the account being given a long password hash, and from that point on, no pre-4.1 client can authenticate to that account until the client upgrades to 4.1.

Scenario 3) Long `Password` column; server started with `--old-passwords` option

- Short or long hashes can be stored in the `Password` column.
- 4.1 clients can authenticate for accounts that have short or long hashes (but note that it is possible to create long hashes only when the server is started without `--old-passwords`).
- Pre-4.1 clients can authenticate only for accounts that have short hashes.
- For connected clients, password hash-generating operations involving `PASSWORD()`, `GRANT`, or `SET PASSWORD` use short hashes exclusively. Any change to an account's password results in that account having a short password hash.

In this scenario, you cannot create accounts that have long password hashes, because `--old-passwords` prevents generation of long hashes. Also, if you create an account with a long hash before using the `--old-passwords` option, changing the account's password while `--old-passwords` is in effect results in the account being given a short password, causing it to lose the security benefits of a longer hash.

The disadvantages for these scenarios may be summarized as follows:

Scenario 1) You cannot take advantage of longer hashes that provide more secure authentication.

Scenario 2) Accounts with short hashes become inaccessible to pre-4.1 clients if you change their passwords without explicitly using `OLD_PASSWORD()`.

Scenario 3) `--old-passwords` prevents accounts with short hashes from becoming inaccessible, but password-changing operations cause accounts with long hashes to revert to short hashes, and you cannot change them back to long hashes while `--old-passwords` is in effect.

Implications of Password Hashing Changes for Application Programs

An upgrade to MySQL 4.1 can cause a compatibility issue for applications that use `PASSWORD()` to generate passwords for their own purposes. (Applications really should

not do this, because `PASSWORD()` should be used only to manage passwords for MySQL accounts. But some applications use `PASSWORD()` for their own purposes anyway.) If you upgrade to 4.1 and run the server under conditions where it generates long password hashes, an application that uses `PASSWORD()` for its own passwords will break. The recommended course of action is to modify the application to use another function such as `SHA1()` or `MD5()` to produce hashed values. If that is not possible, you can use the `OLD_PASSWORD()` function, which is provided to generate short hashes in the old format. (But note that `OLD_PASSWORD()` may one day no longer be supported.)

If the server is running under circumstances where it generates short hashes, `OLD_PASSWORD()` is available but is equivalent to `PASSWORD()`.

Password hashing in MySQL 4.1.0 differs from hashing in 4.1.1 and up. The 4.1.0 differences are:

- Password hashes are 45 bytes long rather than 41 bytes.
- The `PASSWORD()` function is non-repeatable. That is, with a given argument `X`, successive calls to `PASSWORD(X)` generate different results.

4.3.12 Causes of `Access denied` Errors

If you encounter `Access denied` errors when you try to connect to the MySQL server, the following list indicates some courses of action you can take to correct the problem:

- After installing MySQL, did you run the `mysql_install_db` script to set up the initial grant table contents? If not, do so. See Section 4.4.4 [Default privileges], page 245. Test the initial privileges by executing this command:

  ```
  shell> mysql -u root test
  ```

  The server should let you connect without error. You should also make sure you have a file '`user.MYD`' in the MySQL database directory. Ordinarily, this is '`PATH/var/mysql/user.MYD`', where `PATH` is the pathname to the MySQL installation root.

- After a fresh installation, you should connect to the server and set up your users and their access permissions:

  ```
  shell> mysql -u root mysql
  ```

  The server should let you connect because the MySQL `root` user has no password initially. That is also a security risk, so setting the `root` password is something you should do while you're setting up your other MySQL users.

  If you try to connect as `root` and get this error:

  ```
  Access denied for user: '@unknown' to database mysql
  ```

  this means that you don't have an entry in the `user` table with a `User` column value of `'root'` and that `mysqld` cannot resolve the hostname for your client. In this case, you must restart the server with the `--skip-grant-tables` option and edit your '`/etc/hosts`' or '`\windows\hosts`' file to add an entry for your host.

- If you get an error like the following:

  ```
  shell> mysqladmin -u root -pxxxx ver
  Access denied for user: 'root@localhost' (Using password: YES)
  ```

It means that you are using an incorrect password. See Section 4.4.8 [Passwords], page 250.

If you have forgot the root password, you can restart `mysqld` with `--skip-grant-tables` to change the password. See Section A.4.2 [Resetting permissions], page 861.

If you get the above error even if you haven't specified a password, this means that you have an incorrect password in some `my.ini` file. See Section 4.1.2 [Option files], page 203. You can avoid using option files with the `--no-defaults` option, as follows:

```
shell> mysqladmin --no-defaults -u root ver
```

- If you updated an existing MySQL installation from a version earlier than Version 3.22.11 to Version 3.22.11 or later, did you run the `mysql_fix_privilege_tables` script? If not, do so. The structure of the grant tables changed with MySQL Version 3.22.11 when the `GRANT` statement became functional. See Section 2.5.6 [Upgrading-grant-tables], page 119.
- If your privileges seem to have changed in the middle of a session, it may be that a superuser has changed them. Reloading the grant tables affects new client connections, but it also affects existing connections as indicated in Section 4.4.3 [Privilege changes], page 244.
- If you can't get your password to work, remember that you must use the `PASSWORD()` function if you set the password with the `INSERT`, `UPDATE`, or `SET PASSWORD` statements. The `PASSWORD()` function is unnecessary if you specify the password using the `GRANT ... IDENTIFIED BY` statement or the `mysqladmin password` command. See Section 4.4.8 [Passwords], page 250.
- `localhost` is a synonym for your local hostname, and is also the default host to which clients try to connect if you specify no host explicitly. However, connections to `localhost` do not work if you are using a MySQL version prior to 3.23.27 that uses MIT-pthreads (`localhost` connections are made using Unix sockets, which were not supported by MIT-pthreads at that time). To avoid this problem on such systems, you should use the `--host` option to name the server host explicitly. This will make a TCP/IP connection to the `mysqld` server. In this case, you must have your real hostname in `user` table entries on the server host. (This is true even if you are running a client program on the same host as the server.)
- If you get an `Access denied` error when trying to connect to the database with `mysql -u user_name db_name`, you may have a problem with the `user` table. Check this by executing `mysql -u root mysql` and issuing this SQL statement:

  ```
  mysql> SELECT * FROM user;
  ```

  The result should include an entry with the `Host` and `User` columns matching your computer's hostname and your MySQL user name.
- The `Access denied` error message will tell you who you are trying to log in as, the host from which you are trying to connect, and whether or not you were using a password. Normally, you should have one entry in the `user` table that exactly matches the hostname and user name that were given in the error message. For example if you get an error message that contains `Using password: NO`, this means that you tried to login without an password.

- If you get the following error when you try to connect from a different host than the one on which the MySQL server is running, then there is no row in the `user` table that matches that host:

  ```
  Host ... is not allowed to connect to this MySQL server
  ```

  You can fix this by using the command-line tool `mysql` (on the server host!) to add a row to the `user`, `db`, or `host` table for the user/hostname combination from which you are trying to connect and then execute `mysqladmin flush-privileges`. If you are not running MySQL Version 3.22 and you don't know the IP number or hostname of the machine from which you are connecting, you should put an entry with `'%'` as the `Host` column value in the `user` table and restart `mysqld` with the `--log` option on the server machine. After trying to connect from the client machine, the information in the MySQL log will indicate how you really did connect. (Then replace the `'%'` in the `user` table entry with the actual hostname that shows up in the log. Otherwise, you'll have a system that is insecure.)

  Another reason for this error on Linux is that you are using a binary MySQL version that is compiled with a different glibc version than the one you are using. In this case you should either upgrade your OS/glibc or download the source MySQL version and compile this yourself. A source RPM is normally trivial to compile and install, so this isn't a big problem.

- If you get an error message where the hostname is not shown or where the hostname is an IP, even if you try to connect with a hostname:

  ```
  shell> mysqladmin -u root -pxxxx -h some-hostname ver
  Access denied for user: 'root@' (Using password: YES)
  ```

  This means that MySQL got some error when trying to resolve the IP to a hostname. In this case you can execute `mysqladmin flush-hosts` to reset the internal DNS cache. See Section 5.5.5 [DNS], page 432.

  Some permanent solutions are:

  - Try to find out what is wrong with your DNS server and fix this.
  - Specify IPs instead of hostnames in the MySQL privilege tables.
  - Start `mysqld` with `--skip-name-resolve`.
  - Start `mysqld` with `--skip-host-cache`.
  - Connect to `localhost` if you are running the server and the client on the same machine.
  - Put the client machine names in `/etc/hosts`.

- If `mysql -u root test` works but `mysql -h your_hostname -u root test` results in `Access denied`, then you may not have the correct name for your host in the `user` table. A common problem here is that the `Host` value in the user table entry specifies an unqualified hostname, but your system's name resolution routines return a fully qualified domain name (or vice-versa). For example, if you have an entry with host `'tcx'` in the `user` table, but your DNS tells MySQL that your hostname is `'tcx.subnet.se'`, the entry will not work. Try adding an entry to the `user` table that contains the IP number of your host as the `Host` column value. (Alternatively, you could add an entry to the `user` table with a `Host` value that contains a wildcard—for example, `'tcx.%'`. However, use of hostnames ending with '`%`' is **insecure** and is **not** recommended!)

- If `mysql -u user_name test` works but `mysql -u user_name other_db_name` doesn't work, you don't have an entry for `other_db_name` listed in the `db` table.
- If `mysql -u user_name db_name` works when executed on the server machine, but `mysql -h host_name -u user_name db_name` doesn't work when executed on another client machine, you don't have the client machine listed in the `user` table or the `db` table.
- If you can't figure out why you get `Access denied`, remove from the `user` table all entries that have `Host` values containing wildcards (entries that contain '`%`' or '`_`'). A very common error is to insert a new entry with `Host='%'` and `User='some user'`, thinking that this will allow you to specify `localhost` to connect from the same machine. The reason that this doesn't work is that the default privileges include an entry with `Host='localhost'` and `User=''`. Because that entry has a `Host` value `'localhost'` that is more specific than `'%'`, it is used in preference to the new entry when connecting from `localhost`! The correct procedure is to insert a second entry with `Host='localhost'` and `User='some_user'`, or to remove the entry with `Host='localhost'` and `User=''`.
- If you get the following error, you may have a problem with the `db` or `host` table:

  ```
  Access to database denied
  ```

  If the entry selected from the `db` table has an empty value in the `Host` column, make sure there are one or more corresponding entries in the `host` table specifying which hosts the `db` table entry applies to.

  If you get the error when using the SQL commands `SELECT ... INTO OUTFILE` or `LOAD DATA INFILE`, your entry in the `user` table probably doesn't have the `FILE` privilege enabled.
- Remember that client programs will use connection parameters specified in configuration files or environment variables. See Appendix F [Environment variables], page 1019. If a client seems to be sending the wrong default connection parameters when you don't specify them on the command-line, check your environment and the '`.my.cnf`' file in your home directory. You might also check the system-wide MySQL configuration files, though it is far less likely that client connection parameters will be specified there. See Section 4.1.2 [Option files], page 203. If you get `Access denied` when you run a client without any options, make sure you haven't specified an old password in any of your option files! See Section 4.1.2 [Option files], page 203.
- If you make changes to the grant tables directly (using an `INSERT` or `UPDATE` statement) and your changes seem to be ignored, remember that you must issue a `FLUSH PRIVILEGES` statement or execute a `mysqladmin flush-privileges` command to cause the server to re-read the privilege tables. Otherwise, your changes have no effect until the next time the server is restarted. Remember that after you set the `root` password with an `UPDATE` command, you won't need to specify it until after you flush the privileges, because the server won't know you've changed the password yet!
- If you have access problems with a Perl, PHP, Python, or ODBC program, try to connect to the server with `mysql -u user_name db_name` or `mysql -u user_name -pyour_pass db_name`. If you are able to connect using the `mysql` client, there is a problem with your program and not with the access privileges. (Note that there is no space between `-p` and the password; you can also use the `--password=your_pass` syntax to

specify the password. If you use the `-p` option alone, MySQL will prompt you for the password.)

- For testing, start the `mysqld` daemon with the `--skip-grant-tables` option. Then you can change the MySQL grant tables and use the `mysqlaccess` script to check whether your modifications have the desired effect. When you are satisfied with your changes, execute `mysqladmin flush-privileges` to tell the `mysqld` server to start using the new grant tables. **Note**: reloading the grant tables overrides the `--skip-grant-tables` option. This allows you to tell the server to begin using the grant tables again without bringing it down and restarting it.
- If everything else fails, start the `mysqld` daemon with a debugging option (for example, `--debug=d,general,query`). This will print host and user information about attempted connections, as well as information about each command issued. See Section E.1.2 [Making trace files], page 1008.
- If you have any other problems with the MySQL grant tables and feel you must post the problem to the mailing list, always provide a dump of the MySQL grant tables. You can dump the tables with the `mysqldump mysql` command. As always, post your problem using the `mysqlbug` script. See Section 1.6.1.3 [Bug reports], page 27. In some cases you may need to restart `mysqld` with `--skip-grant-tables` to run `mysqldump`.

4.4 MySQL User Account Management

4.4.1 `GRANT` and `REVOKE` Syntax

```
GRANT priv_type [(column_list)] [, priv_type [(column_list)] ...]
    ON {tbl_name | * | *.* | db_name.*}
    TO user_name [IDENTIFIED BY [PASSWORD] 'password']
        [, user_name [IDENTIFIED BY [PASSWORD] 'password'] ...]
    [REQUIRE
        NONE |
        [{SSL| X509}]
        [CIPHER cipher [AND]]
        [ISSUER issuer [AND]]
        [SUBJECT subject]]
    [WITH [GRANT OPTION | MAX_QUERIES_PER_HOUR # |
                          MAX_UPDATES_PER_HOUR # |
                          MAX_CONNECTIONS_PER_HOUR #]]

REVOKE priv_type [(column_list)] [, priv_type [(column_list)] ...]
    ON {tbl_name | * | *.* | db_name.*}
    FROM user_name [, user_name ...]
```

`GRANT` is implemented in MySQL Version 3.22.11 or later. For earlier MySQL versions, the `GRANT` statement does nothing.

The `GRANT` and `REVOKE` commands allow system administrators to create users and grant and revoke rights to MySQL users at four privilege levels:

Global level

Global privileges apply to all databases on a given server. These privileges are stored in the `mysql.user` table. `GRANT ALL ON *.*` and `REVOKE ALL ON *.*` will grant and revoke only global privileges.

Database level

Database privileges apply to all tables in a given database. These privileges are stored in the `mysql.db` and `mysql.host` tables. `GRANT ALL ON db.*` and `REVOKE ALL ON db.*` will grant and revoke only database privileges.

Table level

Table privileges apply to all columns in a given table. These privileges are stored in the `mysql.tables_priv` table. `GRANT ALL ON db.table` and `REVOKE ALL ON db.table` will grant and revoke only table privileges.

Column level

Column privileges apply to single columns in a given table. These privileges are stored in the `mysql.columns_priv` table. When using `REVOKE` you must specify the same columns that were granted.

For the `GRANT` and `REVOKE` statements, `priv_type` may be specified as any of the following:

`ALL [PRIVILEGES]`	Sets all simple privileges except `WITH GRANT OPTION`
`ALTER`	Allows usage of `ALTER TABLE`
`CREATE`	Allows usage of `CREATE TABLE`
`CREATE TEMPORARY TABLES`	Allows usage of `CREATE TEMPORARY TABLE`
`DELETE`	Allows usage of `DELETE`
`DROP`	Allows usage of `DROP TABLE`.
`EXECUTE`	Allows the user to run stored procedures (MySQL 5.0)
`FILE`	Allows usage of `SELECT ... INTO OUTFILE` and `LOAD DATA INFILE`.
`INDEX`	Allows usage of `CREATE INDEX` and `DROP INDEX`
`INSERT`	Allows usage of `INSERT`
`LOCK TABLES`	Allows usage of `LOCK TABLES` on tables for which one has the `SELECT` privilege.
`PROCESS`	Allows usage of `SHOW FULL PROCESSLIST`
`REFERENCES`	For the future
`RELOAD`	Allows usage of `FLUSH`
`REPLICATION CLIENT`	Gives the right to the user to ask where the slaves/masters are.
`REPLICATION SLAVE`	Needed for the replication slaves (to read binlogs from master).
`SELECT`	Allows usage of `SELECT`
`SHOW DATABASES`	`SHOW DATABASES` shows all databases.
`SHUTDOWN`	Allows usage of `mysqladmin shutdown`
`SUPER`	Allows one connect (once) even if max_connections is reached and execute commands `CHANGE MASTER`, `KILL thread`, `mysqladmin debug`, `PURGE MASTER LOGS` and `SET GLOBAL`
`UPDATE`	Allows usage of `UPDATE`
`USAGE`	Synonym for "no privileges."

`GRANT OPTION` Synonym for `WITH GRANT OPTION`

`USAGE` can be used when you want to create a user that has no privileges.

The privileges `CREATE TEMPORARY TABLES`, `EXECUTE`, `LOCK TABLES`, `REPLICATION ...`, `SHOW DATABASES` and `SUPER` are new for in version 4.0.2. To use these new privileges after upgrading to 4.0.2, you have to run the `mysql_fix_privilege_tables` script. See Section 2.5.6 [Upgrading-grant-tables], page 119.

In older MySQL versions, the `PROCESS` privilege gives the same rights as the new `SUPER` privilege.

To revoke the `GRANT` privilege from a user, use a `priv_type` value of `GRANT OPTION`:

```
mysql> REVOKE GRANT OPTION ON ... FROM ...;
```

The only `priv_type` values you can specify for a table are `SELECT`, `INSERT`, `UPDATE`, `DELETE`, `CREATE`, `DROP`, `GRANT OPTION`, `INDEX`, and `ALTER`.

The only `priv_type` values you can specify for a column (that is, when you use a `column_list` clause) are `SELECT`, `INSERT`, and `UPDATE`.

MySQL allows you to create database level privileges even if the database doesn't exist, to make it easy to prepare for database usage. Currently MySQL does however not allow one to create table level grants if the table doesn't exist. MySQL will not automatically revoke any privileges even if you drop a table or drop a database.

You can set global privileges by using `ON *.*` syntax. You can set database privileges by using `ON db_name.*` syntax. If you specify `ON *` and you have a current database, you will set the privileges for that database. (**Warning**: if you specify `ON *` and you **don't** have a current database, you will affect the global privileges!)

Please note: the '`_`' and '`%`' wildcards are allowed when specifying database names in `GRANT` commands. This means that if you wish to use for instance a '`_`' character as part of a database name, you should specify it as '`\_`' in the `GRANT` command, to prevent the user from being able to access additional databases matching the wildcard pattern, for example, `GRANT ... ON 'foo\_bar'.* TO ...`.

In order to accommodate granting rights to users from arbitrary hosts, MySQL supports specifying the `user_name` value in the form `user@host`. If you want to specify a `user` string containing special characters (such as '`-`'), or a `host` string containing special characters or wildcard characters (such as '`%`'), you can quote the user or host name (for example, `'test-user'@'test-hostname'`).

You can specify wildcards in the hostname. For example, `user@'%.loc.gov'` applies to `user` for any host in the `loc.gov` domain, and `user@'144.155.166.%'` applies to `user` for any host in the `144.155.166` class C subnet.

The simple form `user` is a synonym for `user@"%"`.

MySQL doesn't support wildcards in user names. Anonymous users are defined by inserting entries with `User=''` into the `mysql.user` table or creating an user with an empty name with the `GRANT` command.

Note: if you allow anonymous users to connect to the MySQL server, you should also grant privileges to all local users as `user@localhost` because otherwise the anonymous user entry for the local host in the `mysql.user` table will be used when the user tries to log into the MySQL server from the local machine!

You can verify if this applies to you by executing this query:

```
mysql> SELECT Host,User FROM mysql.user WHERE User='';
```

For the moment, `GRANT` only supports host, table, database, and column names up to 60 characters long. A user name can be up to 16 characters.

The privileges for a table or column are formed from the logical OR of the privileges at each of the four privilege levels. For example, if the `mysql.user` table specifies that a user has a global `SELECT` privilege, this can't be denied by an entry at the database, table, or column level.

The privileges for a column can be calculated as follows:

```
global privileges
OR (database privileges AND host privileges)
OR table privileges
OR column privileges
```

In most cases, you grant rights to a user at only one of the privilege levels, so life isn't normally as complicated as above. The details of the privilege-checking procedure are presented in Section 4.3 [Privilege system], page 213.

If you grant privileges for a user/hostname combination that does not exist in the `mysql.user` table, an entry is added and remains there until deleted with a `DELETE` command. In other words, `GRANT` may create `user` table entries, but `REVOKE` will not remove them; you must do that explicitly using `DELETE`.

In MySQL Version 3.22.12 or later, if a new user is created or if you have global grant privileges, the user's password will be set to the password specified by the `IDENTIFIED BY` clause, if one is given. If the user already had a password, it is replaced by the new one.

If you don't want to send the password in clear text you can use the `PASSWORD` option followed by a scrambled password from SQL function `PASSWORD()` or the C API function `make_scrambled_password(char *to, const char *password)`.

Warning: if you create a new user but do not specify an `IDENTIFIED BY` clause, the user has no password. This is insecure.

Passwords can also be set with the `SET PASSWORD` command. See Section 5.5.6 [`SET`], page 432.

If you grant privileges for a database, an entry in the `mysql.db` table is created if needed. When all privileges for the database have been removed with `REVOKE`, this entry is deleted.

If a user doesn't have any privileges on a table, the table is not displayed when the user requests a list of tables (for example, with a `SHOW TABLES` statement). The same is true for `SHOW DATABASES`.

The `WITH GRANT OPTION` clause gives the user the ability to give to other users any privileges the user has at the specified privilege level. You should be careful to whom you give the `GRANT` privilege, as two users with different privileges may be able to join privileges!

`MAX_QUERIES_PER_HOUR #`, `MAX_UPDATES_PER_HOUR #` and `MAX_CONNECTIONS_PER_HOUR #` are new in MySQL version 4.0.2. These options limit the number of queries/updates and logins the user can do during one hour. If `#` is 0 (default), then this means that there are no limitations for that user. See Section 4.4.7 [User resources], page 249. Note: to specify any of these options for an existing user without adding other additional privileges, use `GRANT USAGE ON *.* ... WITH MAX_...`.

You cannot grant another user a privilege you don't have yourself; the `GRANT` privilege allows you to give away only those privileges you possess.

Be aware that when you grant a user the `GRANT` privilege at a particular privilege level, any privileges the user already possesses (or is given in the future!) at that level are also grantable by that user. Suppose you grant a user the `INSERT` privilege on a database. If you then grant the `SELECT` privilege on the database and specify `WITH GRANT OPTION`, the user can give away not only the `SELECT` privilege, but also `INSERT`. If you then grant the `UPDATE` privilege to the user on the database, the user can give away the `INSERT`, `SELECT` and `UPDATE`.

You should not grant `ALTER` privileges to a normal user. If you do that, the user can try to subvert the privilege system by renaming tables!

Note that if you are using table or column privileges for even one user, the server examines table and column privileges for all users and this will slow down MySQL a bit.

When `mysqld` starts, all privileges are read into memory. Database, table, and column privileges take effect at once, and user-level privileges take effect the next time the user connects. Modifications to the grant tables that you perform using `GRANT` or `REVOKE` are noticed by the server immediately. If you modify the grant tables manually (using `INSERT`, `UPDATE`, etc.), you should execute a `FLUSH PRIVILEGES` statement or run `mysqladmin flush-privileges` to tell the server to reload the grant tables. See Section 4.4.3 [Privilege changes], page 244.

The biggest differences between the SQL standard and MySQL versions of `GRANT` are:

- In MySQL privileges are given for an username + hostname combination and not only for an username.
- SQL-99 doesn't have global or database-level privileges, nor does it support all the privilege types that MySQL supports. MySQL doesn't support the SQL-99 `TRIGGER` or `UNDER` privileges.
- SQL-99 privileges are structured in a hierarchal manner. If you remove an user, all privileges the user has granted are revoked. In MySQL the granted privileges are not automatically revoked, but you have to revoke these yourself if needed.
- In MySQL, if you have the `INSERT` privilege on only some of the columns in a table, you can execute `INSERT` statements on the table; the columns for which you don't have the `INSERT` privilege will be set to their default values. SQL-99 requires you to have the `INSERT` privilege on all columns.
- With SQL99, when you drop a table, all privileges for the table are revoked. With SQL-99, when you revoke a privilege, all privileges that were granted based on the privilege are also revoked. In MySQL, privileges can be dropped only with explicit `REVOKE` commands or by manipulating the MySQL grant tables.

For a description of using `REQUIRE`, see Section 4.4.10 [Secure connections], page 252.

4.4.2 MySQL User Names and Passwords

There are several distinctions between the way user names and passwords are used by MySQL and the way they are used by Unix or Windows:

- User names, as used by MySQL for authentication purposes, have nothing to do with Unix user names (login names) or Windows user names. Most MySQL clients by default

try to log in using the current Unix user name as the MySQL user name, but that is for convenience only. Client programs allow a different name to be specified with the `-u` or `--user` options. This means that you can't make a database secure in any way unless all MySQL user names have passwords. Anyone may attempt to connect to the server using any name, and they will succeed if they specify any name that doesn't have a password.

- MySQL user names can be up to 16 characters long; Unix user names typically are limited to 8 characters.
- MySQL passwords have nothing to do with Unix passwords. There is no necessary connection between the password you use to log in to a Unix machine and the password you use to access a database on that machine.
- MySQL encrypts passwords using a different algorithm than the one used during the Unix login process. See the descriptions of the `PASSWORD()` and `ENCRYPT()` functions in Section 6.3.6.2 [Miscellaneous functions], page 515. Note that even if the password is stored 'scrambled', and knowing your 'scrambled' password is enough to be able to connect to the MySQL server! From version 4.1, MySQL employs a different password and login mechanism that is secure even if TCP/IP packets are sniffed and/or the mysql database is captured.

MySQL users and their privileges are normally created with the `GRANT` command. See Section 4.4.1 [GRANT], page 239.

When you login to a MySQL server with a command-line client you should specify the password with `--password=your-password`. See Section 4.3.8 [Connecting], page 224.

```
mysql --user=monty --password=guess database_name
```

If you want the client to prompt for a password, you should use `--password` without any argument

```
mysql --user=monty --password database_name
```

or the short form:

```
mysql -u monty -p database_name
```

Note that in the last example the password is **not** 'database_name'.

If you want to use the `-p` option to supply a password you should do so like this:

```
mysql -u monty -pguess database_name
```

On some systems, the library call that MySQL uses to prompt for a password will automatically cut the password to 8 characters. Internally MySQL doesn't have any limit for the length of the password.

4.4.3 When Privilege Changes Take Effect

When `mysqld` starts, all grant table contents are read into memory and become effective at that point.

Modifications to the grant tables that you perform using `GRANT`, `REVOKE`, or `SET PASSWORD` are noticed by the server immediately.

If you modify the grant tables manually (using `INSERT`, `UPDATE`, etc.), you should execute a `FLUSH PRIVILEGES` statement or run `mysqladmin flush-privileges` or `mysqladmin`

`reload` to tell the server to reload the grant tables. Otherwise, your changes will have *no effect* until you restart the server. If you change the grant tables manually but forget to reload the privileges, you will be wondering why your changes don't seem to make any difference!

When the server notices that the grant tables have been changed, existing client connections are affected as follows:

- Table and column privilege changes take effect with the client's next request.
- Database privilege changes take effect at the next `USE db_name` command.
- Global privilege changes and password changes take effect the next time the client connects.

4.4.4 Setting Up the Initial MySQL Privileges

After installing MySQL, you set up the initial access privileges by running `scripts/mysql_install_db`. See Section 2.3.1 [Quick install], page 88. The `mysql_install_db` script starts up the `mysqld` server, then initialises the grant tables to contain the following set of privileges:

- The MySQL `root` user is created as a superuser who can do anything. Connections must be made from the local host.

  Note: The initial `root` password is empty, so anyone can connect as `root` *without a password* and be granted all privileges.
- An anonymous user is created that can do anything with databases that have a name of `'test'` or starting with `'test_'`. Connections must be made from the local host. This means any local user can connect without a password and be treated as the anonymous user.
- Other privileges are denied. For example, normal users can't use `mysqladmin shutdown` or `mysqladmin processlist`.

Note: the default privileges are different for Windows. See Section 2.1.1.8 [Windows running], page 63.

Because your installation is initially wide open, one of the first things you should do is specify a password for the MySQL `root` user. You can do this as follows (note that you specify the password using the `PASSWORD()` function):

```
shell> mysql -u root mysql
mysql> SET PASSWORD FOR root@localhost=PASSWORD('new_password');
```

Replace `'new_password'` with the password that you want to use.

If you know what you are doing, you can also directly manipulate the privilege tables:

```
shell> mysql -u root mysql
mysql> UPDATE user SET Password=PASSWORD('new_password')
    ->     WHERE user='root';
mysql> FLUSH PRIVILEGES;
```

Another way to set the password is by using the `mysqladmin` command:

```
shell> mysqladmin -u root password new_password
```

Only users with write/update access to the `mysql` database can change the password for other users. All normal users (not anonymous ones) can only change their own password with either of the above commands or with `SET PASSWORD=PASSWORD('new_password')`.

Note that if you update the password in the `user` table directly using `UPDATE`, you must tell the server to re-read the grant tables (with `FLUSH PRIVILEGES`), because the change will go unnoticed otherwise.

Once the `root` password has been set, thereafter you must supply that password when you connect to the server as `root`.

You may wish to leave the `root` password blank so that you don't need to specify it while you perform additional setup or testing. However, be sure to set it before using your installation for any real production work.

See the `scripts/mysql_install_db` script to see how it sets up the default privileges. You can use this as a basis to see how to add other users.

If you want the initial privileges to be different from those just described above, you can modify `mysql_install_db` before you run it.

To re-create the grant tables completely, remove all the '`.frm`', '`.MYI`', and '`.MYD`' files in the directory containing the `mysql` database. (This is the directory named '`mysql`' under the database directory, which is listed when you run `mysqld --help`.) Then run the `mysql_install_db` script, possibly after editing it first to have the privileges you want.

Note: for MySQL versions older than Version 3.22.10, you should not delete the '`.frm`' files. If you accidentally do this, you should copy them back from your MySQL distribution before running `mysql_install_db`.

4.4.5 Adding New Users to MySQL

You can add users two different ways: by using `GRANT` statements or by manipulating the MySQL grant tables directly. The preferred method is to use `GRANT` statements, because they are more concise and less error-prone. See Section 4.4.1 [GRANT], page 239.

There are also several contributed programs (such as `phpMyAdmin`) that can be used to create and administrate users.

The following examples show how to use the `mysql` client to set up new users. These examples assume that privileges are set up according to the defaults described in the previous section. This means that to make changes, you must be on the same machine where `mysqld` is running, you must connect as the MySQL `root` user, and the `root` user must have the `INSERT` privilege for the `mysql` database and the `RELOAD` administrative privilege. Also, if you have changed the `root` user password, you must specify it for the `mysql` commands here.

First, use the `mysql` program to connect to the server as the MySQL `root` user:

```
shell> mysql --user=root mysql
```

Then you can add new users by issuing `GRANT` statements:

```
mysql> GRANT ALL PRIVILEGES ON *.* TO monty@localhost
    ->     IDENTIFIED BY 'some_pass' WITH GRANT OPTION;
mysql> GRANT ALL PRIVILEGES ON *.* TO monty@'%'
    ->     IDENTIFIED BY 'some_pass' WITH GRANT OPTION;
```

```
mysql> GRANT RELOAD,PROCESS ON *.* TO admin@localhost;
mysql> GRANT USAGE ON *.* TO dummy@localhost;
```

These `GRANT` statements set up three new users:

`monty` A full superuser who can connect to the server from anywhere, but who must use a password `'some_pass'` to do so. Note that we must issue `GRANT` statements for both `monty@localhost` and `monty@"%"`. If we don't add the entry with `localhost`, the anonymous user entry for `localhost` that is created by `mysql_install_db` takes precedence when we connect from the local host, because it has a more specific `Host` field value and thus comes earlier in the `user` table sort order.

`admin` A user who can connect from `localhost` without a password and who is granted the `RELOAD` and `PROCESS` administrative privileges. This allows the user to execute the `mysqladmin reload`, `mysqladmin refresh`, and `mysqladmin flush-*` commands, as well as `mysqladmin processlist` . No database-level privileges are granted. (They can be granted later by issuing additional `GRANT` statements.)

`dummy` A user who can connect without a password, but only from the local host. No privileges are granted—the `USAGE` privilege type allows you to create a user with no privileges. It has the effect of setting all the global privileges to `'N'`. It is assumed that you will grant specific privileges to the account later.

You can also add the same user access information directly by issuing `INSERT` statements and then telling the server to reload the grant tables:

```
shell> mysql --user=root mysql
mysql> INSERT INTO user VALUES('localhost','monty',PASSWORD('some_pass'),
    ->          'Y','Y','Y','Y','Y','Y','Y','Y','Y','Y','Y','Y','Y','Y');
mysql> INSERT INTO user VALUES('%','monty',PASSWORD('some_pass'),
    ->          'Y','Y','Y','Y','Y','Y','Y','Y','Y','Y','Y','Y','Y','Y');
mysql> INSERT INTO user SET Host='localhost',User='admin',
    ->           Reload_priv='Y', Process_priv='Y';
mysql> INSERT INTO user (Host,User,Password)
    ->                  VALUES('localhost','dummy','');
mysql> FLUSH PRIVILEGES;
```

Depending on your MySQL version, you may have to use a different number of `'Y'` values above. (Versions prior to Version 3.22.11 have fewer privilege columns, and versions from 4.0.2 on have more.) For the `admin` user, the more readable extended `INSERT` syntax using `SET` that is available starting with Version 3.22.11 is used.

Note that to set up a superuser, you need only create a `user` table entry with the privilege fields set to `'Y'`. No `db` or `host` table entries are necessary.

In the last `INSERT` statement (for the `dummy` user), only the `Host`, `User`, and `Password` columns in the `user` table record are assigned values. None of the privilege columns are set explicitly, so MySQL assigns them all the default value of `'N'`. This is the same thing that `GRANT USAGE` does.

The following example adds a user `custom` who can access the `bankaccount` database only from the local host, the `expenses` database only from the host `whitehouse.gov`, and the

customer database only from the host server.domain. He wants to use the password obscure from all three hosts.

To set up this user's privileges using GRANT statements, run these commands:

```
shell> mysql --user=root mysql
mysql> GRANT SELECT,INSERT,UPDATE,DELETE,CREATE,DROP
    ->     ON bankaccount.*
    ->     TO custom@localhost
    ->     IDENTIFIED BY 'obscure';
mysql> GRANT SELECT,INSERT,UPDATE,DELETE,CREATE,DROP
    ->     ON expenses.*
    ->     TO custom@'whitehouse.gov'
    ->     IDENTIFIED BY 'obscure';
mysql> GRANT SELECT,INSERT,UPDATE,DELETE,CREATE,DROP
    ->     ON customer.*
    ->     TO custom@'server.domain'
    ->     IDENTIFIED BY 'obscure';
```

To set up the user's privileges by modifying the grant tables directly, run these commands (note the FLUSH PRIVILEGES at the end):

```
shell> mysql --user=root mysql
mysql> INSERT INTO user (Host,User,Password)
    -> VALUES('localhost','custom',PASSWORD('obscure'));
mysql> INSERT INTO user (Host,User,Password)
    -> VALUES('whitehouse.gov','custom',PASSWORD('obscure'));
mysql> INSERT INTO user (Host,User,Password)
    -> VALUES('server.domain','custom',PASSWORD('obscure'));
mysql> INSERT INTO db
    -> (Host,Db,User,Select_priv,Insert_priv,Update_priv,Delete_priv,
    ->  Create_priv,Drop_priv)
    -> VALUES
    -> ('localhost','bankaccount','custom','Y','Y','Y','Y','Y','Y');
mysql> INSERT INTO db
    -> (Host,Db,User,Select_priv,Insert_priv,Update_priv,Delete_priv,
    ->  Create_priv,Drop_priv)
    -> VALUES
    -> ('whitehouse.gov','expenses','custom','Y','Y','Y','Y','Y','Y');
mysql> INSERT INTO db
    -> (Host,Db,User,Select_priv,Insert_priv,Update_priv,Delete_priv,
    ->  Create_priv,Drop_priv)
    -> VALUES('server.domain','customer','custom','Y','Y','Y','Y','Y','Y');
mysql> FLUSH PRIVILEGES;
```

As in the preceding example that used INSERT statements, you may need to use a different number of 'Y' values, depending on your version of MySQL.

The first three INSERT statements add user table entries that allow user custom to connect from the various hosts with the given password, but grant no permissions to him (all privileges are set to the default value of 'N'). The next three INSERT statements add db

table entries that grant privileges to `custom` for the `bankaccount`, `expenses`, and `customer` databases, but only when accessed from the proper hosts. As usual, after you modify the grant tables directly , you must tell the server to reload them (with `FLUSH PRIVILEGES`) so that the privilege changes take effect.

If you want to give a specific user access from any machine in a given domain (for example, `mydomain.com`), you can issue a `GRANT` statement like the following:

```
mysql> GRANT ...
    ->     ON *.*
    ->     TO myusername@'%.mydomain.com'
    ->     IDENTIFIED BY 'mypassword';
```

To do the same thing by modifying the grant tables directly, do this:

```
mysql> INSERT INTO user VALUES ('%.mydomain.com', 'myusername',
    ->             PASSWORD('mypassword'),...);
mysql> FLUSH PRIVILEGES;
```

4.4.6 Deleting Users from MySQL

```
DROP USER user_name
```

This command was added to MySQL 4.1.1.

It deletes a user that doesn't have any privileges.

To delete a user from MySQL you should do things in the following order:

1. Check which privileges the user has with `SHOW PRIVILEGES`. See Section 4.6.8.11 [SHOW PRIVILEGES], page 306.
2. Delete all privileges from the user with `REVOKE`. See Section 4.4.1 [GRANT], page 239.
3. Delete the user with `DROP USER`.

If you are using and older MySQL version you should first revoke the privileges and then delete the user with:

```
DELETE FROM mysql.user WHERE user='username' and host='hostname';
FLUSH PRIVILEGES;
```

4.4.7 Limiting user resources

Starting from MySQL 4.0.2 one can limit certain resources per user.

So far, the only available method of limiting usage of MySQL server resources has been setting the `max_user_connections` startup variable to a non-zero value. But this method is strictly global and does not allow for management of individual users, which could be of particular interest to Internet Service Providers.

Therefore, management of three resources is introduced on the individual user level:

- Number of all queries per hour: All commands that could be run by a user.
- Number of all updates per hour: Any command that changes any table or database.
- Number of connections made per hour: New connections opened per hour.

A user in the aforementioned context is a single entry in the `user` table, which is uniquely identified by its `user` and `host` columns.

All users are by default not limited in using the above resources, unless the limits are granted to them. These limits can be granted **only** via global `GRANT (*.*)`, using this syntax:

```
GRANT ... WITH MAX_QUERIES_PER_HOUR N1
               MAX_UPDATES_PER_HOUR N2
               MAX_CONNECTIONS_PER_HOUR N3;
```

One can specify any combination of the above resources. `N1`, `N2`, and `N3` are integers and represent counts per hour.

If a user reaches the limit on number of connections within one hour, no further connections will be accepted until that hour is up. Similarly, if the user reaches the limit on number of queries or updates, further queries or updates will be rejected until the hour is up. In all cases, an appropriate error message shall be issued.

Current usage values for a particular user can be flushed (set to zero) by issuing a `GRANT` statement with any of the above clauses, including a `GRANT` statement with the current values.

Also, current values for all users will be flushed if privileges are reloaded (in the server or using `mysqladmin reload`) or if the `FLUSH USER_RESOURCES` command is issued.

The feature is enabled as soon as a single user is granted with any of the limiting `GRANT` clauses.

As a prerequisite for enabling this feature, the `user` table in the `mysql` database must contain the additional columns, as defined in the table creation scripts `mysql_install_db` and `mysql_install_db.sh` in '`scripts`' subdirectory.

4.4.8 Setting Up Passwords

In most cases you should use `GRANT` to set up your users/passwords, so the following only applies for advanced users. See Section 4.4.1 [`GRANT`], page 239.

The examples in the preceding sections illustrate an important principle: when you store a non-empty password using `INSERT` or `UPDATE` statements, you must use the `PASSWORD()` function to encrypt it. This is because the `user` table stores passwords in encrypted form, not as plaintext. If you forget that fact, you are likely to attempt to set passwords like this:

```
shell> mysql -u root mysql
mysql> INSERT INTO user (Host,User,Password)
    -> VALUES('%','jeffrey','biscuit');
mysql> FLUSH PRIVILEGES;
```

The result is that the plaintext value `'biscuit'` is stored as the password in the `user` table. When the user `jeffrey` attempts to connect to the server using this password, the `mysql` client encrypts it with `PASSWORD()`, generates an authentification vector based on **encrypted** password and a random number, obtained from server, and sends the result to the server. The server uses the `password` value in the `user` table (that is **not encrypted** value `'biscuit'`) to perform the same calculations, and compares results. The comparison fails and the server rejects the connection:

```
shell> mysql -u jeffrey -pbiscuit test
Access denied
```

Passwords must be encrypted when they are inserted in the `user` table, so the `INSERT` statement should have been specified like this instead:

```
mysql> INSERT INTO user (Host,User,Password)
    -> VALUES('%','jeffrey',PASSWORD('biscuit'));
```

You must also use the `PASSWORD()` function when you use `SET PASSWORD` statements:

```
mysql> SET PASSWORD FOR jeffrey@"%" = PASSWORD('biscuit');
```

If you set passwords using the `GRANT ... IDENTIFIED BY` statement or the `mysqladmin password` command, the `PASSWORD()` function is unnecessary. They both take care of encrypting the password for you, so you would specify a password of `'biscuit'` like this:

```
mysql> GRANT USAGE ON *.* TO jeffrey@"%" IDENTIFIED BY 'biscuit';
```

or

```
shell> mysqladmin -u jeffrey password biscuit
```

Note: `PASSWORD()` is different from Unix password encryption. See Section 4.4.2 [User names], page 243.

4.4.9 Keeping Your Password Secure

It is inadvisable to specify your password in a way that exposes it to discovery by other users. The methods you can use to specify your password when you run client programs are listed here, along with an assessment of the risks of each method:

- Never give a normal user access to the `mysql.user` table. Knowing the encrypted password for a user makes it possible to login as this user. The passwords are only scrambled so that one shouldn't be able to see the real password you used (if you happen to use a similar password with your other applications).
- Use a `-pyour_pass` or `--password=your_pass` option on the command line. This is convenient but insecure, because your password becomes visible to system status programs (such as `ps`) that may be invoked by other users to display command-lines. (MySQL clients typically overwrite the command-line argument with zeroes during their initialisation sequence, but there is still a brief interval during which the value is visible.)
- Use a `-p` or `--password` option (with no `your_pass` value specified). In this case, the client program solicits the password from the terminal:

  ```
  shell> mysql -u user_name -p
  Enter password: ********
  ```

  The '`*`' characters represent your password.

  It is more secure to enter your password this way than to specify it on the command-line because it is not visible to other users. However, this method of entering a password is suitable only for programs that you run interactively. If you want to invoke a client from a script that runs non-interactively, there is no opportunity to enter the password from the terminal. On some systems, you may even find that the first line of your script is read and interpreted (incorrectly) as your password!

- Store your password in a configuration file. For example, you can list your password in the `[client]` section of the '`.my.cnf`' file in your home directory:

  ```
  [client]
  password=your_pass
  ```

  If you store your password in '`.my.cnf`', the file should not be group or world readable or writable. Make sure the file's access mode is `400` or `600`.

  See Section 4.1.2 [Option files], page 203.

- You can store your password in the `MYSQL_PWD` environment variable, but this method must be considered extremely insecure and should not be used. Some versions of `ps` include an option to display the environment of running processes; your password will be in plain sight for all to see if you set `MYSQL_PWD`. Even on systems without such a version of `ps`, it is unwise to assume there is no other method to observe process environments. See Appendix F [Environment variables], page 1019.

All in all, the safest methods are to have the client program prompt for the password or to specify the password in a properly protected '`.my.cnf`' file.

4.4.10 Using Secure Connections

4.4.10.1 Basics

Beginning with version 4.0.0, MySQL has support for SSL encrypted connections. To understand how MySQL uses SSL, it's necessary to explain some basic SSL and X509 concepts. People who are already familiar with them can skip this part.

By default, MySQL uses unencrypted connections between the client and the server. This means that someone could watch all your traffic and look at the data being sent or received. They could even change the data while it is in transit between client and server. Sometimes you need to move information over public networks in a secure fashion; in such cases, using an unencrypted connection is unacceptable.

SSL is a protocol that uses different encryption algorithms to ensure that data received over a public network can be trusted. It has mechanisms to detect any change, loss or replay of data. SSL also incorporates algorithms to recognise and provide identity verification using the X509 standard.

Encryption is the way to make any kind of data unreadable. In fact, today's practice requires many additional security elements from encryption algorithms. They should resist many kind of known attacks like just messing with the order of encrypted messages or replaying data twice.

X509 is a standard that makes it possible to identify someone on the Internet. It is most commonly used in e-commerce applications. In basic terms, there should be some company (called a "Certificate Authority") that assigns electronic certificates to anyone who needs them. Certificates rely on asymmetric encryption algorithms that have two encryption keys (a public key and a secret key). A certificate owner can prove his identity by showing his certificate to other party. A certificate consists of its owner's public key. Any data encrypted with this public key can be decrypted only using the corresponding secret key, which is held by the owner of the certificate.

MySQL doesn't use encrypted connections by default, because doing so would make the client/server protocol much slower. Any kind of additional functionality requires the computer to do additional work and encrypting data is a CPU-intensive operation that requires time and can delay MySQL main tasks. By default MySQL is tuned to be fast as possible.

If you need more information about SSL, X509, or encryption, you should use your favourite Internet search engine and search for keywords in which you are interested.

4.4.10.2 Requirements

To get secure connections to work with MySQL you must do the following:

1. Install the OpenSSL library. We have tested MySQL with OpenSSL 0.9.6. `http://www.openssl.org/`.
2. Configure MySQL with `--with-vio --with-openssl`.
3. If you are using an old MySQL installation, you have to update your `mysql.user` table with some new SSL-related columns. This is necessary if your grant tables date from a version prior to MySQL 4.0.0. The procedure is described in Section 2.5.6 [Upgrading-grant-tables], page 119.
4. You can check if a running `mysqld` server supports OpenSSL by examining if `SHOW VARIABLES LIKE 'have_openssl'` returns `YES`.

4.4.10.3 Setting Up SSL Certificates for MySQL

Here is an example for setting up SSL certificates for MySQL:

```
DIR=‘pwd‘/openssl
PRIV=$DIR/private

mkdir $DIR $PRIV $DIR/newcerts
cp /usr/share/ssl/openssl.cnf $DIR
replace ./demoCA $DIR -- $DIR/openssl.cnf

# Create necessary files: $database, $serial and $new_certs_dir
# directory (optional)

touch $DIR/index.txt
echo "01" > $DIR/serial

#
# Generation of Certificate Authority(CA)
#

openssl req -new -x509 -keyout $PRIV/cakey.pem -out $DIR/cacert.pem \
    -config $DIR/openssl.cnf

# Sample output:
# Using configuration from /home/monty/openssl/openssl.cnf
```

```
# Generating a 1024 bit RSA private key
# ................++++++
# .........++++++
# writing new private key to '/home/monty/openssl/private/cakey.pem'
# Enter PEM pass phrase:
# Verifying password - Enter PEM pass phrase:
# -----
# You are about to be asked to enter information that will be incorporated
# into your certificate request.
# What you are about to enter is what is called a Distinguished Name or a DN.
# There are quite a few fields but you can leave some blank
# For some fields there will be a default value,
# If you enter '.', the field will be left blank.
# -----
# Country Name (2 letter code) [AU]:FI
# State or Province Name (full name) [Some-State]:.
# Locality Name (eg, city) []:
# Organization Name (eg, company) [Internet Widgits Pty Ltd]:MySQL AB
# Organizational Unit Name (eg, section) []:
# Common Name (eg, YOUR name) []:MySQL admin
# Email Address []:

#
# Create server request and key
#
openssl req -new -keyout $DIR/server-key.pem -out \
    $DIR/server-req.pem -days 3600 -config $DIR/openssl.cnf

# Sample output:
# Using configuration from /home/monty/openssl/openssl.cnf
# Generating a 1024 bit RSA private key
# ..++++++
# ..........++++++
# writing new private key to '/home/monty/openssl/server-key.pem'
# Enter PEM pass phrase:
# Verifying password - Enter PEM pass phrase:
# -----
# You are about to be asked to enter information that will be incorporated
# into your certificate request.
# What you are about to enter is what is called a Distinguished Name or a DN.
# There are quite a few fields but you can leave some blank
# For some fields there will be a default value,
# If you enter '.', the field will be left blank.
# -----
# Country Name (2 letter code) [AU]:FI
# State or Province Name (full name) [Some-State]:.
# Locality Name (eg, city) []:
```

```
# Organization Name (eg, company) [Internet Widgits Pty Ltd]:MySQL AB
# Organizational Unit Name (eg, section) []:
# Common Name (eg, YOUR name) []:MySQL server
# Email Address []:
#
# Please enter the following 'extra' attributes
# to be sent with your certificate request
# A challenge password []:
# An optional company name []:

#
# Remove the passphrase from the key (optional)
#

openssl rsa -in $DIR/server-key.pem -out $DIR/server-key.pem

#
# Sign server cert
#
openssl ca  -policy policy_anything -out $DIR/server-cert.pem \
    -config $DIR/openssl.cnf -infiles $DIR/server-req.pem

# Sample output:
# Using configuration from /home/monty/openssl/openssl.cnf
# Enter PEM pass phrase:
# Check that the request matches the signature
# Signature ok
# The Subjects Distinguished Name is as follows
# countryName           :PRINTABLE:'FI'
# organizationName      :PRINTABLE:'MySQL AB'
# commonName            :PRINTABLE:'MySQL admin'
# Certificate is to be certified until Sep 13 14:22:46 2003 GMT (365 days)
# Sign the certificate? [y/n]:y
#
#
# 1 out of 1 certificate requests certified, commit? [y/n]y
# Write out database with 1 new entries
# Data Base Updated

#
# Create client request and key
#
openssl req -new -keyout $DIR/client-key.pem -out \
    $DIR/client-req.pem -days 3600 -config $DIR/openssl.cnf

# Sample output:
# Using configuration from /home/monty/openssl/openssl.cnf
```

```
# Generating a 1024 bit RSA private key
# ..................................++++++
# ........................................++++++
# writing new private key to '/home/monty/openssl/client-key.pem'
# Enter PEM pass phrase:
# Verifying password - Enter PEM pass phrase:
# -----
# You are about to be asked to enter information that will be incorporated
# into your certificate request.
# What you are about to enter is what is called a Distinguished Name or a DN.
# There are quite a few fields but you can leave some blank
# For some fields there will be a default value,
# If you enter '.', the field will be left blank.
# -----
# Country Name (2 letter code) [AU]:FI
# State or Province Name (full name) [Some-State]:.
# Locality Name (eg, city) []:
# Organization Name (eg, company) [Internet Widgits Pty Ltd]:MySQL AB
# Organizational Unit Name (eg, section) []:
# Common Name (eg, YOUR name) []:MySQL user
# Email Address []:
#
# Please enter the following 'extra' attributes
# to be sent with your certificate request
# A challenge password []:
# An optional company name []:

#
# Remove a passphrase from the key (optional)
#
openssl rsa -in $DIR/client-key.pem -out $DIR/client-key.pem

#
# Sign client cert
#

openssl ca  -policy policy_anything -out $DIR/client-cert.pem \
    -config $DIR/openssl.cnf -infiles $DIR/client-req.pem

# Sample output:
# Using configuration from /home/monty/openssl/openssl.cnf
# Enter PEM pass phrase:
# Check that the request matches the signature
# Signature ok
# The Subjects Distinguished Name is as follows
# countryName           :PRINTABLE:'FI'
# organizationName      :PRINTABLE:'MySQL AB'
```

```
# commonName            :PRINTABLE:'MySQL user'
# Certificate is to be certified until Sep 13 16:45:17 2003 GMT (365 days)
# Sign the certificate? [y/n]:y
#
#
# 1 out of 1 certificate requests certified, commit? [y/n]y
# Write out database with 1 new entries
# Data Base Updated

#
# Create a my.cnf file that you can use to test the certificates
#

cnf=""
cnf="$cnf [client]"
cnf="$cnf ssl-ca=$DIR/cacert.pem"
cnf="$cnf ssl-cert=$DIR/client-cert.pem"
cnf="$cnf ssl-key=$DIR/client-key.pem"
cnf="$cnf [mysqld]"
cnf="$cnf ssl-ca=$DIR/cacert.pem"
cnf="$cnf ssl-cert=$DIR/server-cert.pem"
cnf="$cnf ssl-key=$DIR/server-key.pem"
echo $cnf | replace " " '
' > $DIR/my.cnf

#
# To test MySQL

mysqld --defaults-file=$DIR/my.cnf &

mysql --defaults-file=$DIR/my.cnf
```

You can also test your setup by modifying the above '`my.cnf`' file to refer to the demo certificates in the mysql-source-dist/SSL direcory.

4.4.10.4 SSL `GRANT` Options

MySQL can check X509 certificate attributes in addition to the normal username/password scheme. All the usual options are still required (username, password, IP address mask, database/table name).

There are different possibilities to limit connections:

- Without any SSL or X509 options, all kind of encrypted/unencrypted connections are allowed if the username and password are valid.
- `REQUIRE SSL` option limits the server to allow only SSL encrypted connections. Note that this option can be omitted if there are any ACL records which allow non-SSL connections.

```
mysql> GRANT ALL PRIVILEGES ON test.* TO root@localhost
    -> IDENTIFIED BY 'goodsecret' REQUIRE SSL;
```

- `REQUIRE X509` means that the client should have a valid certificate but we do not care about the exact certificate, issuer or subject. The only restriction is that it should be possible to verify its signature with one of the CA certificates.

  ```
  mysql> GRANT ALL PRIVILEGES ON test.* TO root@localhost
      -> IDENTIFIED BY 'goodsecret' REQUIRE X509;
  ```

- `REQUIRE ISSUER 'issuer'` places a restriction on connection attempts: The client must present a valid X509 certificate issued by CA `'issuer'`. Using X509 certificates always implies encryption, so the `SSL` option is unneccessary.

  ```
  mysql> GRANT ALL PRIVILEGES ON test.* TO root@localhost
      -> IDENTIFIED BY 'goodsecret'
      -> REQUIRE ISSUER 'C=FI, ST=Some-State, L=Helsinki,
      '> O=MySQL Finland AB, CN=Tonu Samuel/Email=tonu@mysql.com';
  ```

- `REQUIRE SUBJECT 'subject'` requires clients to have valid X509 certificate with subject `'subject'` on it. If the client presents a certificate that is valid but has a different `'subject'`, the connection is disallowed.

  ```
  mysql> GRANT ALL PRIVILEGES ON test.* TO root@localhost
      -> IDENTIFIED BY 'goodsecret'
      -> REQUIRE SUBJECT 'C=EE, ST=Some-State, L=Tallinn,
      '> O=MySQL demo client certificate,
      '> CN=Tonu Samuel/Email=tonu@mysql.com';
  ```

- `REQUIRE CIPHER 'cipher'` is needed to assure enough strong ciphers and keylengths will be used. SSL itself can be weak if old algorithms with short encryption keys are used. Using this option, we can ask for some exact cipher method to allow a connection.

  ```
  mysql> GRANT ALL PRIVILEGES ON test.* TO root@localhost
      -> IDENTIFIED BY 'goodsecret'
      -> REQUIRE CIPHER 'EDH-RSA-DES-CBC3-SHA';
  ```

  The `SUBJECT`, `ISSUER`, and `CIPHER` options can be combined in the `REQUIRE` clause like this:

  ```
  mysql> GRANT ALL PRIVILEGES ON test.* TO root@localhost
      -> IDENTIFIED BY 'goodsecret'
      -> REQUIRE SUBJECT 'C=EE, ST=Some-State, L=Tallinn,
      '> O=MySQL demo client certificate,
      '> CN=Tonu Samuel/Email=tonu@mysql.com'
      -> AND ISSUER 'C=FI, ST=Some-State, L=Helsinki,
      '> O=MySQL Finland AB, CN=Tonu Samuel/Email=tonu@mysql.com'
      -> AND CIPHER 'EDH-RSA-DES-CBC3-SHA';
  ```

  Starting from MySQL 4.0.4 the `AND` keyword is optional between `REQUIRE` options.

  The order of the options does not matter, but no option can be specified twice.

4.4.10.5 SSL Command-line Options

The following table lists options that are used for specifying the use of SSL, certificate files, and key files. These options are available beginning with MySQL 4.0. They may be given on the command line or in option files.

`--ssl` For the server, specifies that the server allows SSL connections. For a client program, allows the client to connect to the server using SSL. This option itself is not sufficient to cause an SSL connection to be used. You must also specify the `--ssl-ca`, `--ssl-cert`, and `--ssl-key` options.

Note that this option doesn't **require** an SSL connection. For example, if the server or client are compiled without SSL support, a normal unencrypted connection will be used.

The secure way to ensure that a SSL connection will be used is to create an account on the server that includes a `REQUIRE SSL` clause in the `GRANT` statement. Then use this account to connect to the server, with both a server and client that have SSL support enabled.

You can use this option to indicate that the connection should not use SSL. Do this by specifying the option as `--skip-ssl` or `--ssl=0`.

`--ssl-ca=file_name`
The path to a file with a list of trusted SSL CAs.

`--ssl-capath=directory_name`
The path to a directory which contains trusted SSL CA certificates in pem format.

`--ssl-cert=file_name`
The name of the SSL certificate file to use used for establishing a secure connection.

`--ssl-cipher=cipher_list`
A list of allowable ciphers to use for SSL encryption. `cipher_list` has the same format as the `openssl ciphers` command.

Example: `--ssl-cipher=ALL:-AES:-EXP`

`--ssl-key=file_name`
The name of the SSL key file to use used for establishing a secure connection.

4.5 Disaster Prevention and Recovery

4.5.1 Database Backups

Because MySQL tables are stored as files, it is easy to do a backup. To get a consistent backup, do a `LOCK TABLES` on the relevant tables followed by `FLUSH TABLES` for the tables. See Section 6.7.5 [`LOCK TABLES`], page 582. See Section 4.6.4 [`FLUSH`], page 282. You only need a read lock; this allows other threads to continue to query the tables while you are

making a copy of the files in the database directory. The `FLUSH TABLE` is needed to ensure that the all active index pages is written to disk before you start the backup.

Starting from 3.23.56 and 4.0.12 `BACKUP TABLE` will not allow you to overwrite existing files as this would be a security risk.

If you want to make an SQL level backup of a table, you can use `SELECT INTO OUTFILE` or `BACKUP TABLE`. See Section 6.4.1 [SELECT], page 530. See Section 4.5.2 [BACKUP TABLE], page 261.

Another way to back up a database is to use the `mysqldump` program or the `mysqlhotcopy script`. See Section 4.9.6 [mysqldump], page 339. See Section 4.9.7 [mysqlhotcopy], page 344.

1. Do a full backup of your database:

   ```
   shell> mysqldump --tab=/path/to/some/dir --opt db_name

   or

   shell> mysqlhotcopy db_name /path/to/some/dir
   ```

   You can also simply copy all table files ('`*.frm`', '`*.MYD`', and '`*.MYI`' files) as long as the server isn't updating anything. The script `mysqlhotcopy` does use this method. (But note that these methods will not work if your database contains `InnoDB` tables. `InnoDB` does not store table contents in database directories, and `mysqlhotcopy` works only for `MyISAM` and `ISAM` tables.)
2. Stop `mysqld` if it's running, then start it with the `--log-bin[=file_name]` option. See Section 4.10.4 [Binary log], page 351. The binary log file(s) provide you with the information you need to replicate changes to the database that are made subsequent to the point at which you executed `mysqldump`.

If your MySQL server is a slave, whatever backup method you choose, when you backup your slave's data, you should also backup the '`master.info`' and '`relay-log.info`' files which are always needed to resume replication after you restore the slave's data. If your slave is subject to replicating `LOAD DATA INFILE` commands, you should also backup the '`SQL-LOAD*`' files which may exist in the '`slave-load-tmpdir`' (which is '`tmpdir`' by default) directory. The slave will need these files to resume replication of any interrupted `LOAD DATA INFILE`.

If you have to restore something, try to recover your tables using `REPAIR TABLE` or `myisamchk -r` first. That should work in 99.9% of all cases. If `myisamchk` fails, try the following procedure (this will only work if you have started MySQL with `--log-bin`, see Section 4.10.4 [Binary log], page 351):

1. Restore the original `mysqldump` backup, or binary backup.
2. Execute the following command to re-run the updates in the binary log:

   ```
   shell> mysqlbinlog hostname-bin.[0-9]* | mysql
   ```

   In your case you may want to re-run only certain binlogs, from certain positions (usually you want to re-run all binlogs from the date of the restored backup, possibly excepted some wrong queries). See Section 4.9.4 [mysqlbinlog], page 336 for more information on the `mysqlbinlog` utility and how to use it.

If you are using the update log (which will be removed in MySQL 5.0) you can execute the content of the update log like this:

```
shell> ls -1 -t -r hostname.[0-9]* | xargs cat | mysql
```

`ls` is used to get all the update log files in the right order.

You can also do selective backups with `SELECT * INTO OUTFILE 'file_name' FROM tbl_name` and restore with `LOAD DATA INFILE 'file_name' REPLACE ...`. To avoid duplicate records, you need a `PRIMARY KEY` or a `UNIQUE` key in the table. The `REPLACE` keyword causes old records to be replaced with new ones when a new record duplicates an old record on a unique key value.

If you get performance problems in making backups on your system, you can solve this by setting up replication and do the backups on the slave instead of on the master. See Section 4.11.1 [Replication Intro], page 355.

If you are using a Veritas filesystem, you can do:

1. From a client (or Perl), execute: `FLUSH TABLES WITH READ LOCK`.
2. From another shell, execute: `mount vxfs snapshot`.
3. From the first client, execute: `UNLOCK TABLES`.
4. Copy files from snapshot.
5. Unmount snapshot.

4.5.2 `BACKUP TABLE` Syntax

```
BACKUP TABLE tbl_name[,tbl_name...] TO '/path/to/backup/directory'
```

Copies to the backup directory the minimum number of table files needed to restore the table, after flushing any buffered changes to disk. Currently works only for `MyISAM` tables. For `MyISAM` tables, copies '`.frm`' (definition) and '`.MYD`' (data) files. The index file can be rebuilt from those two.

Before using this command, please see Section 4.5.1 [Backup], page 259.

During the backup, a read lock will be held for each table, one at time, as they are being backed up. If you want to back up several tables as a snapshot, you must first issue `LOCK TABLES` obtaining a read lock for each table in the group.

The command returns a table with the following columns:

Column	Value
Table	Table name
Op	Always `backup`
Msg_type	One of `status`, `error`, `info`, or `warning`
Msg_text	The message

Note that `BACKUP TABLE` is only available in MySQL version 3.23.25 and later.

4.5.3 `RESTORE TABLE` Syntax

```
RESTORE TABLE tbl_name[,tbl_name...] FROM '/path/to/backup/directory'
```

Restores the table or tables from the backup that was made with `BACKUP TABLE`. Existing tables will not be overwritten; if you try to restore over an existing table, you will get an error. Restoring will take longer than backing up due to the need to rebuild the index. The more keys you have, the longer it will take. Just as `BACKUP TABLE`, `RESTORE TABLE` currently works only for `MyISAM` tables.

The command returns a table with the following columns:

Column	Value
Table	Table name
Op	Always `restore`
Msg_type	One of `status`, `error`, `info`, or `warning`
Msg_text	The message

4.5.4 `CHECK TABLE` Syntax

```
CHECK TABLE tbl_name[,tbl_name...] [option [option...]]

option = QUICK | FAST | MEDIUM | EXTENDED | CHANGED
```

`CHECK TABLE` works only on `MyISAM` and `InnoDB` tables. On `MyISAM` tables, it's the same thing as running `myisamchk --medium-check table_name` on the table.

If you don't specify any option, `MEDIUM` is used.

Checks the table or tables for errors. For `MyISAM` tables, the key statistics are updated. The command returns a table with the following columns:

Column	Value
Table	Table name
Op	Always `check`
Msg_type	One of `status`, `error`, `info`, or `warning`
Msg_text	The message

Note that the statement may produce many rows of information for each checked table. The last row will be of `Msg_type status` and should normally be `OK`. If you don't get `OK`, or `Table is already up to date` you should normally run a repair of the table. See Section 4.5.6 [Table maintenance], page 264. `Table is already up to date` means that the storage manager for the table indicated that there was no need to check the table.

The different check types are as follows:

Type	Meaning
`QUICK`	Don't scan the rows to check for incorrect links.
`FAST`	Only check tables that haven't been closed properly.
`CHANGED`	Only check tables that have been changed since the last check or haven't been closed properly.
`MEDIUM`	Scan rows to verify that deleted links are okay. This also calculates a key checksum for the rows and verifies this with a calculated checksum for the keys.
`EXTENDED`	Do a full key lookup for all keys for each row. This ensures that the table is 100% consistent, but will take a long time!

For dynamically sized MyISAM tables, a started check will always do a MEDIUM check. For statically sized rows, we skip the row scan for QUICK and FAST as the rows are very seldom corrupted.

You can combine check options, as in the following example that does a quick check on the table to see whether it was closed properly:

```
CHECK TABLE test_table FAST QUICK;
```

Note: that in some cases CHECK TABLE will change the table! This happens if the table is marked as 'corrupted' or 'not closed properly' but CHECK TABLE didn't find any problems in the table. In this case, CHECK TABLE will mark the table as okay.

If a table is corrupted, then it's most likely that the problem is in the indexes and not in the data part. All of the above check types checks the indexes thoroughly and should thus find most errors.

If you just want to check a table that you assume is okay, you should use no check options or the QUICK option. The latter should be used when you are in a hurry and can take the very small risk that QUICK didn't find an error in the datafile. (In most cases MySQL should find, under normal usage, any error in the datafile. If this happens then the table will be marked as 'corrupted', in which case the table can't be used until it's repaired.)

FAST and CHANGED are mostly intended to be used from a script (for example to be executed from cron) if you want to check your table from time to time. In most cases, FAST is to be prefered over CHANGED. (The only case when it isn't is when you suspect that you have found a bug in the MyISAM code.)

EXTENDED is only to be used after you have run a normal check but still get strange errors from a table when MySQL tries to update a row or find a row by key (this is very unlikely if a normal check has succeeded!).

Some things reported by CHECK TABLE can't be corrected automatically:

- `Found row where the auto_increment column has the value 0.`

  This means that you have a row in the table where the AUTO_INCREMENT index column contains the value 0. (It's possible to create a row where the AUTO_INCREMENT column is 0 by explicitly setting the column to 0 with an UPDATE statement.)

  This isn't an error in itself, but could cause trouble if you decide to dump the table and restore it or do an ALTER TABLE on the table. In this case, the AUTO_INCREMENT column will change value, according to the rules of AUTO_INCREMENT columns, which could cause problems such as a duplicate key error.

  To get rid of the warning, just execute an UPDATE statement to set the column to some other value than 0.

4.5.5 REPAIR TABLE Syntax

```
REPAIR [LOCAL | NO_WRITE_TO_BINLOG] TABLE tbl_name[,tbl_name...] [QUICK] [EXTENDED] [U
```

REPAIR TABLE works only on MyISAM tables and is the same as running `myisamchk -r table_name` on the table.

Normally you should never have to run this command, but if disaster strikes you are very likely to get back all your data from a MyISAM table with REPAIR TABLE. If your tables get corrupted a lot, you should try to find the reason for it, to eliminate the need to use

`REPAIR TABLE`. See Section A.4.1 [Crashing], page 859. See Section 7.1.3 [MyISAM table problems], page 600.

`REPAIR TABLE` repairs a possibly corrupted table. The command returns a table with the following columns:

Column	Value
Table	Table name
Op	Always `repair`
Msg_type	One of `status`, `error`, `info`, or `warning`
Msg_text	The message

Note that the statement may produce many rows of information for each repaired table. The last one row will be of `Msg_type status` and should normally be `OK`. If you don't get `OK`, you should try repairing the table with `myisamchk --safe-recover`, as `REPAIR TABLE` does not yet implement all the options of `myisamchk`. In the near future, we will make it more flexible.

If `QUICK` is given, `REPAIR TABLE` tries to repair only the index tree.

If you use `EXTENDED`, MySQL will create the index row by row instead of creating one index at a time with sorting; this may be better than sorting on fixed-length keys if you have long `CHAR` keys that compress very well. This type of repair is like that done by `myisamchk --safe-recover`.

As of `MySQL` 4.0.2, there is a `USE_FRM` mode for `REPAIR`. Use it if the '`.MYI`' file is missing or if its header is corrupted. In this mode MySQL will recreate the table, using information from the '`.frm`' file. This kind of repair cannot be done with `myisamchk`.

Warning: If `mysqld` dies during a `REPAIR TABLE`, it's essential that you do at once another `REPAIR` on the table before executing any other commands on it. (It's of course always good to start with a backup). In the worst case you can have a new clean index file without information about the datafile and when the next command you do may overwrite the datafile. This is not a likely, but possible scenario.

Before MySQL 4.1.1, `REPAIR` commands are not written to the binary log. Since MySQL 4.1.1 they are written to the binary log unless the optional `NO_WRITE_TO_BINLOG` keyword (or its alias `LOCAL`) was used.

4.5.6 Using `myisamchk` for Table Maintenance and Crash Recovery

Starting with MySQL Version 3.23.13, you can check MyISAM tables with the `CHECK TABLE` command. See Section 4.5.4 [CHECK TABLE], page 262. You can repair tables with the `REPAIR TABLE` command. See Section 4.5.5 [REPAIR TABLE], page 263.

To check/repair MyISAM tables ('`.MYI`' and '`.MYD`') you should use the `myisamchk` utility. To check/repair ISAM tables ('`.ISM`' and '`.ISD`') you should use the `isamchk` utility. See Chapter 7 [Table types], page 594.

In the following text we will talk about `myisamchk`, but everything also applies to the old `isamchk`.

You can use the `myisamchk` utility to get information about your database tables, check and repair them, or optimise them. The following sections describe how to invoke `myisamchk`

(including a description of its options), how to set up a table maintenance schedule, and how to use `myisamchk` to perform its various functions.

You can, in most cases, also use the command `OPTIMIZE TABLES` to optimise and repair tables, but this is not as fast or reliable (in case of real fatal errors) as `myisamchk`. On the other hand, `OPTIMIZE TABLE` is easier to use and you don't have to worry about flushing tables. See Section 4.6.1 [`OPTIMIZE TABLE`], page 281.

Even though the repair in `myisamchk` is quite secure, it's always a good idea to make a backup *before* doing a repair (or anything that could make a lot of changes to a table)

4.5.6.1 `myisamchk` Invocation Syntax

`myisamchk` is invoked like this:

```
shell> myisamchk [options] tbl_name
```

The `options` specify what you want `myisamchk` to do. They are described here. (You can also get a list of options by invoking `myisamchk --help`.) With no options, `myisamchk` simply checks your table. To get more information or to tell `myisamchk` to take corrective action, specify options as described here and in the following sections.

`tbl_name` is the database table you want to check/repair. If you run `myisamchk` somewhere other than in the database directory, you must specify the path to the file, because `myisamchk` has no idea where your database is located. Actually, `myisamchk` doesn't care whether the files you are working on are located in a database directory; you can copy the files that correspond to a database table into another location and perform recovery operations on them there.

You can name several tables on the `myisamchk` command-line if you wish. You can also specify a name as an index file name (with the '`.MYI`' suffix), which allows you to specify all tables in a directory by using the pattern '`*.MYI`'. For example, if you are in a database directory, you can check all the tables in the directory like this:

```
shell> myisamchk *.MYI
```

If you are not in the database directory, you can check all the tables there by specifying the path to the directory:

```
shell> myisamchk /path/to/database_dir/*.MYI
```

You can even check all tables in all databases by specifying a wildcard with the path to the MySQL data directory:

```
shell> myisamchk /path/to/datadir/*/*.MYI
```

The recommended way to quickly check all tables is:

```
myisamchk --silent --fast /path/to/datadir/*/*.MYI
isamchk --silent /path/to/datadir/*/*.ISM
```

If you want to check all tables and repair all tables that are corrupted, you can use the following line:

```
myisamchk --silent --force --fast --update-state -O key_buffer=64M \
          -O sort_buffer=64M -O read_buffer=1M -O write_buffer=1M \
          /path/to/datadir/*/*.MYI
isamchk --silent --force -O key_buffer=64M -O sort_buffer=64M \
```

```
-O read_buffer=1M -O write_buffer=1M /path/to/datadir/*/*.ISM
```

The above assumes that you have more than 64 M free.

Note that if you get an error like:

```
myisamchk: warning: 1 clients is using or hasn't closed the table properly
```

This means that you are trying to check a table that has been updated by another program (like the `mysqld` server) that hasn't yet closed the file or that has died without closing the file properly.

If `mysqld` is running, you must force a sync/close of all tables with `FLUSH TABLES` and ensure that no one is using the tables while you are running `myisamchk`. In MySQL Version 3.23 the easiest way to avoid this problem is to use `CHECK TABLE` instead of `myisamchk` to check tables.

4.5.6.2 General Options for `myisamchk`

`myisamchk` supports the following options.

`-# or --debug=debug_options`
: Output debug log. The `debug_options` string often is `'d:t:o,filename'`.

`-? or --help`
: Display a help message and exit.

`-O var=option, --set-variable var=option`
: Set the value of a variable. Please note that `--set-variable` is deprecated since MySQL 4.0, just use `--var=option` on its own. The possible variables and their default values for myisamchk can be examined with `myisamchk --help`:

Variable	Value
key_buffer_size	523264
read_buffer_size	262136
write_buffer_size	262136
sort_buffer_size	2097144
sort_key_blocks	16
decode_bits	9

`sort_buffer_size` is used when the keys are repaired by sorting keys, which is the normal case when you use `--recover`.

`key_buffer_size` is used when you are checking the table with `--extended-check` or when the keys are repaired by inserting key row by row in to the table (like when doing normal inserts). Repairing through the key buffer is used in the following cases:

- If you use `--safe-recover`.
- If the temporary files needed to sort the keys would be more than twice as big as when creating the key file directly. This is often the case when you have big `CHAR`, `VARCHAR` or `TEXT` keys as the sort needs to store the whole keys during sorting. If you have lots of temporary space and you can force `myisamchk` to repair by sorting you can use the `--sort-recover` option.

Reparing through the key buffer takes much less disk space than using sorting, but is also much slower.

If you want a faster repair, set the above variables to about 1/4 of your available memory. You can set both variables to big values, as only one of the above buffers will be used at a time.

`-s or --silent`
: Silent mode. Write output only when errors occur. You can use `-s` twice (`-ss`) to make `myisamchk` very silent.

`-v or --verbose`
: Verbose mode. Print more information. This can be used with `-d` and `-e`. Use `-v` multiple times (`-vv`, `-vvv`) for more verbosity!

`-V or --version`
: Print the `myisamchk` version and exit.

`-w or, --wait`
: Instead of giving an error if the table is locked, wait until the table is unlocked before continuing. Note that if you are running `mysqld` on the table with `--skip-external-locking`, the table can only be locked by another `myisamchk` command.

4.5.6.3 Check Options for `myisamchk`

`-c or --check`
: Check table for errors. This is the default operation if you are not giving `myisamchk` any options that override this.

`-e or --extend-check`
: Check the table very thoroughly (which is quite slow if you have many indexes). This option should only be used in extreme cases. Normally, `myisamchk` or `myisamchk --medium-check` should, in most cases, be able to find out if there are any errors in the table.

  If you are using `--extended-check` and have much memory, you should increase the value of `key_buffer_size` a lot!

`-F or --fast`
: Check only tables that haven't been closed properly.

`-C or --check-only-changed`
: Check only tables that have changed since the last check.

`-f or --force`
: Restart `myisamchk` with `-r` (repair) on the table, if `myisamchk` finds any errors in the table.

`-i or --information`
: Print informational statistics about the table that is checked.

`-m or --medium-check`
: Faster than extended-check, but only finds 99.99% of all errors. Should, however, be good enough for most cases.

`-U or --update-state`
: Store in the '`.MYI`' file when the table was checked and if the table crashed. This should be used to get full benefit of the `--check-only-changed` option, but you shouldn't use this option if the `mysqld` server is using the table and you are running `mysqld` with `--skip-external-locking`.

`-T or --read-only`
: Don't mark table as checked. This is useful if you use `myisamchk` to check a table that is in use by some other application that doesn't use locking (like `mysqld --skip-external-locking`).

4.5.6.4 Repair Options for myisamchk

The following options are used if you start `myisamchk` with `-r` or `-o`:

`-B or --backup`
: Make a backup of the '`.MYD`' file as '`filename-time.BAK`'

`--correct-checksum`
: Correct checksum information for table.

`-D # or --data-file-length=#`
: Max length of datafile (when re-creating datafile when it's 'full').

`-e or --extend-check`
: Try to recover every possible row from the datafile. Normally this will also find a lot of garbage rows. Don't use this option if you are not totally desperate.

`-f or --force`
: Overwrite old temporary files ('`table_name.TMD`') instead of aborting.

`-k # or --keys-used=#`
: If you are using `ISAM`, tells the `ISAM` storage engine to update only the first `#` indexes. If you are using `MyISAM`, tells which keys to use, where each binary bit stands for one key (first key is bit 0). This can be used to get faster inserts! Deactivated indexes can be reactivated by using `myisamchk -r`.

`-l or --no-symlinks`
: Do not follow symbolic links. Normally `myisamchk` repairs the table a symlink points at. This option doesn't exist in MySQL 4.0, as MySQL 4.0 will not remove symlinks during repair.

`-p or --parallel-recover`
: Uses the same technique as `-r` and `-n`, but creates all the keys in parallel, in different threads. This option was added in MySQL 4.0.2. **This is alpha code. Use at your own risk!**

`-r or --recover`
: Can fix almost anything except unique keys that aren't unique (which is an extremely unlikely error with `ISAM`/`MyISAM` tables). If you want to recover a table, this is the option to try first. Only if `myisamchk` reports that the table can't be recovered by `-r`, you should then try `-o`. (Note that in the unlikely

case that `-r` fails, the datafile is still intact.) If you have lots of memory, you should increase the size of `sort_buffer_size`!

`-o or --safe-recover`
: Uses an old recovery method (reads through all rows in order and updates all index trees based on the found rows); this is an order of magnitude slower than `-r`, but can handle a couple of very unlikely cases that `-r` cannot handle. This recovery method also uses much less disk space than `-r`. Normally one should always first repair with `-r`, and only if this fails use `-o`.

  If you have lots of memory, you should increase the size of `key_buffer_size`!

`-n or --sort-recover`
: Force `myisamchk` to use sorting to resolve the keys even if the temporary files should be very big.

`--character-sets-dir=...`
: Directory where character sets are stored.

`--set-character-set=name`
: Change the character set used by the index

`-t or --tmpdir=path`
: Path for storing temporary files. If this is not set, `myisamchk` will use the environment variable `TMPDIR` for this. Starting from MySQL 4.1, `tmpdir` can be set to a list of paths separated by colon `:` (semicolon `;` on Windows). They will be used in round-robin fashion.

`-q or --quick`
: Faster repair by not modifying the datafile. One can give a second `-q` to force `myisamchk` to modify the original datafile in case of duplicate keys

`-u or --unpack`
: Unpack file packed with myisampack.

4.5.6.5 Other Options for `myisamchk`

Other actions that `myisamchk` can do, besides repair and check tables:

`-a or --analyze`
: Analyse the distribution of keys. This improves join performance by enabling the join optimiser to better choose in which order it should join the tables and which keys it should use: `myisamchk --describe --verbose table_name'` or using `SHOW KEYS` in MySQL.

`-d or --description`
: Prints some information about table.

`-A or --set-auto-increment[=value]`
: Force `AUTO_INCREMENT` to start at this or higher value. If no value is given, then sets the next `AUTO_INCREMENT` value to the highest used value for the auto key + 1.

`-S or --sort-index`
: Sort the index tree blocks in high-low order. This will optimise seeks and will make table scanning by key faster.

`-R or --sort-records=#`
: Sorts records according to an index. This makes your data much more localised and may speed up ranged `SELECT` and `ORDER BY` operations on this index. (It may be very slow to do a sort the first time!) To find out a table's index numbers, use `SHOW INDEX`, which shows a table's indexes in the same order that `myisamchk` sees them. Indexes are numbered beginning with 1.

4.5.6.6 `myisamchk` Memory Usage

Memory allocation is important when you run `myisamchk`. `myisamchk` uses no more memory than you specify with the `-O` options. If you are going to use `myisamchk` on very large files, you should first decide how much memory you want it to use. The default is to use only about 3M to fix things. By using larger values, you can get `myisamchk` to operate faster. For example, if you have more than 32M RAM, you could use options such as these (in addition to any other options you might specify):

```
shell> myisamchk -O sort=16M -O key=16M -O read=1M -O write=1M ...
```

Using `-O sort=16M` should probably be enough for most cases.

Be aware that `myisamchk` uses temporary files in `TMPDIR`. If `TMPDIR` points to a memory filesystem, you may easily get out of memory errors. If this happens, set `TMPDIR` to point at some directory with more space and restart `myisamchk`.

When repairing, `myisamchk` will also need a lot of disk space:

- Double the size of the record file (the original one and a copy). This space is not needed if one does a repair with `--quick`, as in this case only the index file will be re-created. This space is needed on the same disk as the original record file!
- Space for the new index file that replaces the old one. The old index file is truncated at start, so one usually ignore this space. This space is needed on the same disk as the original index file!
- When using `--recover` or `--sort-recover` (but not when using `--safe-recover`), you will need space for a sort buffer for: `(largest_key + row_pointer_length)*number_of_rows * 2`. You can check the length of the keys and the row_pointer_length with `myisamchk -dv table`. This space is allocated on the temporary disk (specified by `TMPDIR` or `--tmpdir=#`).

If you have a problem with disk space during repair, you can try to use `--safe-recover` instead of `--recover`.

4.5.6.7 Using `myisamchk` for Crash Recovery

If you run `mysqld` with `--skip-external-locking` (which is the default on some systems, like Linux), you can't reliably use `myisamchk` to check a table when `mysqld` is using the same table. If you can be sure that no one is accessing the tables through `mysqld` while you run `myisamchk`, you only have to do `mysqladmin flush-tables` before you start checking

the tables. If you can't guarantee the above, then you must take down `mysqld` while you check the tables. If you run `myisamchk` while `mysqld` is updating the tables, you may get a warning that a table is corrupt even if it isn't.

If you are not using `--skip-external-locking`, you can use `myisamchk` to check tables at any time. While you do this, all clients that try to update the table will wait until `myisamchk` is ready before continuing.

If you use `myisamchk` to repair or optimise tables, you **must** always ensure that the `mysqld` server is not using the table (this also applies if you are using `--skip-external-locking`). If you don't take down `mysqld` you should at least do a `mysqladmin flush-tables` before you run `myisamchk`. Your tables **may be corrupted** if the server and `myisamchk` access the tables simultaneously.

This chapter describes how to check for and deal with data corruption in MySQL databases. If your tables get corrupted frequently you should try to find the reason for this! See Section A.4.1 [Crashing], page 859.

The `MyISAM` table section contains reason for why a table could be corrupted. See Section 7.1.3 [MyISAM table problems], page 600.

When performing crash recovery, it is important to understand that each table `tbl_name` in a database corresponds to three files in the database directory:

File	Purpose
'`tbl_name.frm`'	Table definition (form) file
'`tbl_name.MYD`'	Datafile
'`tbl_name.MYI`'	Index file

Each of these three file types is subject to corruption in various ways, but problems occur most often in datafiles and index files.

`myisamchk` works by creating a copy of the '`.MYD`' (data) file row by row. It ends the repair stage by removing the old '`.MYD`' file and renaming the new file to the original file name. If you use `--quick`, `myisamchk` does not create a temporary '`.MYD`' file, but instead assumes that the '`.MYD`' file is correct and only generates a new index file without touching the '`.MYD`' file. This is safe, because `myisamchk` automatically detects if the '`.MYD`' file is corrupt and aborts the repair in this case. You can also give two `--quick` options to `myisamchk`. In this case, `myisamchk` does not abort on some errors (like duplicate key) but instead tries to resolve them by modifying the '`.MYD`' file. Normally the use of two `--quick` options is useful only if you have too little free disk space to perform a normal repair. In this case you should at least make a backup before running `myisamchk`.

4.5.6.8 How to Check Tables for Errors

To check a MyISAM table, use the following commands:

`myisamchk tbl_name`
: This finds 99.99% of all errors. What it can't find is corruption that involves **only** the datafile (which is very unusual). If you want to check a table, you should normally run `myisamchk` without options or with either the `-s` or `--silent` option.

`myisamchk -m tbl_name`
: This finds 99.999% of all errors. It checks first all index entries for errors and then it reads through all rows. It calculates a checksum for all keys in the rows and verifies that they checksum matches the checksum for the keys in the index tree.

`myisamchk -e tbl_name`
: This does a complete and thorough check of all data (`-e` means "extended check"). It does a check-read of every key for each row to verify that they indeed point to the correct row. This may take a long time on a big table with many keys. `myisamchk` will normally stop after the first error it finds. If you want to obtain more information, you can add the `--verbose` (`-v`) option. This causes `myisamchk` to keep going, up through a maximum of 20 errors. In normal usage, a simple `myisamchk` (with no arguments other than the table name) is sufficient.

`myisamchk -e -i tbl_name`
: Like the previous command, but the `-i` option tells `myisamchk` to print some informational statistics, too.

4.5.6.9 How to Repair Tables

In the following section we only talk about using `myisamchk` on `MyISAM` tables (extensions '`.MYI`' and '`.MYD`'). If you are using `ISAM` tables (extensions '`.ISM`' and '`.ISD`'), you should use `isamchk` instead.

Starting with MySQL Version 3.23.14, you can repair MyISAM tables with the `REPAIR TABLE` command. See Section 4.5.5 [REPAIR TABLE], page 263.

The symptoms of a corrupted table include queries that abort unexpectedly and observable errors such as these:

- '`tbl_name.frm`' is locked against change
- Can't find file '`tbl_name.MYI`' (Errcode: ###)
- Unexpected end of file
- Record file is crashed
- Got error ### from table handler

  To get more information about the error you can run `perror ###`. Here is the most common errors that indicates a problem with the table:

```
shell> perror 126 127 132 134 135 136 141 144 145
126 = Index file is crashed / Wrong file format
127 = Record-file is crashed
132 = Old database file
134 = Record was already deleted (or record file crashed)
135 = No more room in record file
136 = No more room in index file
141 = Duplicate unique key or constraint on write or update
144 = Table is crashed and last repair failed
145 = Table was marked as crashed and should be repaired
```

Note that error 135 (no more room in record file), is not an error that can be fixed by a simple repair. In this case you have to do:

```
ALTER TABLE table MAX_ROWS=xxx AVG_ROW_LENGTH=yyy;
```

You can also use this technique for error 136 (no more room in index file).

In the other cases, you must repair your tables. `myisamchk` can usually detect and fix most things that go wrong.

The repair process involves up to four stages, described here. Before you begin, you should `cd` to the database directory and check the permissions of the table files. Make sure they are readable by the Unix user that `mysqld` runs as (and to you, because you need to access the files you are checking). If it turns out you need to modify files, they must also be writable by you.

If you are using MySQL Version 3.23.16 and above, you can (and should) use the `CHECK` and `REPAIR` commands to check and repair `MyISAM` tables. See Section 4.5.4 [CHECK TABLE], page 262. See Section 4.5.5 [REPAIR TABLE], page 263.

The manual section about table maintenance includes the options to `isamchk`/`myisamchk`. See Section 4.5.6 [Table maintenance], page 264.

The following section is for the cases where the above command fails or if you want to use the extended features that `isamchk`/`myisamchk` provides.

If you are going to repair a table from the command-line, you must first take down the `mysqld` server. Note that when you do `mysqladmin shutdown` on a remote server, the `mysqld` server will still be alive for a while after `mysqladmin` returns, until all queries are stopped and all keys have been flushed to disk.

Stage 1: Checking your tables

Run `myisamchk *.MYI` or `myisamchk -e *.MYI` if you have more time. Use the `-s` (silent) option to suppress unnecessary information.

If the `mysqld` server is done you should use the –update option to tell `myisamchk` to mark the table as 'checked'.

You have to repair only those tables for which `myisamchk` announces an error. For such tables, proceed to Stage 2.

If you get weird errors when checking (such as `out of memory` errors), or if `myisamchk` crashes, go to Stage 3.

Stage 2: Easy safe repair

Note: If you want repairing to go much faster, you should add: `-O sort_buffer=# -O key_buffer=#` (where # is about 1/4 of the available memory) to all `isamchk/myisamchk` commands.

First, try `myisamchk -r -q tbl_name` (`-r -q` means "quick recovery mode"). This will attempt to repair the index file without touching the datafile. If the datafile contains everything that it should and the delete links point at the correct locations within the datafile, this should work, and the table is fixed. Start repairing the next table. Otherwise, use the following procedure:

1. Make a backup of the datafile before continuing.
2. Use `myisamchk -r tbl_name` (`-r` means "recovery mode"). This will remove incorrect records and deleted records from the datafile and reconstruct the index file.

3. If the preceding step fails, use `myisamchk --safe-recover tbl_name`. Safe recovery mode uses an old recovery method that handles a few cases that regular recovery mode doesn't (but is slower).

If you get weird errors when repairing (such as `out of memory` errors), or if `myisamchk` crashes, go to Stage 3.

Stage 3: Difficult repair

You should only reach this stage if the first 16K block in the index file is destroyed or contains incorrect information, or if the index file is missing. In this case, it's necessary to create a new index file. Do so as follows:

1. Move the datafile to some safe place.
2. Use the table description file to create new (empty) data and index files:

```
shell> mysql db_name
mysql> SET AUTOCOMMIT=1;
mysql> TRUNCATE TABLE table_name;
mysql> quit
```

   If your SQL version doesn't have `TRUNCATE TABLE`, use `DELETE FROM table_name` instead.
3. Copy the old datafile back onto the newly created datafile. (Don't just move the old file back onto the new file; you want to retain a copy in case something goes wrong.)

Go back to Stage 2. `myisamchk -r -q` should work now. (This shouldn't be an endless loop.)

As of `MySQL` 4.0.2 you can also use `REPAIR ... USE_FRM` which performs the whole procedure automatically.

Stage 4: Very difficult repair

You should reach this stage only if the description file has also crashed. That should never happen, because the description file isn't changed after the table is created:

1. Restore the description file from a backup and go back to Stage 3. You can also restore the index file and go back to Stage 2. In the latter case, you should start with `myisamchk -r`.
2. If you don't have a backup but know exactly how the table was created, create a copy of the table in another database. Remove the new datafile, then move the description and index files from the other database to your crashed database. This gives you new description and index files, but leaves the datafile alone. Go back to Stage 2 and attempt to reconstruct the index file.

4.5.6.10 Table Optimisation

To coalesce fragmented records and eliminate wasted space resulting from deleting or updating records, run `myisamchk` in recovery mode:

```
shell> myisamchk -r tbl_name
```

You can optimise a table in the same way using the SQL `OPTIMIZE TABLE` statement. `OPTIMIZE TABLE` does a repair of the table and a key analysis, and also sorts the index tree to give faster key lookups. There is also no possibility of unwanted interaction between

a utility and the server, because the server does all the work when you use `OPTIMIZE TABLE`. See Section 4.6.1 [OPTIMIZE TABLE], page 281.

`myisamchk` also has a number of other options you can use to improve the performance of a table:

- `-S`, `--sort-index`
- `-R index_num`, `--sort-records=index_num`
- `-a`, `--analyze`

For a full description of the option. See Section 4.5.6.1 [myisamchk syntax], page 265.

4.5.7 Setting Up a Table Maintenance Regimen

Starting with MySQL Version 3.23.13, you can check MyISAM tables with the `CHECK TABLE` command. See Section 4.5.4 [CHECK TABLE], page 262. You can repair tables with the `REPAIR TABLE` command. See Section 4.5.5 [REPAIR TABLE], page 263.

It is a good idea to perform table checks on a regular basis rather than waiting for problems to occur. For maintenance purposes, you can use `myisamchk -s` to check tables. The `-s` option (short for `--silent`) causes `myisamchk` to run in silent mode, printing messages only when errors occur.

It's also a good idea to check tables when the server starts up. For example, whenever the machine has done a reboot in the middle of an update, you usually need to check all the tables that could have been affected. (This is an "expected crashed table".) You could add a test to `mysqld_safe` that runs `myisamchk` to check all tables that have been modified during the last 24 hours if there is an old '`.pid`' (process ID) file left after a reboot. (The '`.pid`' file is created by `mysqld` when it starts up and removed when it terminates normally. The presence of a '`.pid`' file at system startup time indicates that `mysqld` terminated abnormally.)

An even better test would be to check any table whose last-modified time is more recent than that of the '`.pid`' file.

You should also check your tables regularly during normal system operation. At MySQL AB, we run a `cron` job to check all our important tables once a week, using a line like this in a '`crontab`' file:

```
35 0 * * 0 /path/to/myisamchk --fast --silent /path/to/datadir/*/*.MYI
```

This prints out information about crashed tables so we can examine and repair them when needed.

As we haven't had any unexpectedly crashed tables (tables that become corrupted for reasons other than hardware trouble) for a couple of years now (this is really true), once a week is more than enough for us.

We recommend that to start with, you execute `myisamchk -s` each night on all tables that have been updated during the last 24 hours, until you come to trust MySQL as much as we do.

Normally you don't need to maintain MySQL tables that much. If you are changing tables with dynamic size rows (tables with `VARCHAR`, `BLOB` or `TEXT` columns) or have tables with many deleted rows you may want to from time to time (once a month?) defragment/reclaim space from the tables.

You can do this by using `OPTIMIZE TABLE` on the tables in question or if you can take down the `mysqld` server for a while do:

```
isamchk -r --silent --sort-index -O sort_buffer_size=16M */*.ISM
myisamchk -r --silent --sort-index  -O sort_buffer_size=16M */*.MYI
```

4.5.8 Getting Information About a Table

To get a description of a table or statistics about it, use the commands shown here. We explain some of the information in more detail later:

- myisamchk -d tbl_name Runs `myisamchk` in "describe mode" to produce a description of your table. If you start the MySQL server using the `--skip-external-locking` option, `myisamchk` may report an error for a table that is updated while it runs. However, because `myisamchk` doesn't change the table in describe mode, there isn't any risk of destroying data.
- myisamchk -d -v tbl_name To produce more information about what `myisamchk` is doing, add `-v` to tell it to run in verbose mode.
- myisamchk -eis tbl_name Shows only the most important information from a table. It is slow because it must read the whole table.
- myisamchk -eiv tbl_name This is like `-eis`, but tells you what is being done.

Example of `myisamchk -d` output:

```
MyISAM file:     company.MYI
Record format:   Fixed length
Data records:    1403698  Deleted blocks:         0
Recordlength:    226

table description:
Key Start Len Index   Type
1   2     8   unique  double
2   15    10  multip. text packed stripped
3   219   8   multip. double
4   63    10  multip. text packed stripped
5   167   2   multip. unsigned short
6   177   4   multip. unsigned long
7   155   4   multip. text
8   138   4   multip. unsigned long
9   177   4   multip. unsigned long
    193   1           text
```

Example of `myisamchk -d -v` output:

```
MyISAM file:         company
Record format:       Fixed length
File-version:        1
Creation time:       1999-10-30 12:12:51
Recover time:        1999-10-31 19:13:01
Status:              checked
```

```
Data records:           1403698  Deleted blocks:              0
Datafile parts:         1403698  Deleted data:                0
Datafilepointer (bytes):      3  Keyfile pointer (bytes):     3
Max datafile length: 3791650815  Max keyfile length: 4294967294
Recordlength:               226

table description:
Key Start Len Index   Type                   Rec/key     Root Blocksize
1   2     8   unique  double                       1 15845376      1024
2   15    10  multip. text packed stripped        2 25062400      1024
3   219   8   multip. double                      73 40907776      1024
4   63    10  multip. text packed stripped        5 48097280      1024
5   167   2   multip. unsigned short           4840 55200768      1024
6   177   4   multip. unsigned long            1346 65145856      1024
7   155   4   multip. text                     4995 75090944      1024
8   138   4   multip. unsigned long              87 85036032      1024
9   177   4   multip. unsigned long             178 96481280      1024
    193   1           text
```

Example of `myisamchk -eis` output:

```
Checking MyISAM file: company
Key:  1:  Keyblocks used:  97%  Packed:    0%  Max levels:  4
Key:  2:  Keyblocks used:  98%  Packed:   50%  Max levels:  4
Key:  3:  Keyblocks used:  97%  Packed:    0%  Max levels:  4
Key:  4:  Keyblocks used:  99%  Packed:   60%  Max levels:  3
Key:  5:  Keyblocks used:  99%  Packed:    0%  Max levels:  3
Key:  6:  Keyblocks used:  99%  Packed:    0%  Max levels:  3
Key:  7:  Keyblocks used:  99%  Packed:    0%  Max levels:  3
Key:  8:  Keyblocks used:  99%  Packed:    0%  Max levels:  3
Key:  9:  Keyblocks used:  98%  Packed:    0%  Max levels:  4
Total:    Keyblocks used:  98%  Packed:   17%

Records:          1403698    M.recordlength:     226
Packed:             0%
Recordspace used:     100%   Empty space:          0%
Blocks/Record:   1.00
Record blocks:    1403698    Delete blocks:        0
Recorddata:     317235748    Deleted data:         0
Lost space:             0    Linkdata:             0

User time 1626.51, System time 232.36
Maximum resident set size 0, Integral resident set size 0
Non physical pagefaults 0, Physical pagefaults 627, Swaps 0
Blocks in 0 out 0, Messages in 0 out 0, Signals 0
Voluntary context switches 639, Involuntary context switches 28966
```

Example of `myisamchk -eiv` output:

```
Checking MyISAM file: company
```

```
Data records: 1403698   Deleted blocks:       0
- check file-size
- check delete-chain
block_size 1024:
index  1:
index  2:
index  3:
index  4:
index  5:
index  6:
index  7:
index  8:
index  9:
No recordlinks
- check index reference
- check data record references index: 1
Key:  1:  Keyblocks used:  97%  Packed:    0%  Max levels:  4
- check data record references index: 2
Key:  2:  Keyblocks used:  98%  Packed:   50%  Max levels:  4
- check data record references index: 3
Key:  3:  Keyblocks used:  97%  Packed:    0%  Max levels:  4
- check data record references index: 4
Key:  4:  Keyblocks used:  99%  Packed:   60%  Max levels:  3
- check data record references index: 5
Key:  5:  Keyblocks used:  99%  Packed:    0%  Max levels:  3
- check data record references index: 6
Key:  6:  Keyblocks used:  99%  Packed:    0%  Max levels:  3
- check data record references index: 7
Key:  7:  Keyblocks used:  99%  Packed:    0%  Max levels:  3
- check data record references index: 8
Key:  8:  Keyblocks used:  99%  Packed:    0%  Max levels:  3
- check data record references index: 9
Key:  9:  Keyblocks used:  98%  Packed:    0%  Max levels:  4
Total:    Keyblocks used:   9%  Packed:   17%

- check records and index references
[LOTS OF ROW NUMBERS DELETED]

Records:          1403698    M.recordlength:     226   Packed:              0%
Recordspace used:     100%   Empty space:          0%  Blocks/Record:   1.00
Record blocks:    1403698    Delete blocks:        0
Recorddata:     317235748    Deleted data:         0
Lost space:             0    Linkdata:             0

User time 1639.63, System time 251.61
Maximum resident set size 0, Integral resident set size 0
Non physical pagefaults 0, Physical pagefaults 10580, Swaps 0
```

```
Blocks in 4 out 0, Messages in 0 out 0, Signals 0
Voluntary context switches 10604, Involuntary context switches 122798
```

Here are the sizes of the data and index files for the table used in the preceding examples:

```
-rw-rw-r--   1 monty    tcx     317235748 Jan 12 17:30 company.MYD
-rw-rw-r--   1 davida   tcx      96482304 Jan 12 18:35 company.MYM
```

Explanations for the types of information `myisamchk` produces are given here. The "keyfile" is the index file. "Record" and "row" are synonymous:

- ISAM file Name of the ISAM (index) file.
- Isam-version Version of ISAM format. Currently always 2.
- Creation time When the datafile was created.
- Recover time When the index/datafile was last reconstructed.
- Data records How many records are in the table.
- Deleted blocks How many deleted blocks still have reserved space. You can optimise your table to minimise this space. See Section 4.5.6.10 [Optimisation], page 274.
- Data file: Parts For dynamic record format, this indicates how many data blocks there are. For an optimised table without fragmented records, this is the same as `Data records`.
- Deleted data How many bytes of non-reclaimed deleted data there are. You can optimise your table to minimise this space. See Section 4.5.6.10 [Optimisation], page 274.
- Data file pointer The size of the datafile pointer, in bytes. It is usually 2, 3, 4, or 5 bytes. Most tables manage with 2 bytes, but this cannot be controlled from MySQL yet. For fixed tables, this is a record address. For dynamic tables, this is a byte address.
- Keyfile pointer The size of the index file pointer, in bytes. It is usually 1, 2, or 3 bytes. Most tables manage with 2 bytes, but this is calculated automatically by MySQL. It is always a block address.
- Max datafile length How long the table's datafile ('`.MYD`' file) can become, in bytes.
- Max keyfile length How long the table's key file ('`.MYI`' file) can become, in bytes.
- Recordlength How much space each record takes, in bytes.
- Record format The format used to store table rows. The preceding examples use `Fixed length`. Other possible values are `Compressed` and `Packed`.
- table description A list of all keys in the table. For each key, some low-level information is presented:
  - Key This key's number.
  - Start Where in the record this index part starts.
  - Len How long this index part is. For packed numbers, this should always be the full length of the column. For strings, it may be shorter than the full length of the indexed column, because you can index a prefix of a string column.
  - Index `unique` or `multip.` (multiple). Indicates whether one value can exist multiple times in this index.
  - Type What data-type this index part has. This is an ISAM data-type with the options `packed`, `stripped` or `empty`.
  - Root Address of the root index block.

  - Blocksize The size of each index block. By default this is 1024, but the value may be changed at compile time.
  - Rec/key This is a statistical value used by the optimiser. It tells how many records there are per value for this key. A unique key always has a value of 1. This may be updated after a table is loaded (or greatly changed) with `myisamchk -a`. If this is not updated at all, a default value of 30 is given.
- In the first example above, the 9th key is a multi-part key with two parts.
- Keyblocks used What percentage of the keyblocks are used. Because the table used in the examples had just been reorganised with `myisamchk`, the values are very high (very near the theoretical maximum).
- Packed MySQL tries to pack keys with a common suffix. This can only be used for `CHAR/VARCHAR/DECIMAL` keys. For long strings like names, this can significantly reduce the space used. In the third example above, the 4th key is 10 characters long and a 60% reduction in space is achieved.
- Max levels How deep the B-tree for this key is. Large tables with long keys get high values.
- Records How many rows are in the table.
- M.recordlength The average record length. For tables with fixed-length records, this is the exact record length.
- Packed MySQL strips spaces from the end of strings. The `Packed` value indicates the percentage of savings achieved by doing this.
- Recordspace used What percentage of the datafile is used.
- Empty space What percentage of the datafile is unused.
- Blocks/Record Average number of blocks per record (that is, how many links a fragmented record is composed of). This is always 1.0 for fixed-format tables. This value should stay as close to 1.0 as possible. If it gets too big, you can reorganise the table with `myisamchk`. See Section 4.5.6.10 [Optimisation], page 274.
- Recordblocks How many blocks (links) are used. For fixed format, this is the same as the number of records.
- Deleteblocks How many blocks (links) are deleted.
- Recorddata How many bytes in the datafile are used.
- Deleted data How many bytes in the datafile are deleted (unused).
- Lost space If a record is updated to a shorter length, some space is lost. This is the sum of all such losses, in bytes.
- Linkdata When the dynamic table format is used, record fragments are linked with pointers (4 to 7 bytes each). `Linkdata` is the sum of the amount of storage used by all such pointers.

If a table has been compressed with `myisampack`, `myisamchk -d` prints additional information about each table column. See Section 4.8.4 [`myisampack`], page 317, for an example of this information and a description of what it means.

4.6 Database Administration Language Reference

4.6.1 OPTIMIZE TABLE Syntax

```
OPTIMIZE [LOCAL | NO_WRITE_TO_BINLOG] TABLE tbl_name[,tbl_name]...
```

`OPTIMIZE TABLE` should be used if you have deleted a large part of a table or if you have made many changes to a table with variable-length rows (tables that have `VARCHAR`, `BLOB`, or `TEXT` columns). Deleted records are maintained in a linked list and subsequent `INSERT` operations reuse old record positions. You can use `OPTIMIZE TABLE` to reclaim the unused space and to defragment the datafile.

In most setups you don't have to run `OPTIMIZE TABLE` at all. Even if you do a lot of updates to variable length rows it's not likely that you need to do this more than once a month/week and only on certain tables.

For the moment, `OPTIMIZE TABLE` works only on `MyISAM` and `BDB` tables. For `BDB` tables, `OPTIMIZE TABLE` is currently mapped to `ANALYZE TABLE`. See Section 4.6.2 [ANALYZE TABLE], page 281.

You can get `OPTIMIZE TABLE` to work on other table types by starting `mysqld` with `--skip-new` or `--safe-mode`, but in this case `OPTIMIZE TABLE` is just mapped to `ALTER TABLE`.

`OPTIMIZE TABLE` works the following way:

- If the table has deleted or split rows, repair the table.
- If the index pages are not sorted, sort them.
- If the statistics are not up to date (and the repair couldn't be done by sorting the index), update them.

Note that the table is locked during the time `OPTIMIZE TABLE` is running!

Before MySQL 4.1.1, `OPTIMIZE` commands are not written to the binary log. Since MySQL 4.1.1 they are written to the binary log unless the optional `NO_WRITE_TO_BINLOG` keyword (or its alias `LOCAL`) was used.

4.6.2 ANALYZE TABLE Syntax

```
ANALYZE [LOCAL | NO_WRITE_TO_BINLOG] TABLE tbl_name[,tbl_name...]
```

Analyse and store the key distribution for the table. During the analysis, the table is locked with a read lock. This works on `MyISAM` and `BDB` tables.

This is equivalent to running `myisamchk -a` on the table.

MySQL uses the stored key distribution to decide in which order tables should be joined when one does a join on something else than a constant.

The command returns a table with the following columns:

Column	Value
Table	Table name
Op	Always `analyze`
Msg_type	One of `status`, `error`, `info`, or `warning`
Msg_text	The message

You can check the stored key distribution with the `SHOW INDEX` command. See Section 4.6.8.1 [Show database info], page 285.

If the table hasn't changed since the last `ANALYZE TABLE` command, the table will not be analysed again.

Before MySQL 4.1.1, `ANALYZE` commands are not written to the binary log. Since MySQL 4.1.1 they are written to the binary log unless the optional `NO_WRITE_TO_BINLOG` keyword (or its alias `LOCAL`) was used.

4.6.3 `CHECKSUM TABLE` Syntax

```
CHECKSUM TABLE tbl_name[,tbl_name ...] [ QUICK | EXTENDED ]
```

Reports a table checksum. If `QUICK` is specified, live table checksum is reported, or `NULL` if the table does not support live checksum. This is very fast. In `EXTENDED` mode the whole table is read row by row and the checksum is calculated. This can be very slow for large tables. By default - with neither `QUICK` nor `EXTENDED` - MySQL returns live checksum if the table support it and scans the table otherwise.

This command is implemented in MySQL 4.1.1.

4.6.4 `FLUSH` Syntax

```
FLUSH [LOCAL | NO_WRITE_TO_BINLOG] flush_option [,flush_option] ...
```

You should use the `FLUSH` command if you want to clear some of the internal caches MySQL uses. To execute `FLUSH`, you must have the `RELOAD` privilege.

`flush_option` can be any of the following:

Option	Description
`HOSTS`	Empties the host cache tables. You should flush the host tables if some of your hosts change IP number or if you get the error message `Host ... is blocked`. When more than `max_connect_errors` errors occur in a row for a given host while connection to the MySQL server, MySQL assumes something is wrong and blocks the host from further connection requests. Flushing the host tables allows the host to attempt to connect again. See Section A.2.5 [Blocked host], page 850. You can start `mysqld` with `-O max_connect_errors=999999999` to avoid this error message.
`DES_KEY_FILE`	Reloads the DES keys from the file that was specified with the `--des-key-file` option at server startup time.
`LOGS`	Closes and reopens all log files. If you have specified an update log file or a binary log file without an extension, the extension number of the log file will be incremented by one relative to the previous file. If you have used an extension in the file name, MySQL will close and reopen the update log file. See Section 4.10.3 [Update log], page 351. This is the same thing as sending the `SIGHUP` signal to the `mysqld` server.
`PRIVILEGES`	Reloads the privileges from the grant tables in the `mysql` database.

`QUERY CACHE`	Defragment the query cache to better utilise its memory. This command will not remove any queries from the cache, unlike `RESET QUERY CACHE`.
`TABLES`	Closes all open tables and force all tables in use to be closed. This also flushes the query cache.
`[TABLE | TABLES] tbl_name [,tbl_name...]`	Flushes only the given tables.
`TABLES WITH READ LOCK`	Closes all open tables and locks all tables for all databases with a read lock until you execute `UNLOCK TABLES`. This is very convenient way to get backups if you have a filesystem, like Veritas, that can take snapshots in time.
`STATUS`	Resets most status variables to zero. This is something one should only use when debugging a query.
`USER_RESOURCES`	Resets all user resources to zero. This will enable blocked users to login again. See Section 4.4.7 [User resources], page 249.

Before MySQL 4.1.1, `FLUSH` commands are not written to the binary log. Since MySQL 4.1.1 they are written to the binary log unless the optional `NO_WRITE_TO_BINLOG` keyword (or its alias `LOCAL`) was used, or unless the command contained one of these arguments: `LOGS`, `MASTER`, `SLAVE`, `TABLES WITH READ LOCK`, because any of these arguments may cause problems if replicated to a slave.

You can also access some of the commands shown above with the `mysqladmin` utility, using the `flush-hosts`, `flush-logs`, `flush-privileges`, `flush-status` or `flush-tables` commands.

Take also a look at the `RESET` command used with replication. See Section 4.6.5 [RESET], page 283.

4.6.5 RESET Syntax

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

The `RESET` command is used to clear things. It also acts as an stronger version of the `FLUSH` command. See Section 4.6.4 [FLUSH], page 282.

To execute `RESET`, you must have the `RELOAD` privilege.

Option	Description
`MASTER`	Deletes all binary logs listed in the index file, resetting the binlog index file to be empty. Previously named `FLUSH MASTER`. See Section 4.11.7 [Replication Master SQL], page 376.
`SLAVE`	Makes the slave forget its replication position in the master binlogs. Previously named `FLUSH SLAVE`. See Section 4.11.8 [Replication Slave SQL], page 378.
`QUERY CACHE`	Removes all query results from the query cache.

4.6.6 PURGE MASTER LOGS Syntax

```
PURGE {MASTER|BINARY} LOGS TO binlog_name
PURGE {MASTER|BINARY} LOGS BEFORE date
```

This command is used to delete all binary logs strictly prior to the specified binlog or date. See Section 4.11.7 [Replication Master SQL], page 376.

`PURGE BINARY LOGS` is available as a synonym for `PURGE MASTER LOGS` as of MySQL 4.1.1.

4.6.7 KILL Syntax

```
KILL thread_id
```

Each connection to `mysqld` runs in a separate thread. You can see which threads are running with the `SHOW PROCESSLIST` command and kill a thread with the `KILL thread_id` command.

If you have the `PROCESS` privilege, you can see all threads. If you have the `SUPER` privilege, you can kill all threads. Otherwise, you can only see and kill your own threads.

You can also use the `mysqladmin processlist` and `mysqladmin kill` commands to examine and kill threads.

Note: You currently cannot use `KILL` with the Embedded MySQL Server library, because the embedded server merely runs inside the threads of the host application, it does not create connection threads of its own.

When you do a `KILL`, a thread-specific `kill flag` is set for the thread.

In most cases it may take some time for the thread to die as the kill flag is only checked at specific intervals.

- In `SELECT`, `ORDER BY` and `GROUP BY` loops, the flag is checked after reading a block of rows. If the kill flag is set, the statement is aborted.
- When doing an `ALTER TABLE` the kill flag is checked before each block of rows are read from the original table. If the kill flag was set the command is aborted and the temporary table is deleted.
- When doing an `UPDATE` or `DELETE`, the kill flag is checked after each block read and after each updated or deleted row. If the kill flag is set, the statement is aborted. Note that if you are not using transactions, the changes will not be rolled back!
- `GET_LOCK()` will abort with `NULL`.
- An `INSERT DELAYED` thread will quickly flush all rows it has in memory and die.
- If the thread is in the table lock handler (state: `Locked`), the table lock will be quickly aborted.
- If the thread is waiting for free disk space in a `write` call, the write is aborted with an disk full error message.

4.6.8 SHOW Syntax

```
   SHOW DATABASES [LIKE wild]
or SHOW [OPEN] TABLES [FROM db_name] [LIKE wild]
```

```
or SHOW [FULL] COLUMNS FROM tbl_name [FROM db_name] [LIKE wild]
or SHOW INDEX FROM tbl_name [FROM db_name]
or SHOW TABLE STATUS [FROM db_name] [LIKE wild]
or SHOW STATUS [LIKE wild]
or SHOW VARIABLES [LIKE wild]
or SHOW [BDB] LOGS
or SHOW [FULL] PROCESSLIST
or SHOW GRANTS FOR user
or SHOW CREATE TABLE table_name
or SHOW MASTER STATUS
or SHOW MASTER LOGS
or SHOW SLAVE STATUS
or SHOW WARNINGS [LIMIT row_count]
or SHOW ERRORS [LIMIT row_count]
or SHOW TABLE TYPES
```

`SHOW` provides information about databases, tables, columns, or status information about the server. If the `LIKE wild` part is used, the `wild` string can be a string that uses the SQL '`%`' and '`_`' wildcard characters.

4.6.8.1 Retrieving information about Database, Tables, Columns, and Indexes

You can use `db_name.tbl_name` as an alternative to the `tbl_name FROM db_name` syntax. These two statements are equivalent:

```
mysql> SHOW INDEX FROM mytable FROM mydb;
mysql> SHOW INDEX FROM mydb.mytable;
```

`SHOW DATABASES` lists the databases on the MySQL server host. You can also get this list using the `mysqlshow` command line tool. In version 4.0.2 you will only see those databases for which you have some kind of privilege, if you don't have the global `SHOW DATABASES` privilege.

`SHOW TABLES` lists the tables in a given database. You can also get this list using the `mysqlshow db_name` command.

Note: if a user doesn't have any privileges for a table, the table will not show up in the output from `SHOW TABLES` or `mysqlshow db_name`.

`SHOW OPEN TABLES` lists the tables that are currently open in the table cache. See Section 5.4.7 [Table cache], page 425. The `Comment` field tells how many times the table is `cached` and `in_use`.

`SHOW COLUMNS` lists the columns in a given table. If you specify the `FULL` option, you will also get the privileges you have for each column. If the column types are different from what you expect them to be based on a `CREATE TABLE` statement, note that MySQL sometimes changes column types. See Section 6.5.3.1 [Silent column changes], page 573. As of MySQL 4.1, the `FULL` keyword also causes any per-column comments to be displayed.

The `DESCRIBE` statement provides information similar to `SHOW COLUMNS`. See Section 6.6.2 [DESCRIBE], page 579.

`SHOW FIELDS` is a synonym for `SHOW COLUMNS`, and `SHOW KEYS` is a synonym for `SHOW INDEX`. You can also list a table's columns or indexes with `mysqlshow db_name tbl_name` or `mysqlshow -k db_name tbl_name`.

`SHOW INDEX` returns the index information in a format that closely resembles the `SQLStatistics` call in ODBC. The following columns are returned:

Column	Meaning
`Table`	Name of the table.
`Non_unique`	0 if the index can't contain duplicates, 1 if it can.
`Key_name`	Name of the index.
`Seq_in_index`	Column sequence number in index, starting with 1.
`Column_name`	Column name.
`Collation`	How the column is sorted in the index. In MySQL, this can have values '`A`' (Ascending) or `NULL` (Not sorted).
`Cardinality`	Number of unique values in the index. This is updated by running `isamchk -a`.
`Sub_part`	Number of indexed characters if the column is only partly indexed. `NULL` if the entire key is indexed.
`Null`	Contains 'YES' if the column may contain `NULL`.
`Index_type`	Index method used.
`Comment`	Various remarks. For now, it tells in MySQL < 4.0.2 whether index is `FULLTEXT` or not.

Note that as the `Cardinality` is counted based on statistics stored as integers, it's not necessarily accurate for small tables.

The `Null` and `Index_type` columns were added in MySQL 4.0.2.

4.6.8.2 SHOW TABLE STATUS

```
SHOW TABLE STATUS [FROM db_name] [LIKE wild]
```

`SHOW TABLE STATUS` (new in Version 3.23) works likes `SHOW STATUS`, but provides a lot of information about each table. You can also get this list using the `mysqlshow --status db_name` command. The following columns are returned:

Column	Meaning
`Name`	Name of the table.
`Type`	Type of table. See Chapter 7 [Table types], page 594.
`Row_format`	The row storage format (Fixed, Dynamic, or Compressed).
`Rows`	Number of rows.
`Avg_row_length`	Average row length.
`Data_length`	Length of the datafile.
`Max_data_length`	Max length of the datafile. For fixed row formats, this is the max number of rows in the table. For dynamic row formats, this is the total number of data bytes that can be stored in the table, given the data pointer size used.
`Index_length`	Length of the index file.

`Data_free`	Number of allocated but not used bytes.
`Auto_increment`	Next autoincrement value.
`Create_time`	When the table was created.
`Update_time`	When the datafile was last updated.
`Check_time`	When the table was last checked.
`Collation`	Table's character set and collation. (new 4.1.1)
`Checksum`	Live checksum value (if any). (new in 4.1.1)
`Create_options`	Extra options used with `CREATE TABLE`.
`Comment`	The comment used when creating the table (or some information why MySQL couldn't access the table information).

`InnoDB` tables will report the free space in the tablespace in the table comment.

4.6.8.3 SHOW STATUS

`SHOW STATUS` provides server status information (like `mysqladmin extended-status`). The output resembles that shown here, though the format and numbers probably differ:

```
+--------------------------+------------+
| Variable_name            | Value      |
+--------------------------+------------+
| Aborted_clients          | 0          |
| Aborted_connects         | 0          |
| Bytes_received           | 155372598  |
| Bytes_sent               | 1176560426 |
| Connections              | 30023      |
| Created_tmp_disk_tables  | 0          |
| Created_tmp_tables       | 8340       |
| Created_tmp_files        | 60         |
| Delayed_insert_threads   | 0          |
| Delayed_writes           | 0          |
| Delayed_errors           | 0          |
| Flush_commands           | 1          |
| Handler_delete           | 462604     |
| Handler_read_first       | 105881     |
| Handler_read_key         | 27820558   |
| Handler_read_next        | 390681754  |
| Handler_read_prev        | 6022500    |
| Handler_read_rnd         | 30546748   |
| Handler_read_rnd_next    | 246216530  |
| Handler_update           | 16945404   |
| Handler_write            | 60356676   |
| Key_blocks_used          | 14955      |
| Key_read_requests        | 96854827   |
| Key_reads                | 162040     |
| Key_write_requests       | 7589728    |
| Key_writes               | 3813196    |
| Max_used_connections     | 0          |
```

```
| Not_flushed_key_blocks   | 0          |
| Not_flushed_delayed_rows | 0          |
| Open_tables              | 1          |
| Open_files               | 2          |
| Open_streams             | 0          |
| Opened_tables            | 44600      |
| Questions                | 2026873    |
| Select_full_join         | 0          |
| Select_full_range_join   | 0          |
| Select_range             | 99646      |
| Select_range_check       | 0          |
| Select_scan              | 30802      |
| Slave_running            | OFF        |
| Slave_open_temp_tables   | 0          |
| Slow_launch_threads      | 0          |
| Slow_queries             | 0          |
| Sort_merge_passes        | 30         |
| Sort_range               | 500        |
| Sort_rows                | 30296250   |
| Sort_scan                | 4650       |
| Table_locks_immediate    | 1920382    |
| Table_locks_waited       | 0          |
| Threads_cached           | 0          |
| Threads_created          | 30022      |
| Threads_connected        | 1          |
| Threads_running          | 1          |
| Uptime                   | 80380      |
+--------------------------+------------+
```

The status variables listed above have the following meaning:

Variable	Meaning
`Aborted_clients`	Number of connections aborted because the client died without closing the connection properly. See Section A.2.10 [Communication errors], page 853.
`Aborted_connects`	Number of tries to connect to the MySQL server that failed. See Section A.2.10 [Communication errors], page 853.
`Bytes_received`	Number of bytes received from all clients.
`Bytes_sent`	Number of bytes sent to all clients.
`Com_xxx`	Number of times each xxx command has been executed.
`Connections`	Number of connection attempts to the MySQL server.
`Created_tmp_disk_tables`	Number of implicit temporary tables on disk created while executing statements.
`Created_tmp_tables`	Number of implicit temporary tables in memory created while executing statements.
`Created_tmp_files`	How many temporary files `mysqld` has created.
`Delayed_insert_threads`	Number of delayed insert handler threads in use.
`Delayed_writes`	Number of rows written with `INSERT DELAYED`.

`Delayed_errors`	Number of rows written with `INSERT DELAYED` for which some error occurred (probably `duplicate key`).
`Flush_commands`	Number of executed `FLUSH` commands.
`Handler_commit`	Number of internal `COMMIT` commands.
`Handler_delete`	Number of times a row was deleted from a table.
`Handler_read_first`	Number of times the first entry was read from an index. If this is high, it suggests that the server is doing a lot of full index scans, for example, `SELECT col1 FROM foo`, assuming that col1 is indexed.
`Handler_read_key`	Number of requests to read a row based on a key. If this is high, it is a good indication that your queries and tables are properly indexed.
`Handler_read_next`	Number of requests to read next row in key order. This will be incremented if you are querying an index column with a range constraint. This also will be incremented if you are doing an index scan.
`Handler_read_prev`	Number of requests to read previous row in key order. This is mainly used to optimise `ORDER BY ... DESC`.
`Handler_read_rnd`	Number of requests to read a row based on a fixed position. This will be high if you are doing a lot of queries that require sorting of the result.
`Handler_read_rnd_next`	Number of requests to read the next row in the datafile. This will be high if you are doing a lot of table scans. Generally this suggests that your tables are not properly indexed or that your queries are not written to take advantage of the indexes you have.
`Handler_rollback`	Number of internal `ROLLBACK` commands.
`Handler_update`	Number of requests to update a row in a table.
`Handler_write`	Number of requests to insert a row in a table.
`Key_blocks_used`	The number of used blocks in the key cache.
`Key_read_requests`	The number of requests to read a key block from the cache.
`Key_reads`	The number of physical reads of a key block from disk.
`Key_write_requests`	The number of requests to write a key block to the cache.
`Key_writes`	The number of physical writes of a key block to disk.
`Max_used_connections`	The maximum number of connections in use simultaneously.
`Not_flushed_key_blocks`	Keys blocks in the key cache that has changed but hasn't yet been flushed to disk.
`Not_flushed_delayed_rows`	Number of rows waiting to be written in `INSERT DELAY` queues.
`Open_tables`	Number of tables that are open.
`Open_files`	Number of files that are open.
`Open_streams`	Number of streams that are open (used mainly for logging).
`Opened_tables`	Number of tables that have been opened.
`Rpl_status`	Status of failsafe replication. (Not yet in use).
`Select_full_join`	Number of joins without keys (If this is not 0, you should carefully check the indexes of your tables).
`Select_full_range_join`	Number of joins where we used a range search on reference table.

`Select_range`	Number of joins where we used ranges on the first table. (It's normally not critical even if this is big.)
`Select_scan`	Number of joins where we did a full scan of the first table.
`Select_range_check`	Number of joins without keys where we check for key usage after each row (If this is not 0, you should carefully check the indexes of your tables).
`Questions`	Number of queries sent to the server.
`Slave_open_temp_tables`	Number of temporary tables currently open by the slave thread
`Slave_running`	Is `ON` if this is a slave that is connected to a master.
`Slow_launch_threads`	Number of threads that have taken more than `slow_launch_time` to create.
`Slow_queries`	Number of queries that have taken more than `long_query_time` seconds. See Section 4.10.5 [Slow query log], page 354.
`Sort_merge_passes`	Number of merges passes the sort algoritm have had to do. If this value is large you should consider increasing `sort_buffer`.
`Sort_range`	Number of sorts that were done with ranges.
`Sort_rows`	Number of sorted rows.
`Sort_scan`	Number of sorts that were done by scanning the table.
`ssl_xxx`	Variables used by SSL; Not yet implemented.
`Table_locks_immediate`	Number of times a table lock was acquired immediately. Available after 3.23.33.
`Table_locks_waited`	Number of times a table lock could not be acquired immediately and a wait was needed. If this is high, and you have performance problems, you should first optimise your queries, and then either split your table or tables or use replication. Available after 3.23.33.
`Threads_cached`	Number of threads in the thread cache.
`Threads_connected`	Number of currently open connections.
`Threads_created`	Number of threads created to handle connections.
`Threads_running`	Number of threads that are not sleeping.
`Uptime`	How many seconds the server has been up.

Some comments about the above:

- If `Opened_tables` is big, then your `table_cache` variable is probably too small.
- If `Key_reads` is big, then your `key_buffer_size` variable is probably too small. The **cache miss rate** can be calculated with `Key_reads/Key_read_requests`.
- If `Handler_read_rnd` is big, then you probably have a lot of queries that require MySQL to scan whole tables or you have joins that don't use keys properly.
- If `Threads_created` is big, you may want to increase the `thread_cache_size` variable. The cache hit rate can be calculated with `Threads_created/Connections`.
- If `Created_tmp_disk_tables` is big, you may want to increase the `tmp_table_size` variable to get the temporary tables memory-based instead of disk based.

4.6.8.4 SHOW VARIABLES

```
SHOW [GLOBAL | SESSION] VARIABLES [LIKE wild]
```

`SHOW VARIABLES` shows the values of some MySQL system variables. The options `GLOBAL` and `SESSION` are new in MySQL 4.0.3. With `GLOBAL` you will get the variables that will be used for new connections to MySQL. With `SESSION` you will get the values that are in effect for the current connection. If you are not using either option, `SESSION` is used.

If the default values are unsuitable, you can set most of these variables using command-line options when `mysqld` starts up. See Section 4.1.1 [Command-line options], page 195. It is also possible to change most variables with the `SET` statement. See Section 5.5.6 [SET], page 432.

The output from `SHOW VARIABLES` resembles that shown in the following list, though the format and numbers may differ somewhat. You can also get this information using the `mysqladmin variables` command.

```
+---------------------------------+-----------------------------+
| Variable_name                   | Value                       |
+---------------------------------+-----------------------------|
| back_log                        | 50                          |
| basedir                         | /usr/local/mysql            |
| bdb_cache_size                  | 8388572                     |
| bdb_log_buffer_size             | 32768                       |
| bdb_home                        | /usr/local/mysql            |
| bdb_max_lock                    | 10000                       |
| bdb_logdir                      |                             |
| bdb_shared_data                 | OFF                         |
| bdb_tmpdir                      | /tmp/                       |
| bdb_version                     | Sleepycat Software: ...     |
| binlog_cache_size               | 32768                       |
| bulk_insert_buffer_size         | 8388608                     |
| character_set                   | latin1                      |
| character_sets                  | latin1 big5 czech euc_kr    |
| concurrent_insert               | ON                          |
| connect_timeout                 | 5                           |
| convert_character_set           |                             |
| datadir                         | /usr/local/mysql/data/      |
| delay_key_write                 | ON                          |
| delayed_insert_limit            | 100                         |
| delayed_insert_timeout          | 300                         |
| delayed_queue_size              | 1000                        |
| flush                           | OFF                         |
| flush_time                      | 0                           |
| ft_boolean_syntax               | + -><()~*:""&|              |
| ft_min_word_len                 | 4                           |
| ft_max_word_len                 | 254                         |
| ft_max_word_len_for_sort        | 20                          |
| ft_stopword_file                | (built-in)                  |
| have_bdb                        | YES                         |
| have_innodb                     | YES                         |
| have_isam                       | YES                         |
```

```
| have_raid                       | NO                          |
| have_symlink                    | DISABLED                    |
| have_openssl                    | YES                         |
| have_query_cache                | YES                         |
| init_file                       |                             |
| innodb_additional_mem_pool_size | 1048576                     |
| innodb_buffer_pool_size         | 8388608                     |
| innodb_data_file_path           | ibdata1:10M:autoextend      |
| innodb_data_home_dir            |                             |
| innodb_file_io_threads          | 4                           |
| innodb_force_recovery           | 0                           |
| innodb_thread_concurrency       | 8                           |
| innodb_flush_log_at_trx_commit  | 1                           |
| innodb_fast_shutdown            | ON                          |
| innodb_flush_method             |                             |
| innodb_lock_wait_timeout        | 50                          |
| innodb_log_arch_dir             |                             |
| innodb_log_archive              | OFF                         |
| innodb_log_buffer_size          | 1048576                     |
| innodb_log_file_size            | 5242880                     |
| innodb_log_files_in_group       | 2                           |
| innodb_log_group_home_dir       | ./                          |
| innodb_mirrored_log_groups      | 1                           |
| interactive_timeout             | 28800                       |
| join_buffer_size                | 131072                      |
| key_buffer_size                 | 16773120                    |
| language                        | /usr/local/mysql/share/...  |
| large_files_support             | ON                          |
| local_infile                    | ON                          |
| locked_in_memory                | OFF                         |
| log                             | OFF                         |
| log_update                      | OFF                         |
| log_bin                         | OFF                         |
| log_slave_updates               | OFF                         |
| log_slow_queries                | OFF                         |
| log_warnings                    | OFF                         |
| long_query_time                 | 10                          |
| low_priority_updates            | OFF                         |
| lower_case_table_names          | OFF                         |
| max_allowed_packet              | 1047552                     |
| max_binlog_cache_size           | 4294967295                  |
| max_binlog_size                 | 1073741824                  |
| max_connections                 | 100                         |
| max_connect_errors              | 10                          |
| max_delayed_threads             | 20                          |
| max_heap_table_size             | 16777216                    |
| max_join_size                   | 4294967295                  |
```

```
| max_relay_log_size              | 0                           |
| max_sort_length                 | 1024                        |
| max_user_connections            | 0                           |
| max_tmp_tables                  | 32                          |
| max_write_lock_count            | 4294967295                  |
| myisam_max_extra_sort_file_size | 268435456                   |
| myisam_repair_threads           | 1                           |
| myisam_max_sort_file_size       | 2147483647                  |
| myisam_recover_options          | force                       |
| myisam_sort_buffer_size         | 8388608                     |
| net_buffer_length               | 16384                       |
| net_read_timeout                | 30                          |
| net_retry_count                 | 10                          |
| net_write_timeout               | 60                          |
| open_files_limit                | 1024                        |
| pid_file                        | /usr/local/mysql/name.pid   |
| port                            | 3306                        |
| protocol_version                | 10                          |
| query_cache_limit               | 1048576                     |
| query_cache_size                | 0                           |
| query_cache_type                | ON                          |
| read_buffer_size                | 131072                      |
| read_rnd_buffer_size            | 262144                      |
| rpl_recovery_rank               | 0                           |
| safe_show_database              | OFF                         |
| server_id                       | 0                           |
| slave_net_timeout               | 3600                        |
| skip_external_locking           | ON                          |
| skip_networking                 | OFF                         |
| skip_show_database              | OFF                         |
| slow_launch_time                | 2                           |
| socket                          | /tmp/mysql.sock             |
| sort_buffer_size                | 2097116                     |
| sql_mode                        |                             |
| table_cache                     | 64                          |
| table_type                      | MYISAM                      |
| thread_cache_size               | 3                           |
| thread_stack                    | 131072                      |
| tx_isolation                    | READ-COMMITTED              |
| timezone                        | EEST                        |
| tmp_table_size                  | 33554432                    |
| tmpdir                          | /tmp/:/mnt/hd2/tmp/         |
| version                         | 4.0.4-beta                  |
| wait_timeout                    | 28800                       |
+---------------------------------+-----------------------------+
```

Each option is described here. Values for buffer sizes, lengths, and stack sizes are given in bytes. You can specify values with a suffix of 'K' or 'M' to indicate kilobytes or megabytes. For example, 16M indicates 16 megabytes. The case of suffix letters does not matter; 16M and 16m are equivalent:

- ansi_mode. Is ON if mysqld was started with --ansi. See Section 1.7.2 [ANSI mode], page 33.
- back_log The number of outstanding connection requests MySQL can have. This comes into play when the main MySQL thread gets **very** many connection requests in a very short time. It then takes some time (although very little) for the main thread to check the connection and start a new thread. The back_log value indicates how many requests can be stacked during this short time before MySQL momentarily stops answering new requests. You need to increase this only if you expect a large number of connections in a short period of time.

  In other words, this value is the size of the listen queue for incoming TCP/IP connections. Your operating system has its own limit on the size of this queue. The manual page for the Unix listen(2) system call should have more details. Check your OS documentation for the maximum value for this variable. Attempting to set back_log higher than your operating system limit will be ineffective.
- basedir The value of the --basedir option.
- bdb_cache_size The buffer that is allocated to cache index and rows for BDB tables. If you don't use BDB tables, you should start mysqld with --skip-bdb to not waste memory for this cache.
- bdb_log_buffer_size The buffer that is allocated to cache index and rows for BDB tables. If you don't use BDB tables, you should set this to 0 or start mysqld with --skip-bdb to not waste memory for this cache.
- bdb_home The value of the --bdb-home option.
- bdb_max_lock The maximum number of locks (10,000 by default) you can have active on a BDB table. You should increase this if you get errors of type bdb: Lock table is out of available locks or Got error 12 from ... when you have do long transactions or when mysqld has to examine a lot of rows to calculate the query.
- bdb_logdir The value of the --bdb-logdir option.
- bdb_shared_data Is ON if you are using --bdb-shared-data.
- bdb_tmpdir The value of the --bdb-tmpdir option.
- binlog_cache_size. The size of the cache to hold the SQL statements for the binary log during a transaction. If you often use big, multi-statement transactions you can increase this to get more performance. See Section 6.7.1 [COMMIT], page 580.
- bulk_insert_buffer_size (was myisam_bulk_insert_tree_size) MyISAM uses special tree-like cache to make bulk inserts (that is, INSERT ... SELECT, INSERT ... VALUES (...), (...), ..., and LOAD DATA INFILE) faster. This variable limits the size of the cache tree in bytes per thread. Setting it to 0 will disable this optimisation. **Note**: this cache is only used when adding data to non-empty table. Default value is 8 MB.
- character_set The default character set.
- character_sets The supported character sets.

- `concurrent_inserts` If `ON` (the default), MySQL will allow you to use `INSERT` on `MyISAM` tables at the same time as you run `SELECT` queries on them. You can turn this option off by starting `mysqld` with `--safe` or `--skip-new`.
- `connect_timeout` The number of seconds the `mysqld` server is waiting for a connect packet before responding with `Bad handshake`.
- `datadir` The value of the `--datadir` option.
- `delay_key_write` Option for MyISAM tables. Can have one of the following values:

OFF	All `CREATE TABLE ... DELAYED_KEY_WRITE` are ignored.
ON	(default) MySQL will honor the `DELAY_KEY_WRITE` option for `CREATE TABLE`.
ALL	All new opened tables are treated as if they were created with the `DELAY_KEY_WRITE` option.

  If `DELAY_KEY_WRITE` is enabled this means that the key buffer for tables with this option will not get flushed on every index update, but only when a table is closed. This will speed up writes on keys a lot, but you should add automatic checking of all tables with `myisamchk --fast --force` if you use this.
- `delayed_insert_limit` After inserting `delayed_insert_limit` rows, the `INSERT DELAYED` handler will check if there are any `SELECT` statements pending. If so, it allows these to execute before continuing.
- `delayed_insert_timeout` How long a `INSERT DELAYED` thread should wait for `INSERT` statements before terminating.
- `delayed_queue_size` What size queue (in rows) should be allocated for handling `INSERT DELAYED`. If the queue becomes full, any client that does `INSERT DELAYED` will wait until there is room in the queue again.
- `flush` This is `ON` if you have started MySQL with the `--flush` option.
- `flush_time` If this is set to a non-zero value, then every `flush_time` seconds all tables will be closed (to free up resources and sync things to disk). We only recommend this option on Windows 9x/Me, or on systems where you have very little resources.
- `ft_boolean_syntax` List of operators supported by `MATCH ... AGAINST(... IN BOOLEAN MODE)`. See Section 6.8 [Fulltext Search], page 584.
- `ft_min_word_len` The minimum length of the word to be included in a `FULLTEXT` index. **Note: `FULLTEXT` indexes must be rebuilt after changing this variable.** (This option is new for MySQL 4.0.)
- `ft_max_word_len` The maximum length of the word to be included in a `FULLTEXT` index. **Note: `FULLTEXT` indexes must be rebuilt after changing this variable.** (This option is new for MySQL 4.0.)
- `ft_query_expansion_limit` Number of top matches to use for query expansion (in `MATCH ... AGAINST (... WITH QUERY EXPANSION)`. (This option is new for MySQL 4.1.1)
- `ft_stopword_file` The file from which to read the list of stopwords for full-text searches. All the words from the file will be used; comments are **not** honored. By default, built-in list of stopwords is used (as defined in '`myisam/ft_static.c`'). Setting this parameter to an empty string (`""`) will disable stopword filtering. **Note: `FULLTEXT` indexes must be rebuilt after changing this variable.** (This option is new for MySQL 4.0.10)

- `have_innodb` `YES` if `mysqld` supports InnoDB tables. `DISABLED` if `--skip-innodb` is used.
- `have_bdb` `YES` if `mysqld` supports Berkeley DB tables. `DISABLED` if `--skip-bdb` is used.
- `have_raid` `YES` if `mysqld` supports the `RAID` option.
- `have_openssl` `YES` if `mysqld` supports SSL (encryption) on the client/server protocol.
- `init_file` The name of the file specified with the `--init-file` option when you start the server. This is a file of SQL statements you want the server to execute when it starts.
- `interactive_timeout` The number of seconds the server waits for activity on an interactive connection before closing it. An interactive client is defined as a client that uses the `CLIENT_INTERACTIVE` option to `mysql_real_connect()`. See also `wait_timeout`.
- `join_buffer_size` The size of the buffer that is used for full joins (joins that do not use indexes). The buffer is allocated one time for each full join between two tables. Increase this value to get a faster full join when adding indexes is not possible. (Normally the best way to get fast joins is to add indexes.)
- `key_buffer_size` Index blocks are buffered and are shared by all threads. `key_buffer_size` is the size of the buffer used for index blocks.

  Increase this to get better index handling (for all reads and multiple writes) to as much as you can afford; 64M on a 256M machine that mainly runs MySQL is quite common. If you, however, make this too big (for instance more than 50% of your total memory) your system may start to page and become extremely slow. Remember that because MySQL does not cache data reads, you will have to leave some room for the OS filesystem cache.

  You can check the performance of the key buffer by doing `SHOW STATUS` and examine the variables `Key_read_requests`, `Key_reads`, `Key_write_requests`, and `Key_writes`. The `Key_reads/Key_read_request` ratio should normally be < 0.01. The `Key_write/Key_write_requests` is usually near 1 if you are using mostly updates/deletes but may be much smaller if you tend to do updates that affect many at the same time or if you are using `DELAY_KEY_WRITE`. See Section 4.6.8 [SHOW], page 284.

  To get even more speed when writing many rows at the same time, use `LOCK TABLES`. See Section 6.7.5 [LOCK TABLES], page 582.
- `language` The language used for error messages.
- `large_file_support` If `mysqld` was compiled with options for big file support.
- `locked_in_memory` If `mysqld` was locked in memory with `--memlock`
- `log` If logging of all queries is enabled.
- `log_update` If the update log is enabled.
- `log_bin` If the binary log is enabled.
- `log_slave_updates` If the updates from the slave should be logged.
- `long_query_time` If a query takes longer than this (in seconds), the `Slow_queries` counter will be incremented. If you are using `--log-slow-queries`, the query will be logged to the slow query logfile. This value is measured in real time, not CPU time, so a query that may be under the threshold on a lightly loaded system may be above the threshold on a heavily loaded one. See Section 4.10.5 [Slow query log], page 354.

- `lower_case_table_names` If set to 1 table names are stored in lowercase on disk and table name comparisons will be case-insensitive. From version 4.0.2, this option also applies to database names. From 4.1.1 this option also applies to table alias. See Section 6.1.3 [Name case sensitivity], page 445.
- `max_allowed_packet` The maximum size of one packet. The message buffer is initialised to `net_buffer_length` bytes, but can grow up to `max_allowed_packet` bytes when needed. This value by default is small, to catch big (possibly wrong) packets. You must increase this value if you are using big `BLOB` columns. It should be as big as the biggest `BLOB` you want to use. The protocol limits for `max_allowed_packet` is 16M in MySQL 3.23 and 1G in MySQL 4.0.
- `max_binlog_cache_size` If a multi-statement transaction requires more than this amount of memory, one will get the error "Multi-statement transaction required more than 'max_binlog_cache_size' bytes of storage".
- `max_binlog_size` Available after 3.23.33. If a write to the binary (replication) log exceeds the given value, rotate the logs. You cannot set it to less than 4096 bytes (1024 in MySQL versions older than 4.0.14), or more than 1 GB. Default is 1 GB. Note if you are using transactions: a transaction is written in one chunk to the binary log, hence it is never split between several binary logs. Therefore, if you have big transactions, you may see binlogs bigger than `max_binlog_size`. If `max_relay_log_size` (available starting from MySQL 4.0.14) is 0, then `max_binlog_size` will apply to relay logs as well.
- `max_connections` The number of simultaneous clients allowed. Increasing this value increases the number of file descriptors that `mysqld` requires. See below for comments on file descriptor limits. See Section A.2.6 [Too many connections], page 851.
- `max_connect_errors` If there is more than this number of interrupted connections from a host this host will be blocked from further connections. You can unblock a host with the command `FLUSH HOSTS`.
- `max_delayed_threads` Don't start more than this number of threads to handle `INSERT DELAYED` statements. If you try to insert data into a new table after all `INSERT DELAYED` threads are in use, the row will be inserted as if the `DELAYED` attribute wasn't specified. If you set this to 0, MySQL will never create a max_delayed thread.
- `max_heap_table_size` Don't allow creation of heap tables bigger than this.
- `max_join_size` Joins that are probably going to read more than `max_join_size` records return an error. Set this value if your users tend to perform joins that lack a `WHERE` clause, that take a long time, and that return millions of rows.
- `max_relay_log_size` Available starting from 4.0.14. If a write to the relay log (a kind of log used by replication slaves, see Section 4.11.3 [Replication Implementation Details], page 357) exceeds the given value, rotate the relay log. This variable enables you to put different size constraints on relay logs and binary logs. However, setting the variable to 0 will make MySQL use `max_binlog_size` for both binary logs and relay logs. You have to set `max_relay_log_size` to 0 or more than 4096, and less than 1 GB. Default is 0.
- `max_seeks_for_key` Limit assumed max number of seeks when looking up rows based on a key. The MySQL optimiser will assume that when searching after matching rows in a table through scanning a key, we will not cause more than this number of key seeks

independent of the cardinality of the key. By setting this to a low value (100 ?) you can force MySQL to prefer keys instead of table scans.

- `max_sort_length` The number of bytes to use when sorting `BLOB` or `TEXT` values (only the first `max_sort_length` bytes of each value are used; the rest are ignored).
- `max_user_connections` The maximum number of active connections for a single user (0 = no limit).
- `max_tmp_tables` (This option doesn't yet do anything.) Maximum number of temporary tables a client can keep open at the same time.
- `max_write_lock_count` After this many write locks, allow some read locks to run in between.
- `myisam_recover_options` The value of the `--myisam-recover` option.
- `myisam_sort_buffer_size` The buffer that is allocated when sorting the index when doing a `REPAIR` or when creating indexes with `CREATE INDEX` or `ALTER TABLE`.
- `myisam_max_extra_sort_file_size`. If the temporary file used for fast index creation would be bigger than using the key cache by the amount specified here, then prefer the key cache method. This is mainly used to force long character keys in large tables to use the slower key cache method to create the index. **Note** that this parameter is given in megabytes before 4.0.3 and in bytes beginning with this version.
- `myisam_repair_threads`. If this value is greater than one, MyISAM table indexes during `Repair by sorting` process will be created in parallel - each index in its own thread. **Note:** multi-threaded repair is still **alpha** quality code.
- `myisam_max_sort_file_size` The maximum size of the temporary file MySQL is allowed to use while recreating the index (during `REPAIR`, `ALTER TABLE` or `LOAD DATA INFILE`. If the file-size would be bigger than this, the index will be created through the key cache (which is slower). **Note** that this parameter is given in megabytes before 4.0.3 and in bytes beginning with this version.
- `net_buffer_length` The communication buffer is reset to this size between queries. This should not normally be changed, but if you have very little memory, you can set it to the expected size of a query. (That is, the expected length of SQL statements sent by clients. If statements exceed this length, the buffer is automatically enlarged, up to `max_allowed_packet` bytes.)
- `net_read_timeout` Number of seconds to wait for more data from a connection before aborting the read. Note that when we don't expect data from a connection, the timeout is defined by `write_timeout`. See also `slave_net_timeout`.
- `net_retry_count` If a read on a communication port is interrupted, retry this many times before giving up. This value should be quite high on `FreeBSD` as internal interrupts are sent to all threads.
- `net_write_timeout` Number of seconds to wait for a block to be written to a connection before aborting the write.
- `open_files_limit` Number of files the system allows mysqld to open. This is the real value given for the system and may be different from the value you gave mysqld as a startup parameter. This is 0 on systems where MySQL can't change the number of open files.
- `pid_file` The value of the `--pid-file` option.

- `port` The value of the `--port` option.
- `protocol_version` The protocol version used by the MySQL server.
- `range_alloc_block_size` Size of blocks that are allocated when doing range optimization.
- `read_buffer_size` (was `record_buffer`) Each thread that does a sequential scan allocates a buffer of this size for each table it scans. If you do many sequential scans, you may want to increase this value.
- `read_rnd_buffer_size` (was `record_rnd_buffer`) When reading rows in sorted order after a sort, the rows are read through this buffer to avoid a disk seeks. Can improve `ORDER BY` by a lot if set to a high value. As this is a thread-specific variable, one should not set this big globally, but just change this when running some specific big queries.
- `query_alloc_block_size` Size of memory allocation blocks that are allocated for objects created during query parsing and execution. If you have problem with memory fragmentation it may help increasing this a bit.
- `query_cache_limit` Don't cache results that are bigger than this. (Default 1M).
- `query_cache_size` The memory allocated to store results from old queries. If this is 0, the query cache is disabled (default).
- `query_cache_type` This may be set (only numeric) to

Value	Alias	Comment
0	OFF	Don't cache or retrieve results.
1	ON	Cache all results except `SELECT SQL_NO_CACHE ...` queries.
2	DEMAND	Cache only `SELECT SQL_CACHE ...` queries.

- `query_prealloc_size` Persistent buffer for query parsing and execution. This one is not freed between queries. In theory, by making this "big enough", make MySQL run queries without having to do a single `malloc()` call.
- `safe_show_database` Don't show databases for which the user doesn't have any database or table privileges. This can improve security if you're concerned about people being able to see what databases other users have. See also `skip_show_database`.
- `server_id` The value of the `--server-id` option.
- `skip_locking` Is OFF if `mysqld` uses external locking.
- `skip_networking` Is ON if we only allow local (socket) connections.
- `skip_show_database` This prevents people from doing `SHOW DATABASES` if they don't have the `PROCESS` privilege. This can improve security if you're concerned about people being able to see what databases other users have. See also `safe_show_database`.
- `slave_net_timeout` Number of seconds to wait for more data from a master/slave connection before aborting the read.
- `slow_launch_time` If creating the thread takes longer than this value (in seconds), the `Slow_launch_threads` counter will be incremented.
- `socket` The Unix socket used by the server.
- `sort_buffer_size` Each thread that needs to do a sort allocates a buffer of this size. Increase this value for faster `ORDER BY` or `GROUP BY` operations. See Section A.4.4 [Temporary files], page 863.

- `table_cache` The number of open tables for all threads. Increasing this value increases the number of file descriptors that `mysqld` requires. You can check if you need to increase the table cache by checking the `Opened_tables` variable. See Section 4.6.8.3 [`Opened_tables`], page 287. If this variable is big and you don't do `FLUSH TABLES` a lot (which just forces all tables to be closed and reopenend), then you should increase the value of this variable.

  For more information about the table cache, see Section 5.4.7 [Table cache], page 425.
- `table_type` The default table type.
- `thread_cache_size` How many threads we should keep in a cache for reuse. When a client disconnects, the client's threads are put in the cache if there aren't more than `thread_cache_size` threads from before. All new threads are first taken from the cache, and only when the cache is empty is a new thread created. This variable can be increased to improve performance if you have a lot of new connections. (Normally this doesn't give a notable performance improvement if you have a good thread implementation.) By examing the difference between the `Connections` and `Threads_created` status variables (see Section 4.6.8.3 [`SHOW STATUS`], page 287 for details) you can see how efficient thread cache is.
- `thread_concurrency` On Solaris, `mysqld` will call `thr_setconcurrency()` with this value. `thr_setconcurrency()` permits the application to give the threads system a hint for the desired number of threads that should be run at the same time.
- `thread_stack` The stack size for each thread. Many of the limits detected by the `crash-me` test are dependent on this value. The default is large enough for normal operation. See Section 5.1.4 [MySQL Benchmarks], page 397.
- `timezone` The timezone for the server.
- `tmp_table_size` If an in-memory temporary table exceeds this size, MySQL will automatically convert it to an on-disk `MyISAM` table. Increase the value of `tmp_table_size` if you do many advanced `GROUP BY` queries and you have lots of memory.
- `tmpdir` The directory used for temporary files and temporary tables. Starting from MySQL 4.1, it can be set to a list of paths separated by colon `:` (semicolon `;` on Windows). They will be used in round-robin fashion. This feature can be used to spread load between several physical disks. It is possible to set `tmpdir` to point to a memory-based filesystem, except if the MySQL server is a slave. If it is a slave, it needs some of its temporary files (for replication of temporary tables or of `LOAD DATA INFILE`) to survive a machine's reboot, so a memory-based `tmpdir` which is cleared when the machine reboots is not suitable; a disk-based `tmpdir` is necessary.
- `transaction_alloc_block_size` Size of memory allocation blocks that are allocated for storing queries that are part of a transaction that are to be stored in the binary log when doing a commit.
- `transaction_prealloc_block_size` Persistent buffer for `transaction_alloc_blocks`. that are not freed between queries. By making this "big enough" to fit all queries in a common transaction you can avoid a lot of `malloc()` calls.
- `version` The version number for the server.
- `wait_timeout` The number of seconds the server waits for activity on a not interactive connection before closing it.

On thread startup `SESSION.WAIT_TIMEOUT` is initialised from `GLOBAL.WAIT_TIMEOUT` or `GLOBAL.INTERACTIVE_TIMEOUT` depending on the type of client (as defined by the `CLIENT_INTERACTIVE` connect option). See also `interactive_timeout`.

The manual section that describes tuning MySQL contains some information of how to tune the above variables. See Section 5.5.2 [Server parameters], page 427.

4.6.8.5 SHOW [BDB] LOGS

`SHOW LOGS` shows you status information about existing log files. It currently only displays information about Berkeley DB log files, so an alias for it (available as of MySQL 4.1.1) is `SHOW BDB LOGS`.

- `File` shows the full path to the log file
- `Type` shows the type of the log file (`BDB` for Berkeley DB log files)
- `Status` shows the status of the log file (`FREE` if the file can be removed, or `IN USE` if the file is needed by the transaction subsystem)

4.6.8.6 SHOW PROCESSLIST

`SHOW [FULL] PROCESSLIST` shows you which threads are running. You can also get this information using the `mysqladmin processlist` command. If you have the `SUPER` privilege, you can see all threads. Otherwise, you can see only your own threads. See Section 4.6.7 [KILL], page 284. If you don't use the `FULL` option, then only the first 100 characters of each query will be shown.

Starting from 4.0.12, MySQL reports the hostname for TCP/IP connections in `hostname:client_port` format to make it easier to find out which client is doing what.

This command is very useful if you get the 'too many connections' error message and want to find out what's going on. MySQL reserves one extra connection for a client with the `SUPER` privilege to ensure that you should always be able to login and check the system (assuming you are not giving this privilege to all your users).

Some states commonly seen in `mysqladmin processlist`

- `Checking table` The thread is performing [automatic] checking of the table.
- `Closing tables` Means that the thread is flushing the changed table data to disk and closing the used tables. This should be a fast operation. If not, then you should check that you don't have a full disk or that the disk is not in very heavy use.
- `Connect Out` Slave connecting to master.
- `Copying to tmp table on disk` The temporary result set was larger than `tmp_table_size` and the thread is now changing the in memory-based temporary table to a disk based one to save memory.
- `Creating tmp table` The thread is creating a temporary table to hold a part of the result for the query.
- `deleting from main table` When executing the first part of a multi-table delete and we are only deleting from the first table.

- `deleting from reference tables` When executing the second part of a multi-table delete and we are deleting the matched rows from the other tables.
- `Flushing tables` The thread is executing `FLUSH TABLES` and is waiting for all threads to close their tables.
- `Killed` Someone has sent a kill to the thread and it should abort next time it checks the kill flag. The flag is checked in each major loop in MySQL, but in some cases it may still take a short time for the thread to die. If the thread is locked by some other thread, the kill will take effect as soon as the other thread releases its lock.
- `Sending data` The thread is processing rows for a `SELECT` statement and is also sending data to the client.
- `Sorting for group` The thread is doing a sort to satisfy a `GROUP BY`.
- `Sorting for order` The thread is doing a sort to satisfy a `ORDER BY`.
- `Opening tables` This simply means that the thread is trying to open a table. This is should be very fast procedure, unless something prevents opening. For example an `ALTER TABLE` or a `LOCK TABLE` can prevent opening a table until the command is finished.
- `Removing duplicates` The query was using `SELECT DISTINCT` in such a way that MySQL couldn't optimise that distinct away at an early stage. Because of this MySQL has to do an extra stage to remove all duplicated rows before sending the result to the client.
- `Reopen table` The thread got a lock for the table, but noticed after getting the lock that the underlying table structure changed. It has freed the lock, closed the table and is now trying to reopen it.
- `Repair by sorting` The repair code is using sorting to create indexes.
- `Repair with keycache` The repair code is using creating keys one by one through the key cache. This is much slower than `Repair by sorting`.
- `Searching rows for update` The thread is doing a first phase to find all matching rows before updating them. This has to be done if the `UPDATE` is changing the index that is used to find the involved rows.
- `Sleeping` The thread is wating for the client to send a new command to it.
- `System lock` The thread is waiting for getting to get a external system lock for the table. If you are not using multiple mysqld servers that are accessing the same tables, you can disable system locks with the `--skip-external-locking` option.
- `Upgrading lock` The `INSERT DELAYED` handler is trying to get a lock for the table to insert rows.
- `Updating` The thread is searching for rows to update and updating them.
- `User Lock` The thread is waiting on a `GET_LOCK()`.
- `Waiting for tables` The thread got a notification that the underlying structure for a table has changed and it needs to reopen the table to get the new structure. To be able to reopen the table it must however wait until all other threads have closed the table in question.

  This notification happens if another thread has used `FLUSH TABLES` or one of the following commands on the table in question: `FLUSH TABLES table_name`, `ALTER TABLE`, `RENAME TABLE`, `REPAIR TABLE`, `ANALYZE TABLE` or `OPTIMIZE TABLE`.

- `waiting for handler insert` The `INSERT DELAYED` handler has processed all inserts and are waiting to get new ones.

Most states are very quick operations. If threads last in any of these states for many seconds, there may be a problem around that needs to be investigated.

There are some other states that are not mentioned previously, but most of these are only useful to find bugs in `mysqld`.

4.6.8.7 SHOW GRANTS

`SHOW GRANTS FOR user` lists the grant commands that must be issued to duplicate the grants for a user.

```
mysql> SHOW GRANTS FOR root@localhost;
+---------------------------------------------------------------------+
| Grants for root@localhost                                           |
+---------------------------------------------------------------------+
| GRANT ALL PRIVILEGES ON *.* TO 'root'@'localhost' WITH GRANT OPTION |
+---------------------------------------------------------------------+
```

To list grants for the current session one may use `CURRENT_USER()` function (new in version 4.0.6) to find out what user the session was authenticated as. See Section 6.3.6.2 [`CURRENT_USER()`], page 515.

4.6.8.8 SHOW CREATE TABLE

Shows a `CREATE TABLE` statement that will create the given table:

```
mysql> SHOW CREATE TABLE t\G
*************************** 1. row ***************************
       Table: t
Create Table: CREATE TABLE t (
  id INT(11) default NULL auto_increment,
  s char(60) default NULL,
  PRIMARY KEY (id)
) TYPE=MyISAM
```

`SHOW CREATE TABLE` quotes table and column names according to the value of the `SQL_QUOTE_SHOW_CREATE` option. Section 5.5.6 [`SET SQL_QUOTE_SHOW_CREATE`], page 432.

4.6.8.9 SHOW WARNINGS | ERRORS

```
SHOW WARNINGS [LIMIT row_count]
SHOW ERRORS [LIMIT row_count]
```

This command is implemented in MySQL 4.1.0.

It shows the errors, warnings and notes that one got for the last command. The errors/warnings are reset for each new command that uses a table.

The MySQL server sends back the total number of warnings and errors you got for the last commend; This can be retrieved by calling `mysql_warning_count()`.

Up to `max_error_count` messages are stored (Global and thread specific variable).

You can retrieve the number of errors from `@error_count` and warnings from `@warning_count`.

`SHOW WARNINGS` shows all errors, warnings and notes you got for the last command while `SHOW ERRORS` only shows you the errors.

```
mysql> DROP TABLE IF EXISTS no_such_table;
mysql> SHOW WARNINGS;

+-------+------+-------------------------------+
| Level | Code | Message                       |
+-------+------+-------------------------------+
| Note  | 1051 | Unknown table 'no_such_table' |
+-------+------+-------------------------------+
```

Note that in MySQL 4.1.0 we have just added the frame work for warnings and not many MySQL command do yet generate warnings. 4.1.1 supports all kind of warnings for `LOAD DATA INFILE` and DML statements such as `INSERT`, `UPDATE` and `ALTER` commands.

For example, here is a simple case which produces conversion warnings for a insert statement.

```
mysql> create table t1(a tinyint NOT NULL, b char(4));
Query OK, 0 rows affected (0.00 sec)

mysql> insert into t1 values(10,'mysql'),(NULL,'test'),(300,'open source');
Query OK, 3 rows affected, 4 warnings (0.15 sec)
Records: 3  Duplicates: 0  Warnings: 4

mysql> show warnings;
+---------+------+-----------------------------------------------------------------+
| Level   | Code | Message                                                         |
+---------+------+-----------------------------------------------------------------+
| Warning | 1263 | Data truncated for column 'b' at row 1                          |
| Warning | 1261 | Data truncated, NULL supplied to NOT NULL column 'a' at row 2 |
| Warning | 1262 | Data truncated, out of range for column 'a' at row 3          |
| Warning | 1263 | Data truncated for column 'b' at row 3                          |
+---------+------+-----------------------------------------------------------------+
4 rows in set (0.00 sec)
```

Maximum number of warnings can be specified using the server variable `'max_error_count'`, `SET max_error_count=[count]`; By default it is 64. In case to disable warnings, simply reset this variable to '0'. In case if `max_error_count` is 0, then still the warning count represents how many warnings have occurred, but none of the messages are stored.

For example, consider the following `ALTER` table statement for the above example, which returns only one warning message even though total warnings occurred is 3 when you set max_error_count=1.

```
mysql> show variables like 'max_error_count';
+-----------------+-------+
| Variable_name   | Value |
+-----------------+-------+
```

```
| max_error_count | 64    |
+-----------------+-------+
1 row in set (0.00 sec)

mysql> set max_error_count=1;
Query OK, 0 rows affected (0.00 sec)

mysql> alter table t1 modify b char;
Query OK, 3 rows affected, 3 warnings (0.00 sec)
Records: 3  Duplicates: 0  Warnings: 3

mysql> show warnings;
+---------+------+---------------------------------------+
| Level   | Code | Message                               |
+---------+------+---------------------------------------+
| Warning | 1263 | Data truncated for column 'b' at row 1 |
+---------+------+---------------------------------------+
1 row in set (0.00 sec)

mysql>
```

4.6.8.10 SHOW TABLE TYPES

```
SHOW TABLE TYPES
```

This command is implemented in MySQL 4.1.0.

`SHOW TABLE TYPES` shows you status information about the table types. This is particulary useful for checking if a table type is supported; or to see what is the default table type is.

```
mysql> SHOW TABLE TYPES;

+--------+---------+------------------------------------------------------------+
| Type   | Support | Comment                                                    |
+--------+---------+------------------------------------------------------------+
| MyISAM | DEFAULT | Default type from 3.23 with great performance              |
| HEAP   | YES     | Hash based, stored in memory, useful for temporary tables  |
| MERGE  | YES     | Collection of identical MyISAM tables                      |
| ISAM   | YES     | Obsolete table type; Is replaced by MyISAM                 |
| InnoDB | YES     | Supports transactions, row-level locking and foreign keys  |
| BDB    | NO      | Supports transactions and page-level locking               |
+--------+---------+------------------------------------------------------------+
6 rows in set (0.00 sec)
```

The 'Support' option `DEFAULT` indicates whether the particular table type is supported, and which is the default type. If the server is started with `--default-table-type=InnoDB`, then the InnoDB 'Support' field will have the value `DEFAULT`.

4.6.8.11 SHOW PRIVILEGES

```
SHOW PRIVILEGES
```

This command is implemented in MySQL 4.1.0.

`SHOW PRIVILEGES` shows the list of system privileges that the underlying MySQL server supports.

```
mysql> show privileges;
+------------+--------------------------+--------------------------------------------
| Privilege  | Context                  | Comment
+------------+--------------------------+--------------------------------------------
| Select     | Tables                   | To retrieve rows from table
| Insert     | Tables                   | To insert data into tables
| Update     | Tables                   | To update existing rows
| Delete     | Tables                   | To delete existing rows
| Index      | Tables                   | To create or drop indexes
| Alter      | Tables                   | To alter the table
| Create     | Databases,Tables,Indexes | To create new databases and tables
| Drop       | Databases,Tables         | To drop databases and tables
| Grant      | Databases,Tables         | To give to other users those privileges you
| References | Databases,Tables         | To have references on tables
| Reload     | Server Admin             | To reload or refresh tables, logs and privil
| Shutdown   | Server Admin             | To shutdown the server
| Process    | Server Admin             | To view the plain text of currently executin
| File       | File access on server    | To read and write files on the server
+------------+--------------------------+--------------------------------------------
14 rows in set (0.00 sec)
```

4.7 MySQL Localisation and International Usage

4.7.1 The Character Set Used for Data and Sorting

By default, MySQL uses the ISO-8859-1 (Latin1) character set with sorting according to Swedish/Finnish. This is the character set suitable in the USA and western Europe.

All standard MySQL binaries are compiled with `--with-extra-charsets=complex`. This will add code to all standard programs to be able to handle `latin1` and all multi-byte character sets within the binary. Other character sets will be loaded from a character-set definition file when needed.

The character set determines what characters are allowed in names and how things are sorted by the `ORDER BY` and `GROUP BY` clauses of the `SELECT` statement.

You can change the character set with the `--default-character-set` option when you start the server. The character sets available depend on the `--with-charset=charset` and `--with-extra-charsets= list-of-charset | complex | all | none` options to `configure`, and the character set configuration files listed in '`SHAREDIR/charsets/Index`'. See Section 2.3.3 [configure options], page 91.

If you change the character set when running MySQL (which may also change the sort order), you must run `myisamchk -r -q --set-character-set=charset` on all tables. Otherwise, your indexes may not be ordered correctly.

When a client connects to a MySQL server, the server sends the default character set in use to the client. The client will switch to use this character set for this connection.

One should use `mysql_real_escape_string()` when escaping strings for an SQL query. `mysql_real_escape_string()` is identical to the old `mysql_escape_string()` function, except that it takes the `MYSQL` connection handle as the first parameter.

If the client is compiled with different paths than where the server is installed and the user who configured MySQL didn't include all character sets in the MySQL binary, one must specify for the client where it can find the additional character sets it will need if the server runs with a different character set than the client.

One can specify this by putting in a MySQL option file:

```
[client]
character-sets-dir=/usr/local/mysql/share/mysql/charsets
```

where the path points to the directory in which the dynamic MySQL character sets are stored.

One can force the client to use specific character set by specifying:

```
[client]
default-character-set=character-set-name
```

but normally this is never needed.

4.7.1.1 German character set

To get German sorting order, you should start `mysqld` with `--default-character-set=latin1_de`. This will give you the following characteristics.

When sorting and comparing strings, the following mapping is done on the strings before doing the comparison:

```
ä  ->  ae
ö  ->  oe
ü  ->  ue
ß  ->  ss
```

All accented characters, are converted to their un-accented uppercase counterpart. All letters are converted to uppercase.

When comparing strings with `LIKE` the one `->` two character mapping is not done. All letters are converted to uppercase. Accent are removed from all letters except: `Ü`, `ü`, `Ö`, `ö`, `Ä` and `ä`.

4.7.2 Non-English Error Messages

`mysqld` can issue error messages in the following languages: Czech, Danish, Dutch, English (the default), Estonian, French, German, Greek, Hungarian, Italian, Japanese, Korean, Norwegian, Norwegian-ny, Polish, Portuguese, Romanian, Russian, Slovak, Spanish, and Swedish.

To start `mysqld` with a particular language, use either the `--language=lang` or `-L lang` options. For example:

```
shell> mysqld --language=swedish
```

or:

```
shell> mysqld --language=/usr/local/share/swedish
```

Note that all language names are specified in lowercase.

The language files are located (by default) in '*`mysql_base_dir`*`/share/`*`LANGUAGE/`*'.

To update the error message file, you should edit the '`errmsg.txt`' file and execute the following command to generate the '`errmsg.sys`' file:

```
shell> comp_err errmsg.txt errmsg.sys
```

If you upgrade to a newer version of MySQL, remember to repeat your changes with the new '`errmsg.txt`' file.

4.7.3 Adding a New Character Set

To add another character set to MySQL, use the following procedure.

Decide if the set is simple or complex. If the character set does not need to use special string collating routines for sorting and does not need multi-byte character support, it is simple. If it needs either of those features, it is complex.

For example, `latin1` and `danish` are simple charactersets while `big5` or `czech` are complex character sets.

In the following section, we have assumed that you name your character set `MYSET`.

For a simple character set do the following:

1. Add MYSET to the end of the '`sql/share/charsets/Index`' file Assign a unique number to it.
2. Create the file '`sql/share/charsets/MYSET.conf`'. (You can use '`sql/share/charsets/latin1.conf`' as a base for this.)

   The syntax for the file is very simple:

   - Comments start with a '#' character and proceed to the end of the line.
   - Words are separated by arbitrary amounts of whitespace.
   - When defining the character set, every word must be a number in hexadecimal format
   - The `ctype` array takes up the first 257 words. The `to_lower[]`, `to_upper[]` and `sort_order[]` arrays take up 256 words each after that.

   See Section 4.7.4 [Character arrays], page 309.
3. Add the character set name to the `CHARSETS_AVAILABLE` and `COMPILED_CHARSETS` lists in `configure.in`.
4. Reconfigure, recompile, and test.

For a complex character set do the following:

1. Create the file '`strings/ctype-MYSET.c`' in the MySQL source distribution.

2. Add MYSET to the end of the '`sql/share/charsets/Index`' file. Assign a unique number to it.
3. Look at one of the existing '`ctype-*.c`' files to see what needs to be defined, for example '`strings/ctype-big5.c`'. Note that the arrays in your file must have names like `ctype_MYSET`, `to_lower_MYSET`, and so on. This corresponds to the arrays in the simple character set. See Section 4.7.4 [Character arrays], page 309.
4. Near the top of the file, place a special comment like this:

```
/*
 * This comment is parsed by configure to create ctype.c,
 * so don't change it unless you know what you are doing.
 *
 * .configure. number_MYSET=MYNUMBER
 * .configure. strxfrm_multiply_MYSET=N
 * .configure. mbmaxlen_MYSET=N
 */
```

   The `configure` program uses this comment to include the character set into the MySQL library automatically.

   The strxfrm_multiply and mbmaxlen lines will be explained in the following sections. Only include these if you need the string collating functions or the multi-byte character set functions, respectively.
5. You should then create some of the following functions:
   - `my_strncoll_MYSET()`
   - `my_strcoll_MYSET()`
   - `my_strxfrm_MYSET()`
   - `my_like_range_MYSET()`

   See Section 4.7.5 [String collating], page 310.
6. Add the character set name to the `CHARSETS_AVAILABLE` and `COMPILED_CHARSETS` lists in `configure.in`.
7. Reconfigure, recompile, and test.

The file '`sql/share/charsets/README`' includes some more instructions.

If you want to have the character set included in the MySQL distribution, mail a patch to the MySQL internals mailing list. See Section 1.6.1.1 [Mailing-list], page 25.

4.7.4 The Character Definition Arrays

`to_lower[]` and `to_upper[]` are simple arrays that hold the lowercase and uppercase characters corresponding to each member of the character set. For example:

```
to_lower['A'] should contain 'a'
to_upper['a'] should contain 'A'
```

`sort_order[]` is a map indicating how characters should be ordered for comparison and sorting purposes. Quite often (but not for all character sets) this is the same as `to_upper[]` (which means sorting will be case-insensitive). MySQL will sort characters based on the

value of `sort_order[character]`. For more complicated sorting rules, see the discussion of string collating below. See Section 4.7.5 [String collating], page 310.

`ctype[]` is an array of bit values, with one element for one character. (Note that `to_lower[]`, `to_upper[]`, and `sort_order[]` are indexed by character value, but `ctype[]` is indexed by character value + 1. This is an old legacy to be able to handle `EOF`.)

You can find the following bitmask definitions in '`m_ctype.h`':

```
#define _U      01      /* Uppercase */
#define _L      02      /* Lowercase */
#define _N      04      /* Numeral (digit) */
#define _S      010     /* Spacing character */
#define _P      020     /* Punctuation */
#define _C      040     /* Control character */
#define _B      0100    /* Blank */
#define _X      0200    /* heXadecimal digit */
```

The `ctype[]` entry for each character should be the union of the applicable bitmask values that describe the character. For example, `'A'` is an uppercase character (`_U`) as well as a hexadecimal digit (`_X`), so `ctype['A'+1]` should contain the value:

```
_U + _X = 01 + 0200 = 0201
```

4.7.5 String Collating Support

If the sorting rules for your language are too complex to be handled with the simple `sort_order[]` table, you need to use the string collating functions.

Right now the best documentation on this is the character sets that are already implemented. Look at the `big5`, `czech`, `gbk`, `sjis`, and `tis160` character sets for examples.

You must specify the `strxfrm_multiply_MYSET=N` value in the special comment at the top of the file. `N` should be set to the maximum ratio the strings may grow during `my_strxfrm_MYSET` (it must be a positive integer).

4.7.6 Multi-byte Character Support

If your want to add support for a new character set that includes multi-byte characters, you need to use the multi-byte character functions.

Right now the best documentation on this is the character sets that are already implemented. Look at the `euc_kr`, `gb2312`, `gbk`, `sjis`, and `ujis` character sets for examples. These are implemented in the '`ctype-'charset'.c`' files in the '`strings`' directory.

You must specify the `mbmaxlen_MYSET=N` value in the special comment at the top of the source file. `N` should be set to the size in bytes of the largest character in the set.

4.7.7 Problems With Character Sets

If you try to use a character set that is not compiled into your binary, you can run into a couple of different problems:

- Your program has a wrong path to where the character sets are stored. (Default '`/usr/local/mysql/share/mysql/charsets`'). This can be fixed by using the `--character-sets-dir` option to the program in question.
- The character set is a multi-byte character set that can't be loaded dynamically. In this case you have to recompile the program with the support for the character set.
- The character set is a dynamic character set, but you don't have a configure file for it. In this case you should install the configure file for the character set from a new MySQL distribution.
- Your '`Index`' file doesn't contain the name for the character set.

  ```
  ERROR 1105: File '/usr/local/share/mysql/charsets/?.conf' not found
  (Errcode: 2)
  ```

  In this case you should either get a new `Index` file or add by hand the name of any missing character sets.

For `MyISAM` tables, you can check the character set name and number for a table with `myisamchk -dvv table_name`.

4.8 MySQL Server-Side Scripts and Utilities

4.8.1 Overview of the Server-Side Scripts and Utilities

All MySQL programs take many different options. However, every MySQL program provides a `--help` option that you can use to get a full description of the program's different options. For example, try `mysql --help`.

You can override default options for all standard programs with an option file. Section 4.1.2 [Option files], page 203.

The following list briefly describes the server-side MySQL programs:

`myisamchk`
: Utility to describe, check, optimise, and repair MySQL tables. Because `myisamchk` has many functions, it is described in its own chapter. See Chapter 4 [MySQL Database Administration], page 195.

`make_binary_distribution`
: Makes a binary release of a compiled MySQL. This could be sent by FTP to '`/pub/mysql/Incoming`' on `support.mysql.com` for the convenience of other MySQL users.

`mysqlbug`
: The MySQL bug report script. This script should always be used when filing a bug report to the MySQL list.

`mysqld`
: The SQL daemon. This should always be running.

`mysql_install_db`
: Creates the MySQL grant tables with default privileges. This is usually executed only once, when first installing MySQL on a system.

4.8.2 `mysqld_safe`, The Wrapper Around `mysqld`

`mysqld_safe` is the recommended way to start a `mysqld` daemon on Unix. `mysqld_safe` adds some safety features such as restarting the server when an error occurs and logging run-time information to a log file.

Note: Before MySQL 4.0, `mysqld_safe` is named `safe_mysqld`. To preserve backward compatibility, MySQL binary distributions for some time will include `safe_mysqld` as a symbolic link to `mysqld_safe`.

If you don't use `--mysqld=#` or `--mysqld-version=#` `mysqld_safe` will use an executable named `mysqld-max` if it exists. If not, `mysqld_safe` will start `mysqld`. This makes it very easy to test to use `mysqld-max` instead of `mysqld`; just copy `mysqld-max` to where you have `mysqld` and it will be used.

Normally one should never edit the `mysqld_safe` script, but instead put the options to `mysqld_safe` in the `[mysqld_safe]` section in the '`my.cnf`' file. `mysqld_safe` reads all options from the `[mysqld]`, `[server]` and `[mysqld_safe]` sections from the option files. (For backward compatibility, it also reads the `[safe_mysqld]` sections.) See Section 4.1.2 [Option files], page 203.

Note that all options on the command-line to `mysqld_safe` are passed to `mysqld`. If you wants to use any options in `mysqld_safe` that `mysqld` doesn't support, you must specify these in the option file.

Most of the options to `mysqld_safe` are the same as the options to `mysqld`. See Section 4.1.1 [Command-line options], page 195.

`mysqld_safe` supports the following options:

`--basedir=path`
`--core-file-size=#`
: Size of the core file `mysqld` should be able to create. Passed to `ulimit -c`.

`--datadir=path`
`--defaults-extra-file=path`
`--defaults-file=path`
`--err-log=path (this is marked obsolete in 4.0; Use --log-error instead)`
`--log-error=path`
: Write the error log to the above file. See Section 4.10.1 [Error log], page 350.

`--ledir=path`
: Path to `mysqld`

`--log=path`
`--mysqld=mysqld-version`
: Name of the `mysqld` version in the `ledir` directory you want to start.

`--mysqld-version=version`
: Similar to `--mysqld=` but here you only give the suffix for `mysqld`. For example if you use `--mysqld-version=max`, `mysqld_safe` will start the `ledir/mysqld-max` version. If the argument to `--mysqld-version` is empty, `ledir/mysqld` will be used.

`--nice=# (added in MySQL 4.0.14)`
`--no-defaults`
`--open-files-limit=#`
Number of files `mysqld` should be able to open. Passed to `ulimit -n`. Note that you need to start `mysqld_safe` as `root` for this to work properly!

`--pid-file=path`
`--port=#`

`--socket=path`
`--timezone=#`
Set the timezone (the `TZ`) variable to the value of this parameter.

`--user=#`

The `mysqld_safe` script is written so that it normally is able to start a server that was installed from either a source or a binary version of MySQL, even if these install the server in slightly different locations. `mysqld_safe` expects one of these conditions to be true:

- The server and databases can be found relative to the directory from which `mysqld_safe` is invoked. `mysqld_safe` looks under its working directory for '`bin`' and '`data`' directories (for binary distributions) or for '`libexec`' and '`var`' directories (for source distributions). This condition should be met if you execute `mysqld_safe` from your MySQL installation directory (for example, '`/usr/local/mysql`' for a binary distribution).
- If the server and databases cannot be found relative to the working directory, `mysqld_safe` attempts to locate them by absolute pathnames. Typical locations are '`/usr/local/libexec`' and '`/usr/local/var`'. The actual locations are determined when the distribution was built from which `mysqld_safe` comes. They should be correct if MySQL was installed in a standard location.

Because `mysqld_safe` will try to find the server and databases relative to its own working directory, you can install a binary distribution of MySQL anywhere, as long as you start `mysqld_safe` from the MySQL installation directory:

```
shell> cd mysql_installation_directory
shell> bin/mysqld_safe &
```

If `mysqld_safe` fails, even when invoked from the MySQL installation directory, you can modify it to use the path to `mysqld` and the pathname options that are correct for your system. Note that if you upgrade MySQL in the future, your modified version of `mysqld_safe` will be overwritten, so you should make a copy of your edited version that you can reinstall.

4.8.3 `mysqld_multi`, A Program for Managing Multiple MySQL Servers

`mysqld_multi` is meant for managing several `mysqld` processes that listen for connections on different Unix sockets and TCP/IP ports.

The program will search for groups named `[mysqld#]` from '`my.cnf`' (or the file named by the `--config-file=...` option), where `#` can be any positive number starting from 1.

This number is referred to in the following discussion as the option group number, or GNR. Group numbers distinquish option groups from one another and are used as arguments to `mysqld_multi` to specify which servers you want to start, stop, or obtain status for. Options listed in these groups should be the same as you would use in the usual `[mysqld]` group used for starting `mysqld`. (See, for example, Section 2.4.3 [Automatic start], page 108.) However, for `mysqld_multi`, be sure that each group includes options for values such as the port, socket, etc., to be used for each individual `mysqld` process.

`mysqld_multi` is invoked using the following syntax:

```
Usage: mysqld_multi [OPTIONS] {start|stop|report} [GNR,GNR,GNR...]
or     mysqld_multi [OPTIONS] {start|stop|report} [GNR-GNR,GNR,GNR-GNR,...]
```

Each GNR represents an option group number. You can start, stop or report any GNR, or several of them at the same time. For an example of how you might set up an option file, use this command:

```
shell> mysqld_multi --example
```

The GNR values in the list can be comma-separated or combined with a dash; in the latter case, all the GNRs between GNR1-GNR2 will be affected. With no GNR argument, all groups listed in the option file will be either started, stopped, or reported. Note that you must not have any white spaces in the GNR list. Anything after a white space is ignored.

`mysqld_multi` supports the following options:

`--config-file=...`
: Alternative config file. Note: This will not affect this program's own options (group `[mysqld_multi]`), but only groups `[mysqld#]`. Without this option, everything will be searched from the ordinary '`my.cnf`' file.

`--example`
: Display an example option file.

`--help` Print this help and exit.

`--log=...`
: Log file. Full path to and the name for the log file. Note: If the file exists, everything will be appended.

`--mysqladmin=...`
: `mysqladmin` binary to be used for a server shutdown.

`--mysqld=...`
: `mysqld` binary to be used. Note that you can give `mysqld_safe` to this option also. The options are passed to `mysqld`. Just make sure you have `mysqld` in your environment variable `PATH` or fix `mysqld_safe`.

`--no-log` Print to stdout instead of the log file. By default the log file is turned on.

`--password=...`
: Password for user for `mysqladmin`.

`--tcp-ip` Connect to the MySQL server(s) via the TCP/IP port instead of the Unix socket. This affects stopping and reporting. If a socket file is missing, the server may still be running, but can be accessed only via the TCP/IP port. By default, connections are made using the Unix socket.

`--user=...`
: MySQL user for `mysqladmin`.

`--version`
: Print the version number and exit.

Some notes about `mysqld_multi`:

- Make sure that the MySQL user, who is stopping the `mysqld` services (e.g using the `mysqladmin` program) have the same password and username for all the data directories accessed (to the `mysql` database) And make sure that the user has the `SHUTDOWN` privilege! If you have many data directories and many different `mysql` databases with different passwords for the MySQL `root` user, you may want to create a common `multi_admin` user for each using the same password (see below). Example how to do it:

  ```
  shell> mysql -u root -S /tmp/mysql.sock -proot_password -e
  "GRANT SHUTDOWN ON *.* TO multi_admin@localhost IDENTIFIED BY 'multipass'"
  ```

  See Section 4.3.6 [Privileges], page 219. You will have to do the above for each `mysqld` running in each data directory, that you have (just change the socket, `-S=...`).
- `pid-file` is very important, if you are using `mysqld_safe` to start `mysqld` (for example, `--mysqld=mysqld_safe`) Every `mysqld` should have its own `pid-file`. The advantage using `mysqld_safe` instead of `mysqld` directly here is, that `mysqld_safe` "guards" every `mysqld` process and will restart it, if a `mysqld` process terminates due to a signal sent using `kill -9`, or for other reasons such as a segmentation fault (which MySQL should never do, of course;). Please note that the `mysqld_safe` script may require that you start it from a certain place. This means that you may have to `cd` to a certain directory, before you start the `mysqld_multi`. If you have problems starting, please see the `mysqld_safe` script. Check especially the lines:

  ```
  ----------------------------------------------------------------------
  MY_PWD=`pwd` Check if we are starting this relative (for the binary
  release) if test -d /data/mysql -a -f ./share/mysql/english/errmsg.sys
  -a -x ./bin/mysqld
  ----------------------------------------------------------------------
  ```

  See Section 4.8.2 [`mysqld_safe`], page 312. The above test should be successful, or you may encounter problems.
- Beware of the dangers starting multiple `mysqld`s in the same data directory. Use separate data directories, unless you **know** what you are doing!
- The socket file and the TCP/IP port must be different for every `mysqld`.
- The first and fifth `mysqld` group were intentionally left out from the example. You may have 'gaps' in the config file. This gives you more flexibility. The order in which the `mysqlds` are started or stopped depends on the order in which they appear in the config file.
- When you want to refer to a certain group using GNR with this program, just use the number in the end of the group name. For example, the GNR for a group named `[mysqld17]` is 17.
- You may want to use option `--user` for `mysqld`, but in order to do this you need to run the `mysqld_multi` script as the Unix `root` user. Having the option in the config

file doesn't matter; you will just get a warning, if you are not the superuser and the `mysqlds` are started under **your** Unix account. **Important**: Make sure that the `pid-file` and the data directory are read+write(+execute for the latter one) accessible for **that** Unix user, who the specific `mysqld` process is started as. **Do not** use the Unix root account for this, unless you **know** what you are doing!

- **Most important**: Make sure that you understand the meanings of the options that are passed to the `mysqld`s and **why one would want** to have separate `mysqld` processes. Starting multiple `mysqld`s in one data directory **will not** give you extra performance in a threaded system!

See Section 4.2 [Multiple servers], page 206.

This is an example of the config file on behalf of `mysqld_multi`.

```
# This file should probably be in your home dir (~/.my.cnf) or /etc/my.cnf
# Version 2.1 by Jani Tolonen

[mysqld_multi]
mysqld     = /usr/local/bin/mysqld_safe
mysqladmin = /usr/local/bin/mysqladmin
user       = multi_admin
password   = multipass

[mysqld2]
socket     = /tmp/mysql.sock2
port       = 3307
pid-file   = /usr/local/mysql/var2/hostname.pid2
datadir    = /usr/local/mysql/var2
language   = /usr/local/share/mysql/english
user       = john

[mysqld3]
socket     = /tmp/mysql.sock3
port       = 3308
pid-file   = /usr/local/mysql/var3/hostname.pid3
datadir    = /usr/local/mysql/var3
language   = /usr/local/share/mysql/swedish
user       = monty

[mysqld4]
socket     = /tmp/mysql.sock4
port       = 3309
pid-file   = /usr/local/mysql/var4/hostname.pid4
datadir    = /usr/local/mysql/var4
language   = /usr/local/share/mysql/estonia
user       = tonu

[mysqld6]
socket     = /tmp/mysql.sock6
```

```
port       = 3311
pid-file   = /usr/local/mysql/var6/hostname.pid6
datadir    = /usr/local/mysql/var6
language   = /usr/local/share/mysql/japanese
user       = jani
```

See Section 4.1.2 [Option files], page 203.

4.8.4 myisampack, The MySQL Compressed Read-only Table Generator

`myisampack` is used to compress MyISAM tables, and `pack_isam` is used to compress ISAM tables. Because ISAM tables are deprecated, we will only discuss `myisampack` here, but everything said about `myisampack` should also be true for `pack_isam`.

`myisampack` works by compressing each column in the table separately. The information needed to decompress columns is read into memory when the table is opened. This results in much better performance when accessing individual records, because you only have to uncompress exactly one record, not a much larger disk block as when using Stacker on MS-DOS. Usually, `myisampack` packs the datafile 40%-70%.

MySQL uses memory mapping (`mmap()`) on compressed tables and falls back to normal read/write file usage if `mmap()` doesn't work.

Please note the following:

- After packing, the table is read-only. This is generally intended (such as when accessing packed tables on a CD). Also allowing writes to a packed table is on our TODO list but with low priority.
- `myisampack` can also pack `BLOB` or `TEXT` columns. The older `pack_isam` (for `ISAM` tables) can not do this.

`myisampack` is invoked like this:

```
shell> myisampack [options] filename ...
```

Each filename should be the name of an index ('`.MYI`') file. If you are not in the database directory, you should specify the pathname to the file. It is permissible to omit the '`.MYI`' extension.

`myisampack` supports the following options:

`-b, --backup`
: Make a backup of the table as `tbl_name.OLD`.

`-#, --debug=debug_options`
: Output debug log. The `debug_options` string often is `'d:t:o,filename'`.

`-f, --force`
: Force packing of the table even if it becomes bigger or if the temporary file exists. `myisampack` creates a temporary file named '`tbl_name.TMD`' while it compresses the table. If you kill `myisampack`, the '`.TMD`' file may not be deleted. Normally, `myisampack` exits with an error if it finds that '`tbl_name.TMD`' exists. With `--force`, `myisampack` packs the table anyway.

`-?, --help`
: Display a help message and exit.

`-j big_tbl_name, --join=big_tbl_name`
: Join all tables named on the command-line into a single table `big_tbl_name`. All tables that are to be combined **must** be identical (same column names and types, same indexes, etc.).

`-p #, --packlength=#`
: Specify the record length storage size, in bytes. The value should be 1, 2, or 3. (`myisampack` stores all rows with length pointers of 1, 2, or 3 bytes. In most normal cases, `myisampack` can determine the right length value before it begins packing the file, but it may notice during the packing process that it could have used a shorter length. In this case, `myisampack` will print a note that the next time you pack the same file, you could use a shorter record length.)

`-s, --silent`
: Silent mode. Write output only when errors occur.

`-t, --test`
: Don't actually pack table, just test packing it.

`-T dir_name, --tmp_dir=dir_name`
: Use the named directory as the location in which to write the temporary table.

`-v, --verbose`
: Verbose mode. Write information about progress and packing result.

`-V, --version`
: Display version information and exit.

`-w, --wait`
: Wait and retry if table is in use. If the `mysqld` server was invoked with the `--skip-external-locking` option, it is not a good idea to invoke `myisampack` if the table might be updated during the packing process.

The sequence of commands shown here illustrates a typical table compression session:

```
shell> ls -l station.*
-rw-rw-r--   1 monty    my         994128 Apr 17 19:00 station.MYD
-rw-rw-r--   1 monty    my          53248 Apr 17 19:00 station.MYI
-rw-rw-r--   1 monty    my           5767 Apr 17 19:00 station.frm

shell> myisamchk -dvv station

MyISAM file:     station
Isam-version:  2
Creation time: 1996-03-13 10:08:58
Recover time:  1997-02-02  3:06:43
Data records:              1192  Deleted blocks:              0
Datafile: Parts:           1192  Deleted data:                0
Datafile pointer (bytes):     2  Keyfile pointer (bytes):     2
Max datafile length:   54657023  Max keyfile length:   33554431
```

```
Recordlength:               834
Record format: Fixed length

table description:
Key Start Len Index   Type                          Root  Blocksize    Rec/key
1   2     4   unique  unsigned long                 1024       1024          1
2   32    30  multip. text                         10240       1024          1

Field Start Length Type
1     1     1
2     2     4
3     6     4
4     10    1
5     11    20
6     31    1
7     32    30
8     62    35
9     97    35
10    132   35
11    167   4
12    171   16
13    187   35
14    222   4
15    226   16
16    242   20
17    262   20
18    282   20
19    302   30
20    332   4
21    336   4
22    340   1
23    341   8
24    349   8
25    357   8
26    365   2
27    367   2
28    369   4
29    373   4
30    377   1
31    378   2
32    380   8
33    388   4
34    392   4
35    396   4
36    400   4
37    404   1
38    405   4
```

```
39    409   4
40    413   4
41    417   4
42    421   4
43    425   4
44    429   20
45    449   30
46    479   1
47    480   1
48    481   79
49    560   79
50    639   79
51    718   79
52    797   8
53    805   1
54    806   1
55    807   20
56    827   4
57    831   4

shell> myisampack station.MYI
Compressing station.MYI: (1192 records)
- Calculating statistics

normal:     20  empty-space:      16  empty-zero:        12  empty-fill:  11
pre-space:   0  end-space:        12  table-lookups:      5  zero:         7
Original trees:  57  After join: 17
- Compressing file
87.14%

shell> ls -l station.*
-rw-rw-r--   1 monty    my         127874 Apr 17 19:00 station.MYD
-rw-rw-r--   1 monty    my          55296 Apr 17 19:04 station.MYI
-rw-rw-r--   1 monty    my           5767 Apr 17 19:00 station.frm

shell> myisamchk -dvv station

MyISAM file:     station
Isam-version:  2
Creation time: 1996-03-13 10:08:58
Recover time:  1997-04-17 19:04:26
Data records:              1192  Deleted blocks:              0
Datafile: Parts:           1192  Deleted data:                0
Datafilepointer (bytes):      3  Keyfile pointer (bytes):     1
Max datafile length:   16777215  Max keyfile length:     131071
Recordlength:               834
Record format: Compressed
```

```
table description:
Key Start Len Index   Type                          Root  Blocksize    Rec/key
1   2     4   unique  unsigned long                10240       1024          1
2   32    30  multip. text                         54272       1024          1

Field Start Length Type                              Huff tree  Bits
1     1     1      constant                                  1     0
2     2     4      zerofill(1)                               2     9
3     6     4      no zeros, zerofill(1)                     2     9
4     10    1                                                3     9
5     11    20     table-lookup                              4     0
6     31    1                                                3     9
7     32    30     no endspace, not_always                   5     9
8     62    35     no endspace, not_always, no empty         6     9
9     97    35     no empty                                  7     9
10    132   35     no endspace, not_always, no empty         6     9
11    167   4      zerofill(1)                               2     9
12    171   16     no endspace, not_always, no empty         5     9
13    187   35     no endspace, not_always, no empty         6     9
14    222   4      zerofill(1)                               2     9
15    226   16     no endspace, not_always, no empty         5     9
16    242   20     no endspace, not_always                   8     9
17    262   20     no endspace, no empty                     8     9
18    282   20     no endspace, no empty                     5     9
19    302   30     no endspace, no empty                     6     9
20    332   4      always zero                               2     9
21    336   4      always zero                               2     9
22    340   1                                                3     9
23    341   8      table-lookup                              9     0
24    349   8      table-lookup                             10     0
25    357   8      always zero                               2     9
26    365   2                                                2     9
27    367   2      no zeros, zerofill(1)                     2     9
28    369   4      no zeros, zerofill(1)                     2     9
29    373   4      table-lookup                             11     0
30    377   1                                                3     9
31    378   2      no zeros, zerofill(1)                     2     9
32    380   8      no zeros                                  2     9
33    388   4      always zero                               2     9
34    392   4      table-lookup                             12     0
35    396   4      no zeros, zerofill(1)                    13     9
36    400   4      no zeros, zerofill(1)                     2     9
37    404   1                                                2     9
38    405   4      no zeros                                  2     9
39    409   4      always zero                               2     9
40    413   4      no zeros                                  2     9
```

```
41    417   4      always zero                    2     9
42    421   4      no zeros                       2     9
43    425   4      always zero                    2     9
44    429   20     no empty                       3     9
45    449   30     no empty                       3     9
46    479   1                                    14     4
47    480   1                                    14     4
48    481   79     no endspace, no empty          15     9
49    560   79     no empty                       2     9
50    639   79     no empty                       2     9
51    718   79     no endspace                    16     9
52    797   8      no empty                       2     9
53    805   1                                    17     1
54    806   1                                    3     9
55    807   20     no empty                       3     9
56    827   4      no zeros, zerofill(2)          2     9
57    831   4      no zeros, zerofill(1)          2     9
```

The information printed by `myisampack` is described here:

`normal` The number of columns for which no extra packing is used.

`empty-space`
: The number of columns containing values that are only spaces; these will occupy 1 bit.

`empty-zero`
: The number of columns containing values that are only binary 0's; these will occupy 1 bit.

`empty-fill`
: The number of integer columns that don't occupy the full byte range of their type; these are changed to a smaller type (for example, an `INTEGER` column may be changed to `MEDIUMINT`).

`pre-space`
: The number of decimal columns that are stored with leading spaces. In this case, each value will contain a count for the number of leading spaces.

`end-space`
: The number of columns that have a lot of trailing spaces. In this case, each value will contain a count for the number of trailing spaces.

`table-lookup`
: The column had only a small number of different values, which were converted to an `ENUM` before Huffman compression.

`zero` The number of columns for which all values are zero.

`Original trees`
: The initial number of Huffman trees.

`After join`
: The number of distinct Huffman trees left after joining trees to save some header space.

After a table has been compressed, `myisamchk -dvv` prints additional information about each field:

`Type` The field type may contain the following descriptors:

`constant` All rows have the same value.

`no endspace`
: Don't store endspace.

`no endspace, not_always`
: Don't store endspace and don't do end space compression for all values.

`no endspace, no empty`
: Don't store endspace. Don't store empty values.

`table-lookup`
: The column was converted to an `ENUM`.

`zerofill(n)`
: The most significant `n` bytes in the value are always 0 and are not stored.

`no zeros` Don't store zeros.

`always zero`
: 0 values are stored in 1 bit.

`Huff tree` The Huffman tree associated with the field.

`Bits` The number of bits used in the Huffman tree.

After you have run `pack_isam`/`myisampack` you must run `isamchk`/`myisamchk` to re-create the index. At this time you can also sort the index blocks and create statistics needed for the MySQL optimiser to work more efficiently:

```
myisamchk -rq --analyze --sort-index table_name.MYI
isamchk   -rq --analyze --sort-index table_name.ISM
```

After you have installed the packed table into the MySQL database directory you should do `mysqladmin flush-tables` to force `mysqld` to start using the new table.

If you want to unpack a packed table, you can do this with the `--unpack` option to `isamchk` or `myisamchk`.

4.8.5 `mysqld-max`, An Extended `mysqld` Server

`mysqld-max` is the MySQL server (`mysqld`) configured with the following configure options:

Option	Comment
–with-server-suffix=-max	Add a suffix to the `mysqld` version string
–with-innodb	Support for InnoDB tables (MySQL 3.23 only)

–with-bdb	Support for Berkeley DB (BDB) tables
CFLAGS=-DUSE_SYMDIR	Symbolic link support for Windows

The option for enabling InnoDB support is needed only in MySQL 3.23. In MySQL 4 and up, InnoDB is included by default.

You can find the MySQL-Max binaries at `http://www.mysql.com/downloads/mysql-max-4.0.html`.

The Windows MySQL binary distributions includes both the standard `mysqld.exe` binary and the `mysqld-max.exe` binary. `http://www.mysql.com/downloads/mysql-4.0.html`. See Section 2.1.1 [Windows installation], page 56.

Note that as BerkeleyDB (BDB) is not available for all platforms, so some of the `Max` binaries may not have support for it. You can check which table types are supported by doing the following query:

```
mysql> SHOW VARIABLES LIKE "have_%";
+------------------+----------+
| Variable_name    | Value    |
+------------------+----------+
| have_bdb         | NO       |
| have_crypt       | YES      |
| have_innodb      | YES      |
| have_isam        | YES      |
| have_raid        | NO       |
| have_symlink     | DISABLED |
| have_openssl     | NO       |
| have_query_cache | YES      |
+------------------+----------+
```

The meanings of the values in the second column are:

Value	**Meaning**
`YES`	The option is activated and usable.
`NO`	MySQL is not compiled with support for this option.
`DISABLED`	The xxxx option is disabled because one started `mysqld` with `--skip-xxxx` or because one didn't start `mysqld` with all needed options to enable the option. In this case the `hostname.err` file should contain a reason indicating why the option is disabled.

Note: To be able to create InnoDB tables in MySQL version 3.23 you **must** edit your startup options to include at least the `innodb_data_file_path` option. See Section 7.5.2 [InnoDB in MySQL 3.23], page 606.

To get better performance for BDB tables, you should add some configuration options for these, too. See Section 7.6.3 [BDB start], page 655.

`mysqld_safe` automatically tries to start any `mysqld` binary with the `-max` suffix. This makes it very easy to test out another `mysqld` binary in an existing installation. Just run `configure` with the options you want and then install the new `mysqld` binary as `mysqld-max` in the same directory where your old `mysqld` binary is. See Section 4.8.2 [`mysqld_safe`], page 312.

On Linux, the `MySQL-Max` RPM uses the above mentioned `mysqld_safe` feature. (It just installs the `mysqld-max` executable, so `mysqld_safe` automatically uses this executable when `mysqld_safe` is restarted.)

The following table shows which table types our MySQL-Max binaries include:

System	BDB	InnoDB
Windows/NT	Y	Y
AIX 4.3	N	Y
HP-UX 11.0	N	Y
Linux-Alpha	N	Y
Linux-Intel	Y	Y
Linux-IA-64	N	Y
Solaris-Intel	N	Y
Solaris-SPARC	Y	Y
SCO OSR5	Y	Y
UnixWare	Y	Y
Mac OS X	N	Y

Note that as of MySQL 4, you do not need a MySQL Max server for InnoDB, because InnoDB is included by default.

4.9 MySQL Client-Side Scripts and Utilities

4.9.1 Overview of the Client-Side Scripts and Utilities

All MySQL clients that communicate with the server using the `mysqlclient` library use the following environment variables:

Name	Description
`MYSQL_UNIX_PORT`	The default socket; used for connections to `localhost`
`MYSQL_TCP_PORT`	The default TCP/IP port
`MYSQL_PWD`	The default password
`MYSQL_DEBUG`	Debug-trace options when debugging
`TMPDIR`	The directory where temporary tables/files are created

Use of `MYSQL_PWD` is insecure. See Section 4.3.8 [Connecting], page 224.

On Unix, the '`mysql`' client uses the file named in the `MYSQL_HISTFILE` environment variable to save the command-line history. The default value for the history file is '`$HOME/.mysql_history`', where `$HOME` is the value of the `HOME` environment variable. See Appendix F [Environment variables], page 1019.

If you do not want to maintain a file that contains a record of your queries, first remove '`.mysql_history`' if it exists, then use either of the following techniques:

- Set the `MYSQL_HISTFILE` variable to '`/dev/null`'. To cause this setting to take effect each time you log in, put the setting in one of your shell's startup files.
- Create '`.mysql_histfile`' as a symbolic link to '`/dev/null`':

```
shell> ln -s /dev/null $HOME/.mysql_history
```

You need do this only once.

All MySQL programs take many different options. However, every MySQL program provides a `--help` option that you can use to get a full description of the program's different options. For example, try `mysql --help`.

You can override default options for all standard client programs with an option file. Section 4.1.2 [Option files], page 203.

The following list briefly describes the client-side MySQL programs:

`msql2mysql`
: A shell script that converts `mSQL` programs to MySQL. It doesn't handle all cases, but it gives a good start when converting.

`mysql`
: The command-line tool for interactively entering queries or executing queries from a file in batch mode. See Section 4.9.2 [`mysql`], page 327.

`mysqlaccess`
: A script that checks the access privileges for a host, user, and database combination.

`mysqladmin`
: Utility for performing administrative operations, such as creating or dropping databases, reloading the grant tables, flushing tables to disk, and reopening log files. `mysqladmin` can also be used to retrieve version, process, and status information from the server. See Section 4.9.3 [`mysqladmin`], page 334.

`mysqlbinlog`
: Utility for reading queries from a binary log. Can be used to recover from a crash with an old backup. See Section 4.9.4 [`mysqlbinlog`], page 336.

`mysqldump`
: Dumps a MySQL database into a file as SQL statements or as tab-separated text files. Enhanced freeware originally by Igor Romanenko. See Section 4.9.6 [`mysqldump`], page 339.

`mysqlimport`
: Imports text files into their respective tables using `LOAD DATA INFILE`. See Section 4.9.8 [`mysqlimport`], page 345.

`mysqlshow`
: Displays information about databases, tables, columns, and indexes.

`replace`
: A utility program that is used by `msql2mysql`, but that has more general applicability as well. `replace` changes strings in place in files or on the standard input. Uses a finite state machine to match longer strings first. Can be used to swap strings. For example, this command swaps `a` and `b` in the given files:

```
shell> replace a b b a -- file1 file2 ...
```

4.9.2 `mysql`, The Command-line Tool

`mysql` is a simple SQL shell (with GNU `readline` capabilities). It supports interactive and non-interactive use. When used interactively, query results are presented in an ASCII-table format. When used non-interactively (for example, as a filter), the result is presented in tab-separated format. (The output format can be changed using command-line options.) You can run scripts simply like this:

```
shell> mysql database < script.sql > output.tab
```

If you have problems due to insufficient memory in the client, use the `--quick` option! This forces `mysql` to use `mysql_use_result()` rather than `mysql_store_result()` to retrieve the result set.

Using `mysql` is very easy. Just start it as follows: `mysql database` or `mysql --user=user_name --password=your_password database`. Type an SQL statement, end it with '`;`', '`\g`', or '`\G`' and press Enter.

`mysql` supports the following options:

`-?, --help`
: Display this help and exit.

`-A, --no-auto-rehash`
: No automatic rehashing. One has to use 'rehash' to get table and field completion. This gives a quicker start of mysql.

`--prompt=...`
: Set the mysql prompt to specified format.

`-b, --no-beep`
: Turn off beep-on-error.

`-B, --batch`
: Print results with a tab as separator, each row on a new line. Doesn't use history file.

`--character-sets-dir=...`
: Directory where character sets are located.

`-C, --compress`
: Use compression in server/client protocol.

`-#, --debug[=...]`
: Debug log. Default is 'd:t:o,/tmp/mysql.trace'.

`-D, --database=...`
: Database to use. This is mainly useful in the '`my.cnf`' file.

`--default-character-set=...`
: Set the default character set.

`-e, --execute=...`
: Execute command and quit. (Output like with –batch)

`-E, --vertical`
: Print the output of a query (rows) vertically. Without this option you can also force this output by ending your statements with `\G`.

`-f, --force`
: Continue even if we get an SQL error.

`-g, --no-named-commands`
: Named commands are disabled. Use * form only, or use named commands only in the beginning of a line ending with a semicolon (';'). Since Version 10.9, the client now starts with this option **enabled** by default! With the -g option, long format commands will still work from the first line, however.

`-G, --enable-named-commands`
: Named commands are **enabled**. Long format commands are allowed as well as shortened * commands.

`-i, --ignore-space`
: Ignore space after function names.

`-h, --host=...`
: Connect to the given host.

`-H, --html`
: Produce HTML output.

`-X, --xml` Produce XML output.

`-L, --skip-line-numbers`
: Don't write line number for errors. Useful when one wants to compare result files that includes error messages

`--no-pager`
: Disable pager and print to stdout. See interactive help (\h) also.

`--no-tee` Disable outfile. See interactive help (\h) also.

`-n, --unbuffered`
: Flush buffer after each query.

`-N, --skip-column-names`
: Don't write column names in results.

`-O, --set-variable var=option`
: Give a variable a value. `--help` lists variables. Please note that `--set-variable` is deprecated since MySQL 4.0, just use `--var=option` on its own.

`-o, --one-database`
: Only update the default database. This is useful for skipping updates to other database in the binary log.

`--pager[=...]`
: Output type. Default is your `ENV` variable `PAGER`. Valid pagers are less, more, cat [> filename], etc. See interactive help (\h) also. This option does not work in batch mode. Pager works only in Unix.

`-p[password], --password[=...]`
: Password to use when connecting to server. If a password is not given on the command-line, you will be prompted for it. Note that if you use the short form `-p` you can't have a space between the option and the password.

`-P port_num, --port=port_num`
: TCP/IP port number to use for connection.

`--protocol=(TCP | SOCKET | PIPE | MEMORY)`
: To specify the connect protocol to use. New in MySQL 4.1.

`-q, --quick`
: Don't cache result, print it row-by-row. This may slow down the server if the output is suspended. Doesn't use history file.

`-r, --raw` Write column values without escape conversion. Used with `--batch`

`--reconnect`
: If the connection is lost, automatically try to reconnect to the server (but only once).

`-s, --silent`
: Be more silent.

`-S --socket=...`
: Socket file to use for connection.

`-t --table`
: Output in table format. This is default in non-batch mode.

`-T, --debug-info`
: Print some debug information at exit.

`--tee=...`
: Append everything into outfile. See interactive help (\h) also. Does not work in batch mode.

`-u, --user=#`
: User for login if not current user.

`-U, --safe-updates[=#], --i-am-a-dummy[=#]`
: Only allow `UPDATE` and `DELETE` that uses keys. See below for more information about this option. You can reset this option if you have it in your '`my.cnf`' file by using `--safe-updates=0`.

`-v, --verbose`
: More verbose output (-v -v -v gives the table output format).

`-V, --version`
: Output version information and exit.

`-w, --wait`
: Wait and retry if connection is down instead of aborting.

You can also set the following variables with `-O` or `--set-variable`; please note that `--set-variable` is deprecated since MySQL 4.0, just use `--var=option` on its own:

Variable Name	Default	Description
connect_timeout	0	Number of seconds before timeout connection.
max_allowed_packet	16777216	Max packetlength to send/receive from to server
net_buffer_length	16384	Buffer for TCP/IP and socket communication
select_limit	1000	Automatic limit for SELECT when using –i-am-a-dummy
max_join_size	1000000	Automatic limit for rows in a join when using –i-am-a-dummy.

If the `mysql` client loses connection to the server while sending it a query, it will immediately and automatically try to reconnect once to the server and send the query again. Note that even if it succeeds in reconnecting, as your first connection has ended, all your previous session objects are lost: temporary tables, user and session variables. Therefore, the above behaviour may be dangerous for you, as in this example where the server was shut down and restarted without you knowing it:

```
mysql> set @a=1;
Query OK, 0 rows affected (0.05 sec)

mysql> insert into t values(@a);
ERROR 2006: MySQL server has gone away
No connection. Trying to reconnect...
Connection id:    1
Current database: test

Query OK, 1 row affected (1.30 sec)

mysql> select * from t;
+------+
| a    |
+------+
| NULL |
+------+
1 row in set (0.05 sec)
```

The `@a` user variable has been lost with the connection, and after the reconnection it is undefined. To protect from this risk, you can start the `mysql` client with the `--disable-reconnect` option.

If you type 'help' on the command-line, `mysql` will print out the commands that it supports:

```
mysql> help

MySQL commands:
help      (\h)    Display this text.
?         (\h)    Synonym for ‘help’.
clear     (\c)    Clear command.
connect   (\r)    Reconnect to the server.
                  Optional arguments are db and host.
delimiter (\d)    Set query delimiter.
edit      (\e)    Edit command with $EDITOR.
```

```
ego       (\G)    Send command to mysql server,
                  display result vertically.
exit      (\q)    Exit mysql. Same as quit.
go        (\g)    Send command to mysql server.
nopager   (\n)    Disable pager, print to stdout.
notee     (\t)    Don't write into outfile.
pager     (\P)    Set PAGER [to_pager].
                  Print the query results via PAGER.
print     (\p)    Print current command.
prompt    (\R)    Change your mysql prompt.
quit      (\q)    Quit mysql.
rehash    (\#)    Rebuild completion hash.
source    (\.)    Execute an SQL script file.
                  Takes a file name as an argument.
status    (\s)    Get status information from the server.
system    (\!)    Execute a system shell command.
tee       (\T)    Set outfile [to_outfile].
                  Append everything into given outfile.
use       (\u)    Use another database.
                  Takes database name as argument.
```

The `edit`, `nopager`, `pager`, and `system` commands work only in Unix.

The `status` command gives you some information about the connection and the server you are using. If you are running in the `--safe-updates` mode, `status` will also print the values for the `mysql` variables that affect your queries.

A useful startup option for beginners (introduced in MySQL Version 3.23.11) is `--safe-updates` (or `--i-am-a-dummy` for users that once may have done a `DELETE FROM table_name` but forgot the `WHERE` clause). When using this option, `mysql` sends the following command to the MySQL server when opening the connection:

```
SET SQL_SAFE_UPDATES=1,SQL_SELECT_LIMIT=#select_limit#,
    SQL_MAX_JOIN_SIZE=#max_join_size#"
```

where `#select_limit#` and `#max_join_size#` are variables that can be set from the `mysql` command-line. See Section 5.5.6 [SET OPTION], page 432.

The effect of the above is:

- You are not allowed to do an `UPDATE` or `DELETE` statement if you don't have a key constraint in the `WHERE` part. One can, however, force an `UPDATE/DELETE` by using `LIMIT`:

  ```
  UPDATE table_name SET not_key_column=# WHERE not_key_column=# LIMIT 1;
  ```

- All big results are automatically limited to `#select_limit#` rows.
- `SELECT`s that will probably need to examine more than `#max_join_size` row combinations will be aborted.

Some useful hints about the `mysql` client:

Some data is much more readable when displayed vertically, instead of the usual horizontal box type output. For example longer text, which includes new lines, is often much easier to be read with vertical output.

```
mysql> SELECT * FROM mails WHERE LENGTH(txt) < 300 lIMIT 300,1\G
*************************** 1. row ***************************
  msg_nro: 3068
     date: 2000-03-01 23:29:50
time_zone: +0200
mail_from: Monty
    reply: monty@no.spam.com
  mail_to: "Thimble Smith" <tim@no.spam.com>
      sbj: UTF-8
      txt: >>>>> "Thimble" == Thimble Smith writes:

Thimble> Hi.  I think this is a good idea.  Is anyone familiar with UTF-8
Thimble> or Unicode? Otherwise, I'll put this on my TODO list and see what
Thimble> happens.

Yes, please do that.

Regards,
Monty
     file: inbox-jani-1
     hash: 190402944
1 row in set (0.09 sec)
```

For logging, you can use the `tee` option. The `tee` can be started with option `--tee=...`, or from the command-line interactively with command `tee`. All the data displayed on the screen will also be appended into a given file. This can be very useful for debugging purposes also. The `tee` can be disabled from the command-line with command `notee`. Executing `tee` again starts logging again. Without a parameter the previous file will be used. Note that `tee` will flush the results into the file after each command, just before the command-line appears again waiting for the next command.

Browsing, or searching the results in the interactive mode in Unix less, more, or any other similar program, is now possible with option `--pager[=...]`. Without argument, `mysql` client will look for the `PAGER` environment variable and set `pager` to that. `pager` can be started from the interactive command-line with command `pager` and disabled with command `nopager`. The command takes an argument optionally and the `pager` will be set to that. Command `pager` can be called without an argument, but this requires that the option `--pager` was used, or the `pager` will default to stdout. `pager` works only in Unix, since it uses the `popen()` function, which doesn't exist in Windows. In Windows, the `tee` option can be used instead, although it may not be as handy as `pager` can be in some situations.

A few tips about `pager`:

- You can use it to write to a file:

  ```
  mysql> pager cat > /tmp/log.txt
  ```

  and the results will only go to a file. You can also pass any options for the programs that you want to use with the `pager`:

  ```
  mysql> pager less -n -i -S
  ```

- From the above do note the option `-S`. You may find it very useful when browsing the results; try the option with horizontal output (end commands with `\g`, or '`;`') and with vertical output (end commands with `\G`). Sometimes a very wide result set is hard to be read from the screen, with option `-S` to `less` you can browse the results within the interactive `less` from left to right, preventing lines longer than your screen from being continued to the next line. This can make the result set much more readable. You can switch the mode between on and off within the interactive `less` with `-S`. See the 'h' for more help about `less`.
- You can combine very complex ways to handle the results, for example the following would send the results to two files in two different directories, on two different hard-disks mounted on /dr1 and /dr2, yet let the results still be seen on the screen via less:

```
mysql> pager cat | tee /dr1/tmp/res.txt | \
tee /dr2/tmp/res2.txt | less -n -i -S
```

You can also combine the two functions above; have the `tee` enabled, `pager` set to 'less' and you will be able to browse the results in Unix 'less' and still have everything appended into a file the same time. The difference between Unix `tee` used with the `pager` and the `mysql` client in-built `tee`, is that the in-built `tee` works even if you don't have the Unix `tee` available. The in-built `tee` also logs everything that is printed on the screen, where the Unix `tee` used with `pager` doesn't log quite that much. Last, but not least, the interactive `tee` is more handy to switch on and off, when you want to log something into a file, but want to be able to turn the feature off sometimes.

From MySQL version 4.0.2 it is possible to change the prompt in the `mysql` command-line client.

You can use the following prompt options:

Option	**Description**
\v	mysqld version
\d	database in use
\h	host connected to
\p	port connected on
\u	username
\U	full username@host
\\	'\'
\n	new line break
\t	tab
\	space
_	space
\R	military hour time (0-23)
\r	standard hour time (1-12)
\m	minutes
\y	two digit year
\Y	four digit year
\D	full date format
\s	seconds
\w	day of the week in three letter format (Mon, Tue, ...)

\P	am/pm
\o	month in number format
\O	month in three letter format (Jan, Feb, ...)
\c	counter that counts up for each command you do

'\' followed by any other letter just becomes that letter.

You may set the prompt in the following places:

Environment Variable

You may set the `MYSQL_PS1` environment variable to a prompt string. For example:

```
shell> export MYSQL_PS1="(\u@\h) [\d]> "
```

'my.cnf'

'.my.cnf' You may set the `prompt` option in any MySQL configuration file, in the `mysql` group. For example:

```
[mysql]
prompt=(\u@\h) [\d]>\_
```

Command Line

You may set the `--prompt` option on the command line to `mysql`. For example:

```
shell> mysql --prompt="(\u@\h) [\d]> "

(user@host) [database]>
```

Interactively

You may also use the `prompt` (or `\R`) command to change your prompt interactively. For example:

```
mysql> prompt (\u@\h) [\d]>\_
PROMPT set to '(\u@\h) [\d]>\_'
(user@host) [database]>
(user@host) [database]> prompt
Returning to default PROMPT of mysql>
mysql>
```

4.9.3 `mysqladmin`, Administrating a MySQL Server

A utility for performing administrative operations. The syntax is:

```
shell> mysqladmin [OPTIONS] command [command-option] command ...
```

You can get a list of the options your version of `mysqladmin` supports by executing `mysqladmin --help`.

The current `mysqladmin` supports the following commands:

`create databasename`

Create a new database.

`drop databasename`

Delete a database and all its tables.

`extended-status`
: Gives an extended status message from the server.

`flush-hosts`
: Flush all cached hosts.

`flush-logs`
: Flush all logs.

`flush-tables`
: Flush all tables.

`flush-privileges`
: Reload grant tables (same as reload).

`kill id,id,...`
: Kill mysql threads.

`password` Set a new password. Change old password to new-password.

`ping` Check if mysqld is alive.

`processlist`
: Show list of active threads in server, as with the `SHOW PROCESSLIST` statement. If the `--verbose` option is given, the output is like that of `SHOW FULL PROCESSLIST`.

`reload` Reload grant tables.

`refresh` Flush all tables and close and open logfiles.

`shutdown` Take down the server.

`slave-start`
: Start slave replication thread.

`slave-stop`
: Stop slave replication thread.

`status` Gives a short status message from the server.

`variables`
: Prints variables available.

`version` Get version information from server.

All commands can be shortened to their unique prefix. For example:

```
shell> mysqladmin proc stat
+----+-------+-----------+----+-------------+------+-------+------+
| Id | User  | Host      | db | Command     | Time | State | Info |
+----+-------+-----------+----+-------------+------+-------+------+
| 6  | monty | localhost |    | Processlist | 0    |       |      |
+----+-------+-----------+----+-------------+------+-------+------+
Uptime: 10077  Threads: 1  Questions: 9  Slow queries: 0
Opens: 6 Flush tables: 1  Open tables: 2
Memory in use: 1092K  Max memory used: 1116K
```

The `mysqladmin status` command result has the following columns:

Column	Description
Uptime	Number of seconds the MySQL server has been up.
Threads	Number of active threads (clients).
Questions	Number of questions from clients since `mysqld` was started.
Slow queries	Queries that have taken more than `long_query_time` seconds. See Section 4.10.5 [Slow query log], page 354.
Opens	How many tables `mysqld` has opened.
Flush tables	Number of `flush ...`, `refresh`, and `reload` commands.
Open tables	Number of tables that are open now.
Memory in use	Memory allocated directly by the `mysqld` code (only available when MySQL is compiled with –with-debug=full).
Max memory used	Maximum memory allocated directly by the `mysqld` code (only available when MySQL is compiled with –with-debug=full).

If you do `mysqladmin shutdown` on a socket (in other words, on a the computer where `mysqld` is running), `mysqladmin` will wait until the MySQL `pid-file` is removed to ensure that the `mysqld` server has stopped properly.

4.9.4 `mysqlbinlog`, Executing the queries from a binary log

You can examine the binary log file (see Section 4.10.4 [Binary log], page 351) with the `mysqlbinlog` utility.

```
shell> mysqlbinlog hostname-bin.001
```

will print all queries contained in binlog '`hostname-bin.001`', together with information (time the query took, ID of the thread which issued it, timestamp when it was issued etc).

You can pipe the output of `mysqlbinlog` into a `mysql` client; this is used to recover from a crash when you have an old backup (see Section 4.5.1 [Backup], page 259):

```
shell> mysqlbinlog hostname-bin.001 | mysql
```

or

```
shell> mysqlbinlog hostname-bin.[0-9]* | mysql
```

You can also redirect the output of `mysqlbinlog` to a text file instead, modify this text file (to cut queries you don't want to execute for some reason), then execute the queries from the text file into `mysql`.

`mysqlbinlog` has the `position=#` options which will print only queries whose offset in the binlog is greater or equal to `#`.

If you have more than one binary log to execute on the MySQL server, the safe method is to do it in one unique MySQL connection. Here is what may be UNsafe:

```
shell> mysqlbinlog hostname-bin.001 | mysql # DANGER!!
shell> mysqlbinlog hostname-bin.002 | mysql # DANGER!!
```

It will cause problems if the first binlog contains a `CREATE TEMPORARY TABLE` and the second one contains a query which uses this temporary table: when the first `mysql` terminates, it

will drop the temporary table, so the second `mysql` will report "unknown table". This is why you should run all binlogs you want in one unique connection, especially if you use temporary tables. Here are two possible ways:

```
shell> mysqlbinlog hostname-bin.001 hostname-bin.002 | mysql
```

```
shell> mysqlbinlog hostname-bin.001 >  /tmp/queries.sql
shell> mysqlbinlog hostname-bin.002 >> /tmp/queries.sql
shell> mysql -e "source /tmp/queries.sql"
```

Starting from MySQL 4.0.14, `mysqlbinlog` can prepare suitable input for `mysql` to execute a `LOAD DATA INFILE` from a binlog. As the binlog contains the data to load (this is true for MySQL 4.0; MySQL 3.23 did not write the loaded data into the binlog, so the original file was needed when one wanted to execute the content of the binlog), `mysqlbinlog` will copy this data to a temporary file and print a `LOAD DATA INFILE` command for `mysql` to load this temporary file. The location where the temporary file is created is by default the temporary directory; it can be changed with the `local-load` option of `mysqlbinlog`.

Before MySQL 4.1, `mysqlbinlog` could not prepare suitable output for `mysql` when the binary log contained queries from different threads using temporary tables of the same name, if these queries were interlaced. This is solved in MySQL 4.1.

You can also use `mysqlbinlog --read-from-remote-server` to read the binary log directly from a remote MySQL server. However, this is something that is deprecated as we instead want to make it easy to to apply binary logs to a running MySQL server.

`mysqlbinlog --help` will give you more information.

4.9.5 Using `mysqlcheck` for Table Maintenance and Crash Recovery

Since MySQL version 3.23.38 you will be able to use a new checking and repairing tool for `MyISAM` tables. The difference to `myisamchk` is that `mysqlcheck` should be used when the `mysqld` server is running, whereas `myisamchk` should be used when it is not. The benefit is that you no longer have to take down the server for checking or repairing your tables.

`mysqlcheck` uses MySQL server commands `CHECK`, `REPAIR`, `ANALYZE` and `OPTIMIZE` in a convenient way for the user.

There are three alternative ways to invoke `mysqlcheck`:

```
shell> mysqlcheck [OPTIONS] database [tables]
shell> mysqlcheck [OPTIONS] --databases DB1 [DB2 DB3...]
shell> mysqlcheck [OPTIONS] --all-databases
```

So it can be used in a similar way as `mysqldump` when it comes to what databases and tables you want to choose.

`mysqlcheck` does have a special feature compared to the other clients; the default behaviour, checking tables (-c), can be changed by renaming the binary. So if you want to have a tool that repairs tables by default, you should just copy `mysqlcheck` to your harddrive with a new name, `mysqlrepair`, or alternatively make a symbolic link to `mysqlrepair` and name the symbolic link as `mysqlrepair`. If you invoke `mysqlrepair` now, it will repair tables by default.

The names that you can use to change `mysqlcheck` default behaviour are here:

```
mysqlrepair:   The default option will be -r
mysqlanalyze:  The default option will be -a
mysqloptimize: The default option will be -o
```

The options available for `mysqlcheck` are listed here, please check what your version supports with `mysqlcheck --help`.

`-A, --all-databases`
: Check all the databases. This will be same as –databases with all databases selected

`-1, --all-in-1`
: Instead of making one query for each table, execute all queries in 1 query separately for each database. Table names will be in a comma separated list.

`-a, --analyze`
: Analyse given tables.

`--auto-repair`
: If a checked table is corrupted, automatically fix it. Repairing will be done after all tables have been checked, if corrupted ones were found.

`-#, --debug=...`
: Output debug log. Often this is 'd:t:o,filename'

`--character-sets-dir=...`
: Directory where character sets are

`-c, --check`
: Check table for errors

`-C, --check-only-changed`
: Check only tables that have changed since last check or haven't been closed properly.

`--compress`
: Use compression in server/client protocol.

`-?, --help`
: Display this help message and exit.

`-B, --databases`
: To check several databases. Note the difference in usage; in this case no tables are given. All name arguments are regarded as database names.

`--default-character-set=...`
: Set the default character set

`-F, --fast`
: Check only tables that hasn't been closed properly

`-f, --force`
: Continue even if we get an sql-error.

`-e, --extended`
: If you are using this option with CHECK TABLE, it will ensure that the table is 100 percent consistent, but will take a long time.

If you are using this option with REPAIR TABLE, it will run an extended repair on the table, which may not only take a long time to execute, but may produce a lot of garbage rows also!

`-h, --host=...`
Connect to host.

`-m, --medium-check`
Faster than extended-check, but only finds 99.99 percent of all errors. Should be good enough for most cases.

`-o, --optimize`
Optimise table

`-p, --password[=...]`
Password to use when connecting to server. If password is not given it's solicited on the tty.

`-P, --port=...`
Port number to use for TCP/IP connections.

`--protocol=(TCP | SOCKET | PIPE | MEMORY)`
To specify the connect protocol to use. New in MySQL 4.1.

`-q, --quick`
If you are using this option with CHECK TABLE, it prevents the check from scanning the rows to check for wrong links. This is the fastest check.

If you are using this option with REPAIR TABLE, it will try to repair only the index tree. This is the fastest repair method for a table.

`-r, --repair`
Can fix almost anything except unique keys that aren't unique.

`-s, --silent`
Print only error messages.

`-S, --socket=...`
Socket file to use for connection.

`--tables` Overrides option –databases (-B).

`-u, --user=#`
User for login if not current user.

`-v, --verbose`
Print information about the various stages.

`-V, --version`
Output version information and exit.

4.9.6 `mysqldump`, Dumping Table Structure and Data

Utility to dump a database or a collection of database for backup or for transferring the data to another SQL server (not necessarily a MySQL server). The dump will contain SQL statements to create the table and/or populate the table.

If you are doing a backup on the server, you should consider using the `mysqlhotcopy` instead. See Section 4.9.7 [mysqlhotcopy], page 344.

```
shell> mysqldump [OPTIONS] database [tables]
OR     mysqldump [OPTIONS] --databases [OPTIONS] DB1 [DB2 DB3...]
OR     mysqldump [OPTIONS] --all-databases [OPTIONS]
```

If you don't give any tables or use the `--databases` or `--all-databases`, the whole database(s) will be dumped.

You can get a list of the options your version of `mysqldump` supports by executing `mysqldump --help`.

Note that if you run `mysqldump` without `--quick` or `--opt`, `mysqldump` will load the whole result set into memory before dumping the result. This will probably be a problem if you are dumping a big database.

Note that if you are using a new copy of the `mysqldump` program and you are going to do a dump that will be read into a very old MySQL server, you should not use the `--opt` or `-e` options.

`mysqldump` supports the following options:

`--add-locks`
: Add `LOCK TABLES` before and `UNLOCK TABLE` after each table dump. (To get faster inserts into MySQL.)

`--add-drop-table`
: Add a `drop table` before each create statement.

`-A, --all-databases`
: Dump all the databases. This will be same as `--databases` with all databases selected.

`-a, --all`
: Include all MySQL-specific create options.

`--allow-keywords`
: Allow creation of column names that are keywords. This works by prefixing each column name with the table name.

`-c, --complete-insert`
: Use complete insert statements (with column names).

`-C, --compress`
: Compress all information between the client and the server if both support compression.

`-B, --databases`
: To dump several databases. Note the difference in usage. In this case no tables are given. All name arguments are regarded as database names. `USE db_name;` will be included in the output before each new database.

`--delayed`
: Insert rows with the `INSERT DELAYED` command.

`-e, --extended-insert`
: Use the new multiline `INSERT` syntax. (Gives more compact and faster inserts statements.)

`-#, --debug[=option_string]`
: Trace usage of the program (for debugging).

`--help`
: Display a help message and exit.

`--fields-terminated-by=...`
`--fields-enclosed-by=...`
`--fields-optionally-enclosed-by=...`
`--fields-escaped-by=...`
`--lines-terminated-by=...`
: These options are used with the `-T` option and have the same meaning as the corresponding clauses for `LOAD DATA INFILE`. See Section 6.4.8 [`LOAD DATA`], page 555.

`-F, --flush-logs`
: Flush log file in the MySQL server before starting the dump.

`-f, --force,`
: Continue even if we get an SQL error during a table dump.

`-h, --host=..`
: Dump data from the MySQL server on the named host. The default host is `localhost`.

`-l, --lock-tables.`
: Lock all tables before starting the dump. The tables are locked with `READ LOCAL` to allow concurrent inserts in the case of `MyISAM` tables.

  Please note that when dumping multiple databases, `--lock-tables` will lock tables for each database separately. So using this option will not guarantee your tables will be logically consistent between databases. Tables in different databases may be dumped in completely different states.

`-K, --disable-keys`
: `/*!40000 ALTER TABLE tb_name DISABLE KEYS */;` and `/*!40000 ALTER TABLE tb_name ENABLE KEYS */;` will be put in the output. This will make loading the data into a MySQL 4.0 server faster as the indexes are created after all data are inserted.

`-n, --no-create-db`
: `CREATE DATABASE /*!32312 IF NOT EXISTS*/ db_name;` will not be put in the output. The above line will be added otherwise, if a `--databases` or `--all-databases` option was given.

`-t, --no-create-info`
: Don't write table creation information (the `CREATE TABLE` statement).

`-d, --no-data`
: Don't write any row information for the table. This is very useful if you just want to get a dump of the structure for a table!

`--opt`
: Same as `--quick --add-drop-table --add-locks --extended-insert --lock-tables`. Should give you the fastest possible dump for reading into a MySQL server.

`-pyour_pass, --password[=your_pass]`
: The password to use when connecting to the server. If you specify no '`=your_pass`' part, `mysqldump` you will be prompted for a password.

`-P, --port=...`
: Port number to use for TCP/IP connections.

`--protocol=(TCP | SOCKET | PIPE | MEMORY)`
: To specify the connect protocol to use. New in MySQL 4.1.

`-q, --quick`
: Don't buffer query, dump directly to stdout. Uses `mysql_use_result()` to do this.

`-Q, --quote-names`
: Quote table and column names within '`'` characters.

`-r, --result-file=...`
: Direct output to a given file. This option should be used in MSDOS, because it prevents new line '`\n`' from being converted to '`\n\r`' (new line + carriage return).

`--single-transaction`
: This option issues a `BEGIN` SQL command before dumping data from server. It is mostly useful with `InnoDB` tables and `READ_COMMITTED` transaction isolation level, as in this mode it will dump the consistent state of the database at the time then `BEGIN` was issued without blocking any applications.

  When using this option you should keep in mind that only transactional tables will be dumped in a consistent state, for example, any `MyISAM` or `HEAP` tables dumped while using this option may still change state.

  The `--single-transaction` option was added in version 4.0.2. This option is mutually exclusive with the `--lock-tables` option as `LOCK TABLES` already commits a previous transaction internally.

`-S /path/to/socket, --socket=/path/to/socket`
: The socket file to use when connecting to `localhost` (which is the default host).

`--tables` Overrides option –databases (-B).

`-T, --tab=path-to-some-directory`
: Creates a `table_name.sql` file, that contains the SQL CREATE commands, and a `table_name.txt` file, that contains the data, for each give table. The format of the '`.txt`' file is made according to the `--fields-xxx` and `--lines--xxx` options. **Note**: This option only works if `mysqldump` is run on the same machine as the `mysqld` daemon. You must use a MySQL account that has the `FILE` privilege, and the login user/group that `mysqld` is running as (normally user `mysql`, group `mysql`) must have permission to create/write a file at the location you specify.

`-u user_name, --user=user_name`
: The MySQL user name to use when connecting to the server. The default value is your Unix login name.

`-O var=option, --set-variable var=option`
: Set the value of a variable. The possible variables are listed below. Please note that `--set-variable` is deprecated since MySQL 4.0, just use `--var=option` on its own.

`-v, --verbose`
: Verbose mode. Print out more information on what the program does.

`-V, --version`
: Print version information and exit.

`-w, --where='where-condition'`
: Dump only selected records. Note that quotes are mandatory:

```
"--where=user='jimf'" "-wuserid>1" "-wuserid<1"
```

`-X, --xml` Dumps a database as well formed XML

`-x, --first-slave`
: Locks all tables across all databases.

`--master-data`
: Like `--first-slave`, but also prints some `CHANGE MASTER TO` commands which will later make your slave start from the right position in the master's binlogs, if you have set up your slave using this SQL dump of the master.

`-O net_buffer_length=#, where # < 16M`
: When creating multi-row-insert statements (as with option `--extended-insert` or `--opt`), `mysqldump` will create rows up to `net_buffer_length` length. If you increase this variable, you should also ensure that the `max_allowed_packet` variable in the MySQL server is bigger than the `net_buffer_length`.

The most normal use of `mysqldump` is probably for making a backup of whole databases. See Section 4.5.1 [Backup], page 259.

```
mysqldump --opt database > backup-file.sql
```

You can read this back into MySQL with:

```
mysql database < backup-file.sql
```

or

```
mysql -e "source /path-to-backup/backup-file.sql" database
```

However, it's also very useful to populate another MySQL server with information from a database:

```
mysqldump --opt database | mysql ---host=remote-host -C database
```

It is possible to dump several databases with one command:

```
mysqldump --databases database1 [database2 ...] > my_databases.sql
```

If all the databases are wanted, one can use:

```
mysqldump --all-databases > all_databases.sql
```

4.9.7 `mysqlhotcopy`, Copying MySQL Databases and Tables

`mysqlhotcopy` is a Perl script that uses `LOCK TABLES`, `FLUSH TABLES` and `cp` or `scp` to quickly make a backup of a database. It's the fastest way to make a backup of the database or single tables, but it can only be run on the same machine where the database directories are. `mysqlhotcopy` works only on Unix, and it works only for `MyISAM` and `ISAM` tables.

```
mysqlhotcopy db_name [/path/to/new_directory]

mysqlhotcopy db_name_1 ... db_name_n /path/to/new_directory

mysqlhotcopy db_name./regex/
```

`mysqlhotcopy` supports the following options:

`-?, --help`
: Display a help screen and exit

`-u, --user=#`
: User for database login

`-p, --password=#`
: Password to use when connecting to server

`-P, --port=#`
: Port to use when connecting to local server

`-S, --socket=#`
: Socket to use when connecting to local server

`--allowold`
: Don't abort if target already exists (rename it _old)

`--keepold`
: Don't delete previous (now renamed) target when done

`--noindices`
: Don't include full index files in copy to make the backup smaller and faster The indexes can later be reconstructed with `myisamchk -rq`..

`--method=#`
: Method for copy (`cp` or `scp`).

`-q, --quiet`
: Be silent except for errors

`--debug` Enable debug

`-n, --dryrun`
: Report actions without doing them

`--regexp=#`
: Copy all databases with names matching regexp

`--suffix=#`
: Suffix for names of copied databases

`--checkpoint=#`
: Insert checkpoint entry into specified db.table

`--flushlog`
: Flush logs once all tables are locked.

`--tmpdir=#`
: Temporary directory (instead of /tmp).

You can use `perldoc mysqlhotcopy` to get more complete documentation for `mysqlhotcopy`.

`mysqlhotcopy` reads the groups `[client]` and `[mysqlhotcopy]` from the option files.

To be able to execute `mysqlhotcopy` you need write access to the backup directory, the `SELECT` privilege for the tables you are about to copy and the MySQL `RELOAD` privilege (to be able to execute `FLUSH TABLES`).

4.9.8 `mysqlimport`, Importing Data from Text Files

`mysqlimport` provides a command-line interface to the `LOAD DATA INFILE` SQL statement. Most options to `mysqlimport` correspond directly to the same options to `LOAD DATA INFILE`. See Section 6.4.8 [`LOAD DATA`], page 555.

`mysqlimport` is invoked like this:

```
shell> mysqlimport [options] database textfile1 [textfile2 ...]
```

For each text file named on the command-line, `mysqlimport` strips any extension from the filename and uses the result to determine which table to import the file's contents into. For example, files named '`patient.txt`', '`patient.text`', and '`patient`' would all be imported into a table named `patient`.

`mysqlimport` supports the following options:

`-c, --columns=...`
: This option takes a comma-separated list of field names as an argument. The field list is used to create a proper `LOAD DATA INFILE` command, which is then passed to MySQL. See Section 6.4.8 [`LOAD DATA`], page 555.

`-C, --compress`
: Compress all information between the client and the server if both support compression.

`-#, --debug[=option_string]`
: Trace usage of the program (for debugging).

`-d, --delete`
: Empty the table before importing the text file.

`--fields-terminated-by=...`
`--fields-enclosed-by=...`
`--fields-optionally-enclosed-by=...`
`--fields-escaped-by=...`
`--lines-terminated-by=...`
: These options have the same meaning as the corresponding clauses for `LOAD DATA INFILE`. See Section 6.4.8 [`LOAD DATA`], page 555.

`-f, --force`
: Ignore errors. For example, if a table for a text file doesn't exist, continue processing any remaining files. Without `--force`, `mysqlimport` exits if a table doesn't exist.

`--help`
: Display a help message and exit.

`-h host_name, --host=host_name`
: Import data to the MySQL server on the named host. The default host is `localhost`.

`-i, --ignore`
: See the description for the `--replace` option.

`--ignore-lines=n`
: Ignore first `n` lines of the datafile.

`-l, --lock-tables`
: Lock **all** tables for writing before processing any text files. This ensures that all tables are synchronised on the server.

`-L, --local`
: Read input files from the client. By default, text files are assumed to be on the server if you connect to `localhost` (which is the default host).

`-pyour_pass, --password[=your_pass]`
: The password to use when connecting to the server. If you specify no '`=your_pass`' part, `mysqlimport` you will be prompted for a password.

`-P port_num, --port=port_num`
: TCP/IP port number to use for connection.

`--protocol=(TCP | SOCKET | PIPE | MEMORY)`
: To specify the connect protocol to use. New in MySQL 4.1.

`-r, --replace`
: The `--replace` and `--ignore` options control handling of input records that duplicate existing records on unique key values. If you specify `--replace`, new rows replace existing rows that have the same unique key value. If you specify `--ignore`, input rows that duplicate an existing row on a unique key value are skipped. If you don't specify either option, an error occurs when a duplicate key value is found, and the rest of the text file is ignored.

`-s, --silent`
: Silent mode. Write output only when errors occur.

`-S /path/to/socket, --socket=/path/to/socket`
: The socket file to use when connecting to `localhost` (which is the default host).

`-u user_name, --user=user_name`
: The MySQL user name to use when connecting to the server. The default value is your Unix login name.

`-v, --verbose`
: Verbose mode. Print out more information what the program does.

`-V, --version`
: Print version information and exit.

Here is a sample run using `mysqlimport`:

```
$ mysql --version
mysql  Ver 9.33 Distrib 3.22.25, for pc-linux-gnu (i686)
$ uname -a
Linux xxx.com 2.2.5-15 #1 Mon Apr 19 22:21:09 EDT 1999 i586 unknown
$ mysql -e 'CREATE TABLE imptest(id INT, n VARCHAR(30))' test
$ ed
a
100     Max Sydow
101     Count Dracula
.
w imptest.txt
32
q
$ od -c imptest.txt
0000000   1   0   0  \t   M   a   x       S   y   d   o   w  \n   1   0
0000020   1  \t   C   o   u   n   t       D   r   a   c   u   l   a  \n
0000040
$ mysqlimport --local test imptest.txt
test.imptest: Records: 2  Deleted: 0  Skipped: 0  Warnings: 0
$ mysql -e 'SELECT * FROM imptest' test
+------+---------------+
| id   | n             |
+------+---------------+
|  100 | Max Sydow     |
|  101 | Count Dracula |
+------+---------------+
```

4.9.9 `mysqlshow`, Showing Databases, Tables, and Columns

`mysqlshow` can be used to quickly look at which databases exist, their tables, and the table's columns.

With the `mysql` program you can get the same information with the `SHOW` commands. See Section 4.6.8 [SHOW], page 284.

`mysqlshow` is invoked like this:

```
shell> mysqlshow [OPTIONS] [database [table [column]]]
```

- If no database is given, all matching databases are shown.
- If no table is given, all matching tables in the database are shown.
- If no column is given, all matching columns and column types in the table are shown.

Note that in newer MySQL versions, you only see those database/tables/columns for which you have some privileges.

If the last argument contains a shell or SQL wildcard (*, ?, % or _) then only what's matched by the wildcard is shown. If a database contains underscore(s), those should be escaped with backslash (some Unix shells will require two), in order to get tables / columns properly. '*' are converted into SQL '%' wildcard and '?' into SQL '_' wildcard. This may cause some confusion when you try to display the columns for a table with a _ as in this case `mysqlshow` only shows you the table names that match the pattern. This is easily fixed by adding an extra % last on the command-line (as a separate argument).

4.9.10 `mysql_config`, Get compile options for compiling clients

`mysql_config` provides you with useful information how to compile your MySQL client and connect it to MySQL.

`mysql_config` supports the following options:

`--cflags` Compiler flags to find include files and critical ccompiler flags and defines used when compiling the `libmysqlclient` library.

`--include`
Compiler options to find MySQL include files. (Normally one would use `--cflags` instead of this)

`--libs` Libraries and options required to link with the MySQL client library.

`--libs_r` Libraries and options required to link with the thread-safe MySQL client library.

`--socket` The default socket name, defined when configuring MySQL.

`--port` The default port number, defined when configuring MySQL.

`--version`
Version number and version for the MySQL distribution.

`--libmysqld-libs or --embedded`
Libraries and options required to link with the MySQL embedded server.

If you execute `mysql_config` without any options it will print all options it supports plus the value of all options:

```
shell> mysql_config
Usage: /usr/local/mysql/bin/mysql_config [OPTIONS]
Options:
        --cflags         [-I/usr/local/mysql/include/mysql -mcpu=pentiumpro]
        --include        [-I/usr/local/mysql/include/mysql]
        --libs           [-L/usr/local/mysql/lib/mysql -lmysqlclient -lz -lcrypt -lnsl
        --libs_r         [-L/usr/local/mysql/lib/mysql -lmysqlclient_r -lpthread -lz -
        --socket         [/tmp/mysql.sock]
        --port           [3306]
        --version        [4.0.16]
        --libmysqld-libs [-L/usr/local/mysql/lib/mysql -lmysqld -lpthread -lz -lcrypt
```

You can use this to compile a MySQL client by as follows:

```
CFG=/usr/local/mysql/bin/mysql_config
sh -c "gcc -o progname `$CFG --cflags` progname.c `$CFG --libs`"
```

4.9.11 `perror`, Explaining Error Codes

For most system errors MySQL will, in addition to a internal text message, also print the system error code in one of the following styles: `message ... (errno: #)` or `message ... (Errcode: #)`.

You can find out what the error code means by either examining the documentation for your system or use the `perror` utility.

`perror` prints a description for a system error code, or an MyISAM/ISAM storage engine (table handler) error code.

`perror` is invoked like this:

```
shell> perror [OPTIONS] [ERRORCODE [ERRORCODE...]]

Example:

shell> perror 13 64
Error code  13:  Permission denied
Error code  64:  Machine is not on the network
```

Note that the error messages are mostly system dependent!

4.9.12 How to Run SQL Commands from a Text File

The `mysql` client typically is used interactively, like this:

```
shell> mysql database
```

However, it's also possible to put your SQL commands in a file and tell `mysql` to read its input from that file. To do so, create a text file '`text_file`' that contains the commands you wish to execute. Then invoke `mysql` as shown here:

```
shell> mysql database < text_file
```

You can also start your text file with a `USE db_name` statement. In this case, it is unnecessary to specify the database name on the command line:

```
shell> mysql < text_file
```

If you are already running `mysql`, you can execute an SQL script file using the `source` command:

```
mysql> source filename;
```

For more information about batch mode, Section 3.5 [Batch mode], page 181.

4.10 The MySQL Log Files

MySQL has several different log files that can help you find out what's going on inside `mysqld`:

Log file	Description
The error log	Problems encountering starting, running or stopping `mysqld`.
The isam log	Logs all changes to the ISAM tables. Used only for debugging the isam code.

The query log	Established connections and executed queries.
The update log	Deprecated: Stores all statements that changes data
The binary log	Stores all statements that changes something. Used also for replication
The slow log	Stores all queries that took more than `long_query_time` seconds to execute or didn't use indexes.

All logs can be found in the `mysqld` data directory. You can force `mysqld` to reopen the log files (or in some cases switch to a new log) by executing `FLUSH LOGS`. See Section 4.6.4 [FLUSH], page 282.

4.10.1 The Error Log

The error log file contains information indicating when `mysqld` was started and stopped and also any critical errors found when running.

If `mysqld` dies unexpectedly and `mysqld_safe` needs to restart `mysqld`, `mysqld_safe` will write a `restarted mysqld` row in this file. This log also holds a warning if `mysqld` notices a table that needs to be automatically checked or repaired.

On some operating systems, the error log will contain a stack trace for where `mysqld` died. This can be used to find out where `mysqld` died. See Section E.1.4 [Using stack trace], page 1010.

Beginning with MySQL 4.0.10 you can specify where `mysqld` stores the error log file with the option `--log-error[=filename]`. If no file name is given `mysqld` will use `mysql-data-dir/'hostname'.err` on Unix and '`\mysql\data\mysql.err`' on Windows. If you execute `flush logs` the old file will be prefixed with `--old` and `mysqld` will create a new empty log file.

In older MySQL versions the error log handling was done by `mysqld_safe` which redirected the error file to `'hostname'.err`. One could change this file name with the option `--err-log=filename`.

If you don't specify `--log-error` or if you use the `--console` option the errors will be written to stderr (the terminal).

On Windows, the output is always written to the `.err` file if `--console` is not given.

4.10.2 The General Query Log

If you want to know what happens within `mysqld`, you should start it with `--log[=file]`. This will log all connections and queries to the log file (by default named '`'hostname'.log`'). This log can be very useful when you suspect an error in a client and want to know exactly what `mysqld` thought the client sent to it.

Older versions of the `mysql.server` script (from MySQL 3.23.4 to 3.23.8) pass `safe_mysqld` a `--log` option (enable general query log). If you need better performance when you start using MySQL in a production environment, you can remove the `--log` option from `mysql.server` or change it to `--log-bin`. See Section 4.10.4 [Binary log], page 351.

The entries in this log are written as `mysqld` receives the questions. This may be different from the order in which the statements are executed. This is in contrast to the update log and the binary log which are written after the query is executed, but before any locks are released.

4.10.3 The Update Log

Note: the update log has been deprecated and replaced by the binary log. See Section 4.10.4 [Binary log], page 351. The binary log can do anything the old update log could do, and more. **The update log will be removed in MySQL 5.0**.

When started with the `--log-update[=file_name]` option, `mysqld` writes a log file containing all SQL commands that update data. If no filename is given, it defaults to the name of the host machine. If a filename is given, but it doesn't contain a path, the file is written in the data directory. If '`file_name`' doesn't have an extension, `mysqld` will create log file names like so: '`file_name.###`', where `###` is a number that is incremented each time you execute `mysqladmin refresh`, execute `mysqladmin flush-logs`, execute the `FLUSH LOGS` statement, or restart the server.

Note: for the above scheme to work, you must not create your own files with the same filename as the update log `+` some extensions that may be regarded as a number, in the directory used by the update log!

If you use the `--log` or `-l` options, `mysqld` writes a general log with a filename of '`hostname.log`', and restarts and refreshes do not cause a new log file to be generated (although it is closed and reopened). In this case you can copy it (on Unix) by doing:

```
mv hostname.log hostname-old.log
mysqladmin flush-logs
cp hostname-old.log to-backup-directory
rm hostname-old.log
```

Update logging is smart because it logs only statements that really update data. So an `UPDATE` or a `DELETE` with a `WHERE` that finds no rows is not written to the log. It even skips `UPDATE` statements that set a column to the value it already has.

The update logging is done immediately after a query completes but before any locks are released or any commit is done. This ensures that the log will be logged in the execution order.

If you want to update a database from update log files, you could do the following (assuming your update logs have names of the form '`file_name.###`'):

```
shell> ls -1 -t -r file_name.[0-9]* | xargs cat | mysql
```

`ls` is used to get all the log files in the right order.

This can be useful if you have to revert to backup files after a crash and you want to redo the updates that occurred between the time of the backup and the crash.

4.10.4 The Binary Log

The binary log has replaced the old update log. The update log will be removed in MySQL 5.0. The binary log contains all information that is available in the update log in a more efficient format and in a manner that is transactionally safe.

The binary log, like the old update log, only logs statements that really update data. So an `UPDATE` or a `DELETE` with a `WHERE` that finds no rows is not written to the log. It even skips `UPDATE` statements that set a column to the value it already has.

The primary purpose of the binary log is to be able to update the database during a restore operation as fully as possible, as the binary log would contain all updates done after a backup was made.

The binary log is also used when you are replicating a slave from a master. See Section 4.11 [Replication], page 355.

The binary log also contains information about how long each query took that updated the database. It doesn't contain queries that don't modify any data. If you want to log all queries (for example to find a problem query) you should use the general query log. See Section 4.10.2 [Query log], page 350.

When started with the `--log-bin[=file_name]` option, `mysqld` writes a log file containing all SQL commands that update data. If no file name is given, it defaults to the name of the host machine followed by `-bin`. If file name is given, but it doesn't contain a path, the file is written in the data directory.

If you supply an extension to `--log-bin=filename.extension`, the extension will be silenty removed.

To the binary log filename `mysqld` will append an extension that is a number that is incremented each time you execute `mysqladmin refresh`, execute `mysqladmin flush-logs`, execute the `FLUSH LOGS` statement or restart the server. A new binary log will also automatically be created when the current one's size reaches `max_binlog_size`. Note if you are using transactions: a transaction is written in one chunk to the binary log, hence it is never split between several binary logs. Therefore, if you have big transactions, you may see binlogs bigger than `max_binlog_size`.

You can delete all binary log files with the `RESET MASTER` command (see Section 4.6.5 [RESET], page 283), or only some of them with `PURGE MASTER LOGS` (see Section 4.11.7 [Replication Master SQL], page 376).

You can use the following options to `mysqld` to affect what is logged to the binary log (please make sure to read the notes which follow this table):

Option	Description
`binlog-do-db=database_name`	Tells the master that it should log updates to the binary log if the current database (that is, the one selected by `USE`) database is 'database_name'. All others databases which are not explicitly mentioned are ignored. Note that if you use this you should ensure that you only do updates in the current database. (Example: `binlog-do-db=some_database`) Example of what does not work as you could expect it: if the server is started with `binlog-do-db=sales`, and you do `USE prices; UPDATE sales.january SET amount=amount+1000;`, this query will not be written into the binary log.

`binlog-ignore-db=database_name`
: Tells the master that updates where the current database (that is, the one selected by `USE`) is 'database_name' should not be stored in the binary log. Note that if you use this you should ensure that you only do updates in the current database. (Example: `binlog-ignore-db=some_database`)
Example of what does not work as you could expect it: if the server is started with `binlog-ignore-db=sales`, and you do `USE prices; UPDATE sales.january SET amount=amount+1000;`, this query will be written into the binary log.

The rules are evaluated in the following order, to decide if the query should be written to the binary log or not:

1. Are there `binlog-do-db` or `binlog-ignore-db` rules?
   - No: write the query to the binlog and exit.
   - Yes: go to step below.
2. So there are some rules (`binlog-do-db` or `binlog-ignore-db` or both). Is there a current database (has any database been selected by `USE`?)?
   - No: do **NOT** write the query, and exit.
   - Yes: go to step below.
3. There is a current database. Are there some `binlog-do-db` rules?
   - Yes: Does the current database match any of the `binlog-do-db` rules?
     - Yes: write the query and exit.
     - No: do **NOT** write the query, and exit.
   - No: go to step below.
4. There are some `binlog-ignore-db` rules. Does the current database match any of the `binlog-ignore-db` rules?
   - Yes: do not write the query, and exit.
   - No: write the query and exit.

So for example, a slave running with only `binlog-do-db=sales` will not write to the binlog any query whose current database is different from `sales` (in other words, `binlog-do-db` can sometimes mean "ignore other databases").

To be able to know which different binary log files have been used, `mysqld` will also create a binary log index file that contains the name of all used binary log files. By default this has the same name as the binary log file, with the extension `'.index'`. You can change the name of the binary log index file with the `--log-bin-index=[filename]` option. You should not manually edit this file while `mysqld` is running; doing this would confuse `mysqld`.

If you are using replication, you should not delete old binary log files until you are sure that no slave will ever need to use them. One way to do this is to do `mysqladmin flush-logs` once a day and then remove any logs that are more than 3 days old. You can remove them manually, or preferably using `PURGE MASTER LOGS` (see Section 4.11.7 [Replication Master SQL], page 376) which will also safely update the binary log index file for you (and which can take a date argument since MySQL 4.1)

A connection with the `SUPER` privilege can disable the binary logging of its queries using `SET SQL_LOG_BIN=0`. See Section 4.11.7 [Replication Master SQL], page 376.

You can examine the binary log file with the `mysqlbinlog` utility. For example, you can update a MySQL server from the binary log as follows:

```
shell> mysqlbinlog log-file | mysql -h server_name
```

See Section 4.9.4 [mysqlbinlog], page 336 for more information on the `mysqlbinlog` utility and how to use it.

If you are using `BEGIN [WORK]` or `SET AUTOCOMMIT=0`, you must use the MySQL binary log for backups instead of the old update log, which will be removed in MySQL 5.0.

The binary logging is done immediately after a query completes but before any locks are released or any commit is done. This ensures that the log will be logged in the execution order.

Updates to non-transactional tables are stored in the binary log immediately after execution. For transactional tables such as `BDB` or `InnoDB` tables, all updates (`UPDATE`, `DELETE` or `INSERT`) that change tables are cached until a `COMMIT` command is sent to the server. At this point `mysqld` writes the whole transaction to the binary log before the `COMMIT` is executed. Every thread will, on start, allocate a buffer of `binlog_cache_size` to buffer queries. If a query is bigger than this, the thread will open a temporary file to store the transaction. The temporary file will be deleted when the thread ends.

The `max_binlog_cache_size` (default 4G) can be used to restrict the total size used to cache a multi-query transaction. If a transaction is bigger than this it will fail and roll back.

If you are using the update or binary log, concurrent inserts will be converted to normal inserts when using `CREATE ... SELECT` or `INSERT ... SELECT`. This is to ensure that you can recreate an exact copy of your tables by applying the log on a backup.

4.10.5 The Slow Query Log

When started with the `--log-slow-queries[=file_name]` option, `mysqld` writes a log file containing all SQL commands that took more than `long_query_time` seconds to execute. The time to get the initial table locks are not counted as execution time.

The slow query log is logged after the query is executed and after all locks has been released. This may be different from the order in which the statements are executed.

If no file name is given, it defaults to the name of the host machine suffixed with `-slow.log`. If a filename is given, but doesn't contain a path, the file is written in the data directory.

The slow query log can be used to find queries that take a long time to execute and are thus candidates for optimisation. With a large log, that can become a difficult task. You can pipe the slow query log through the `mysqldumpslow` command to get a summary of the queries which appear in the log.

You are using `--log-long-format` then also queries that are not using indexes are printed. See Section 4.1.1 [Command-line options], page 195.

4.10.6 Log File Maintenance

The MySQL Server can create a number of different log files, which make it easy to see what is going on. See Section 4.10 [Log Files], page 349. However, you must clean up these files regularly, to ensure that the logs don't take up too much disk space.

When using MySQL with log files, you will want to remove/backup old log files from time to time and tell MySQL to start logging to new files. See Section 4.5.1 [Backup], page 259.

On a Linux (`Red Hat`) installation, you can use the `mysql-log-rotate` script for this. If you installed MySQL from an RPM distribution, the script should have been installed automatically. Note that you should be careful with this script if you are using the binary log for replication!

On other systems you must install a short script yourself that you start from `cron` to handle log files.

You can force MySQL to start using new log files by using `mysqladmin flush-logs` or by using the SQL command `FLUSH LOGS`. If you are using MySQL Version 3.21, you must use `mysqladmin refresh`.

The above command does the following:

- If standard logging (`--log`) or slow query logging (`--log-slow-queries`) is used, closes and reopens the log file ('`mysql.log`' and '`‘hostname‘-slow.log`' as default).
- If update logging (`--log-update`) is used, closes the update log and opens a new log file with a higher sequence number.

If you are using only an update log, you only have to flush the logs and then move away the old update log files to a backup. If you are using the normal logging, you can do something like:

```
shell> cd mysql-data-directory
shell> mv mysql.log mysql.old
shell> mysqladmin flush-logs
```

and then take a backup and remove '`mysql.old`'.

4.11 Replication in MySQL

Replication capabilities allowing the databases on one MySQL server to be duplicated on another were introduced in MySQL version 3.23.15. This section describes the various replication features in MySQL. It serves as a reference to the options available with replication. You will be introduced to replication and learn how to implement it. Toward that end, there are some frequently asked questions, descriptions of problems, and how to solve them.

We suggest that you visit our website at `http://www.mysql.com/` often and read updates to this section. Replication is constantly being improved, and we update the manual frequently with the most current information.

4.11.1 Introduction

Starting in Version 3.23.15, MySQL supports one-way replication internally. One server acts as the master, while one or more other servers act as slaves. The master server keeps a

binary log of updates (see Section 4.10.4 [Binary log], page 351). It also maintains an index file of the binary logs to keep track of log rotation. Each slave, upon connecting, informs the master where it left off since the last successfully propagated update, catches up any updates that have occurred since then, and then blocks and waits for the master to notify it of new updates.

A slave can also serve as a master if you set up chained replication servers.

Note that when you are using replication, all updates to the tables that are replicated should be performed on the master server. Otherwise, you must always be careful to avoid conflicts between updates that users make to tables on the master and updates that they make to tables on the slave.

One-way replication has benefits for robustness, speed, and system administration:

- Robustness is increased with a master/slave setup. In the event of problems with the master, you can switch to the slave as a backup.
- The extra speed is achieved by splitting the load for processing client queries between the master and slave servers, resulting in better client response time. `SELECT` queries may be sent to the slave to reduce query processing load of the master. Queries that modify data should still be sent to the master so that the master and slave to not get out of sync. This load-balancing strategy if effective if non-updating queries dominate, but that is the normal case.
- Another benefit of using replication is that one can get non-disturbing backups of the system by doing a backup on a slave instead of doing it on the master. See Section 4.5.1 [Backup], page 259.

4.11.2 Replication Implementation Overview

MySQL replication is based on the master server keeping track of all changes to your database (updates, deletes, etc) in the binary log (see Section 4.10.4 [Binary log], page 351). Each slave server receives from the master the saved queries that the master has recorded in its binary log, so that the slave can execute the same queries on its copy of the data.

It is **very important** to realise that the binary log is simply a record starting from a fixed point in time (the moment you enable binary logging). Any slaves that you set up will need copies of the databases on your master as they existed at the moment you enabled binary logging on the master. If you start your slaves with data that is not the same as what was on the master **when the binary log was started**, your slaves may fail.

The following table indicates master/slave replication compatibility between different versions of MySQL.

		Master 3.23.33 and up	**Master 4.0.0**	**Master 4.0.1**	**Master 4.0.3 and up**
Slave	**3.23.33 and up**	yes	no	no	no
Slave	**4.0.0**	no	yes	no	no
Slave	**4.0.1**	yes	no	yes	no
Slave	**4.0.3 and up**	yes	no	no	yes

As a general rule, it's always recommended to use recent MySQL versions, because replication capabilities are continually being improved. With regard to version 4.0, we recommend using same version for both the master and the slave, with the exception that MySQL 4.0.2 is not recommended for replication.

Note that when you upgrade a master from MySQL 3.23 to MySQL 4.0 (or 4.1) you should not restart replication using old 3.23 binary logs, because this will unfortunately confuse the 4.0 slave. The upgrade can safely be done this way, assuming you have a 3.23 master to upgrade and you have 4.0 slaves:

1. Block all updates on the master (`FLUSH TABLES WITH READ LOCK`).
2. Wait until all the slaves have caught up all changes from the master (use `SHOW MASTER STATUS` on the master, and `SELECT MASTER_POS_WAIT()` on the slaves). Then run `STOP SLAVE` on the slaves.
3. Shut down MySQL on the master and upgrade the master to MySQL 4.0.
4. Restart MySQL on the master. Record the name '`<name>`' of the master's newly created binary log. You can obtain the name of the file by issuing `SHOW MASTER STATUS` on the master. Then issue these commands on each slave:

```
mysql> CHANGE MASTER TO MASTER_LOG_FILE='<name>', MASTER_LOG_POS=4;
mysql> START SLAVE;
```

If you also must upgrade your slaves from 3.23 to 4.0, you should first upgrade your slaves: Shut down each one, upgrade it, and restart it. Then upgrade the master as just described.

Starting from 4.0.0, you can use `LOAD DATA FROM MASTER` to set up a slave. Be aware that `LOAD DATA FROM MASTER` currently works only if all the tables on the master are `MyISAM` type. Also, this statement acquires a global read lock, so no writes are possible while the tables are being transferred from the master. When we implement lock-free hot table backup (in MySQL 5.0), this global read lock will no longer be necessary.

Due to these limitations, we recommend that at this point you use `LOAD DATA FROM MASTER` only if the dataset on the master is relatively small, or if a prolonged read lock on the master is acceptable. While the actual speed of `LOAD DATA FROM MASTER` may vary from system to system, a good rule of thumb for how long it is going to take is 1 second per 1 MB of the datafile. You will get close to the estimate if both master and slave are equivalent to 700 MHz Pentium and are connected through a 100 MBit/s network. Of course, this is only a rough estimate.

Once a slave is properly configured and running, it will simply connect to the master and wait for updates to process. If the master goes away or the slave loses connectivity with your master, it will keep trying to connect periodically until it is able to reconnect and resume listening for updates. The retry interval is controlled by the `--master-connect-retry` option. The default is 60 seconds.

Each slave keeps track of where it left off. The master server has no knowledge of how many slaves there are or which ones are up-to-date at any given time.

4.11.3 Replication Implementation Details

Three threads are involved in replication: one on the master and two on the slave. When `START SLAVE` is issued, the I/O thread is created on the slave. It connects to the master

and asks it to send the queries recorded in its binlogs. Then one thread is created on the master to send these binlogs. This thread is identified by `Binlog Dump` in `SHOW PROCESSLIST` output on the master. The I/O thread reads what the master `Binlog Dump` thread sends and simply copies it to some local files in the slave's data directory called relay logs. The last thread, the SQL thread, is created on the slave; it reads the relay logs and executes the queries it contains.

Note that the master has one thread for each currently connected slave server.

With `SHOW PROCESSLIST` you can know what is happening on the master and on the slave as regards replication.

The following example illustrates how the three threads show up in `SHOW PROCESSLIST`. The output format is that used by `SHOW PROCESSLIST` as of MySQL version 4.0.15, when the content of the `State` column was changed to be more meaningful compared to earlier versions.

On the master server, the output looks like this:

```
mysql> SHOW PROCESSLIST\G
*************************** 1. row ***************************
     Id: 2
   User: root
   Host: localhost:32931
     db: NULL
Command: Binlog Dump
   Time: 94
  State: Has sent all binlog to slave; waiting for binlog to be updated
   Info: NULL
```

On the slave server, the output looks like this:

```
mysql> SHOW PROCESSLIST\G
*************************** 1. row ***************************
     Id: 10
   User: system user
   Host:
     db: NULL
Command: Connect
   Time: 11
  State: Waiting for master to send event
   Info: NULL
*************************** 2. row ***************************
     Id: 11
   User: system user
   Host:
     db: NULL
Command: Connect
   Time: 11
  State: Has read all relay log; waiting for the I/O slave thread to update it
   Info: NULL
```

Here thread 2 is on the master. Thread 10 is the I/O thread on the slave. Thread 11 is the SQL thread on the slave; note that the value in the `Time` column can tell how late the slave is compared to the master (see Section 4.11.9 [Replication FAQ], page 386).

The following list shows the most common states you will see in the `State` column for the master's `Binlog Dump` thread. If you don't see this thread on a master server, replication is not running.

`Sending binlog event to slave`
: Binlogs consist of events, where an event is usually a query plus some other information. The thread has read an event from the binlog and is sending it to the slave.

`Finished reading one binlog; switching to next binlog`
: The thread has finished reading a binlog file and is opening the next one to send to the slave.

`Has sent all binlog to slave; waiting for binlog to be updated`
: The thread has read all binary log files and is idle. It is waiting for new events to appear in the binary log as a result of new update queries being executed on the master.

`Waiting to finalize termination`
: A very brief state that happens as the thread is stopping.

Here are the most common states you will see in the `State` column for the I/O thread of a slave server. Beginning with MySQL 4.1.1, this state also appears in the `Slave_IO_State` column of `SHOW SLAVE STATUS` output. This means that you can get a good view of what is happening by using only `SHOW SLAVE STATUS`.

`Connecting to master`
: The thread is attempting to connect to the master.

`Checking master version`
: A very brief state that happens just after the connection to the master is established.

`Registering slave on master`
: A very brief state that happens just after the connection to the master is established.

`Requesting binlog dump`
: A very brief state that happens just after the connection to the master is established. The thread sends to the master a request for the contents of its binlogs, starting from the requested binlog filename and position.

`Waiting to reconnect after a failed binlog dump request`
: If the binlog dump request failed (due to disconnection), the thread goes into this state while it sleeps. The thread sleeps for `master-connect-retry` seconds before retrying.

`Reconnecting after a failed binlog dump request`
: Then the thread tries to reconnect to the master.

`Waiting for master to send event`
: The thread has connected and is waiting for binlog events to arrive. This can last for a long time if the master is idle. If the wait lasts for `slave_read_timeout` seconds, a timeout will occur. At that point, the thread will consider the connection to be broken and make an attempt to reconnect.

`Queueing master event to the relay log`
: The thread has read an event and is copying it to the relay log so the SQL thread can process it.

`Waiting to reconnect after a failed master event read`
: An error occurred while reading (due to disconnection). The thread is sleeping for `master-connect-retry` seconds before attempting to reconnect.

`Reconnecting after a failed master event read`
: Then the thread tries to reconnect. When connection is established again, the state will become `Waiting for master to send event`.

`Waiting for the SQL slave thread to free enough relay log space`
: You are using a non-zero `relay_log_space_limit` value, and the relay logs have grown so much that their combined size exceeds this value. The I/O thread is waiting until the SQL thread frees enough space by processing relay log contents so that it can delete some relay log files.

`Waiting for slave mutex on exit`
: A very brief state that happens as the thread is stopping.

Here are the most common states you will see in the `State` column for the SQL thread of a slave server:

`Reading event from the relay log`
: The thread has read an event from the relay log so that it can process it.

`Has read all relay log; waiting for the I/O slave thread to update it`
: The thread has processed all events in the relay log files and is waiting for the I/O thread to write new events to the relay log.

`Waiting for slave mutex on exit`
: A very brief state that happens as the thread is stopping.

The `State` column for the I/O thread may also show a query string. This indicates that the thread has read an event from the relay log, extracted the query from it and is executing the query.

Before MySQL 4.0.2, the slave I/O and SQL threads were combined as a single thread, and no relay log files were used. The advantage of using two threads is that it separates query reading and query execution into two independent tasks, so the task of reading queries is not slowed down if query execution is slow. For example, if the slave server has not been running for a while, its I/O thread can quickly fetch all the binlog contents from the master when the slave starts, even if the SQL thread lags far behind and may take hours to catch up. If the slave stops before the SQL thread has executed all the fetched queries, the I/O thread has at least fetched everything so that a safe copy of the queries is locally stored in the slave's relay logs for execution when next the slave starts. This allows the binlogs to be purged on the master, because it no longer need wait for the slave to fetch their contents.

By default, relay logs are named using filenames of the form '`host_name-relay-bin.nnn`', where `host_name` is the name of the slave server host, and `nnn` is a sequence number. Successive relay log files are created using successive sequence numbers, beginning with `001`. The slave keeps track of relay logs currently in use in an index file. The default relay log index filename is '`host_name-relay-bin.index`'. By default these files are created in the slave's data directory. The default filenames may be overridden with the `--relay-log` and `--relay-log-index` server options.

Relay logs have the same format as binary logs, so they can be read with `mysqlbinlog`. A relay log is automatically deleted by the SQL thread as soon as it no longer needs it (that is, as soon as it has executed all its events). There is no command to delete relay logs, because the SQL thread takes care of doing so. However, from MySQL 4.0.14, `FLUSH LOGS` rotates relay logs, which will influence when the SQL thread deletes them.

A new relay log is created under the following conditions:

- The first time the I/O thread starts after the slave server starts. (In MySQL 5.0, a new relay log will be created each time the I/O thread starts, not just the first time.)
- A `FLUSH LOGS` statement is issued (4.0.14 and up only).
- The size of the current relay log file becomes too big. The meaning of "too big" is determined as follows:
  - `max_relay_log_size`, if `max_relay_log_size` > 0
  - `max_binlog_size`, if `max_relay_log_size` = 0 or MySQL is older than 4.0.14

A slave replication server creates additional two small files in the data directory. These files are named '`master.info`' and '`relay-log.info`' by default. They contain information like that shown in the output of the `SHOW SLAVE STATUS` statement (see Section 4.11.8 [Replication Slave SQL], page 378 for a description of this command). As disk files they survive slave's shutdown. The next time the slave starts up, it can read these files to know how far it has proceeded in reading binlogs from the master and in processing its own relay logs.

The '`master.info`' file is updated by the I/O thread. The correspondance between the lines in the file and the columns displayed by `SHOW SLAVE STATUS` is as follows:

Line	Description
1	`Master_Log_File`
2	`Read_Master_Log_Pos`
3	`Master_Host`
4	`Master_User`
5	Password (not shown by `SHOW SLAVE STATUS`)
6	`Master_Port`
7	`Connect_Retry`

The '`relay-log.info`' file is updated by the SQL thread. The correspondance between the lines in the file and the columns displayed by `SHOW SLAVE STATUS` is as follows:

Line	Description
1	`Relay_Log_File`
2	`Relay_Log_Pos`
3	`Relay_Master_Log_File`
4	`Exec_master_log_pos`

When you back up your slave's data, you should back up these 2 small files as well, along with the relay log files. because they are needed to resume replication after you restore the slave's data. If you lose the relay logs but still have the '`relay-log.info`' file, you can check it to determine how far the SQL thread has executed in the master binlogs. Then you can use `CHANGE MASTER TO` with the `MASTER_RELAY_LOG` and `MASTER_RELAY_POS` options to tell the slave to re-read the binlogs from that point. This requires that the binlogs still exist on the master server, of course.

If your slave is subject to replicating `LOAD DATA INFILE` statements, you should also backup the '`SQL-LOAD*`' files that may exist in the directory that the slave uses for this purpose. The slave needs these files to resume replication of any interrupted `LOAD DATA INFILE` statements. (The directory location is specified using the '`--slave-load-tmpdir`' option. Its default value if not specified is the value of the `tmpdir` variable.)

4.11.4 How to Set Up Replication

Here is a quick description of how to set up complete replication on your current MySQL server. It assumes you want to replicate all your databases and have not configured replication before. You will need to shut down your master server briefly to complete the steps outlined here.

The procedure is written in terms of setting up a single slave, but you can use it to set up multiple slaves.

While this method is the most straightforward way to set up a slave, it is not the only one. For example, if you already have a snapshot of the master's data, and the master already has its server ID set and binary logging enabled, you can set up a slave without shutting down the master or even blocking updates to it. For more details, please see Section 4.11.9 [Replication FAQ], page 386.

If you want to administer a MySQL replication setup, we suggest that you read this entire chapter through and try all commands mentioned in Section 4.11.7 [Replication Master SQL], page 376 ans Section 4.11.8 [Replication Slave SQL], page 378. You should also familiarise yourself with replication startup options in '`my.cnf`' in Section 4.11.6 [Replication Options], page 369.

Note that this procedure and some of the replication SQL statements in later sections refer to the `SUPER` privilege. Prior to MySQL 4.0.2, use the `PROCESS` privilege instead.

1. Make sure you have a recent version of MySQL installed on the master and slave(s), and that these versions are compatible according to the table shown in Section 4.11.2 [Replication Implementation], page 356.

   Please do not report bugs until you have verified that the problem is present in the latest release.

2. Set up an account on the master server that the slave server can use to connnect. This account must be given the `REPLICATION SLAVE` privilege. (If MySQL versions older than 4.0.2, give the account the `FILE` privilege instead.) If the account is only for replication (which is recommended), you don't need to grant any additional privileges.

   The hostname in the account name should be such that each of the slave servers can use the account to connect to the master. For example, to create a user named `repl` which can access your master from any host, you might use this command:

```
mysql> GRANT REPLICATION SLAVE ON *.* TO repl@'%' IDENTIFIED BY '<password>';
```

For MySQL versions older than 4.0.2, use this command instead:

```
mysql> GRANT FILE ON *.* TO repl@'%' IDENTIFIED BY '<password>';
```

If you plan to use the `LOAD TABLE FROM MASTER` or `LOAD DATA FROM MASTER` statements from the slave host, you will need to grant this account additional privileges:

- Grant to the account the `SUPER` and `RELOAD` global privileges.
- Grant the `SELECT` privilege for all tables that you want to load. Any master tables from which the account cannot `SELECT` will be ignored by `LOAD DATA FROM MASTER`.

3. If you are using MyISAM tables, flush all the tables and block write queries by executing `FLUSH TABLES WITH READ LOCK` command.

```
mysql> FLUSH TABLES WITH READ LOCK;
```

and then take a snapshot of the data on your master server.

The easiest way to create a snapshot is to simply use an archiving program (`tar` on Unix, `PowerArchiver`, `WinRAR`, `WinZIP` or any similar software on Windows) to produce an archive of the databases in your master's data directory. For example, to use `tar` to create an archive that includes all databases, change location into the master server's data directory, then execute this command:

```
shell> tar -cvf /tmp/mysql-snapshot.tar .
```

If you want the archive to include only a database called `this_db`, use this command instead:

```
shell> tar -cvf /tmp/mysql-snapshot.tar ./this_db
```

Then copy the archive file to the '`/tmp`' directory on the slave server host. On that machine, change location into the slave's data directory, and unpack the archive file using this command:

```
shell> tar -xvf /tmp/mysql-snapshot.tar
```

You may not want to replicate the `mysql` database. If not, you can exclude it from the archive. You also need not include any log files in the archive, or the '`master.info`' or '`relay-log.info`' files.

While the read lock placed by `FLUSH TABLES WITH READ LOCK` is in effect, read the value of the current binary log name and offset on the master:

```
mysql > SHOW MASTER STATUS;
+---------------+----------+--------------+------------------+
| File          | Position | Binlog_do_db | Binlog_ignore_db |
+---------------+----------+--------------+------------------+
| mysql-bin.003 | 73       | test,bar     | foo,manual,mysql |
+---------------+----------+--------------+------------------+
1 row in set (0.06 sec)
```

The `File` column shows the name of the log, while `Position` shows the offset. In the above example, the binary log value is `mysql-bin.003` and the offset is 73. Record the values. You will need to use them later when you are setting up the slave.

Once you have taken the snapshot and recorded the log name and offset, you can re-enable write activity on the master:

```
mysql> UNLOCK TABLES;
```

If you are using InnoDB tables, ideally you should use the InnoDB Hot Backup tool that is available to those who purchase MySQL commercial licenses, support, or the backup tool itself. It takes a consistent snapshot without acquiring any locks on the master server, and records the log name and offset corresponding to the snapshot to be later used on the slave. More information about the tool is avalaible at `http://www.innodb.com/hotbackup.html`.

Without the Hot Backup tool, the quickest way to take a snapshot of InnoDB tables is to shut down the master server and copy the InnoDB datafiles and logs, and the table definition files (`.frm`). To record the current log file name and offset, you should do the following before you shut down the server:

```
mysql> FLUSH TABLES WITH READ LOCK;
mysql> SHOW MASTER STATUS;
```

And then record the log name and the offset from the output of `SHOW MASTER STATUS` as was shown earlier. Once you have recorded the log name and the offset, shut down the server without unlocking the tables to make sure it goes down with the snapshot corresponding to the current log file and offset:

```
shell> mysqladmin -uroot shutdown
```

An alternative for both MyISAM and InnoDB tables is to take an SQL dump of the master instead of a binary copy like above; for this you can use `mysqldump --master-data` on your master and later run this SQL dump into your slave. However, this is slower than doing a binary copy.

If the master has been previously running without `--log-bin` enabled, the log name and position values displayed by `SHOW MASTER STATUS` or `mysqldump` will be empty. In that case, record empty string (”) for the log name, and 4 for the offset.

4. Make sure the `[mysqld]` section of the ‘`my.cnf`’ file on the master host includes a `log-bin` option. The section should also have a `server-id=master_id` option, where `master_id` must be an integer value from 1 to 2^32 - 1. For example:

   ```
   [mysqld]
   log-bin
   server-id=1
   ```

   If those options are not present, add them and restart the server.

5. Stop the server that is to be used as a slave server and add the following to its ‘`my.cnf`’ file:

   ```
   [mysqld]
   server-id=slave_id
   ```

   The `slave_id` value, like the `master_id` value, must be an integer value from 1 to 2^32 - 1. In addition, it is very important that the ID of the slave be different than the ID of the master. For example:

   ```
   [mysqld]
   server-id=2
   ```

   If you are setting up multiple slaves, each one must have a `server-id` value that differs from that of the master and from each of the other slaves. Think of `server-id` values

as something similar to IP addresses: These IDs uniquely identify each server instance in the community of replication partners.

If you don't specify a `server-id` value, it will be set to 1 if you have not defined `master-host`, else it will be set to 2. Note that in the case of `server-id` omission, a master will refuse connections from all slaves, and a slave will refuse to connect to a master. Thus, omitting `server-id` is only good for backup with a binary log.

6. If you made a binary backup of the master server's data, copy it to the slave server's data directory before starting the slave. Make sure that the privileges on the files and directories are correct. The user which MySQL runs as needs to be able to read from and write to them, just as on the master.

   If you made a backup using `mysqldump`, start the slave first (see next step).

7. Start the slave server. If it has been replicating previously, start the slave server with the `--skip-slave-start` option. You also may want to start the slave server with the `--log-warnings` option. That way, you will get more messages about problems (for example, network or connection problems).

8. If you made a backup of the master server's data using `mysqldump`, load the dump file into the slave server:

   ```
   shell> mysql -u root -p < dump_file.sql
   ```

9. Execute the following command on the slave, replacing the values within `<>` with the actual values relevant to your system:

   ```
   mysql> CHANGE MASTER TO
       ->     MASTER_HOST='<master host name>',
       ->     MASTER_USER='<replication user name>',
       ->     MASTER_PASSWORD='<replication password>',
       ->     MASTER_LOG_FILE='<recorded log file name>',
       ->     MASTER_LOG_POS=<recorded log offset>;
   ```

   The following table lists the maximum string length for these variables:

`MASTER_HOST`	60
`MASTER_USER`	16
`MASTER_PASSWORD`	32
`MASTER_LOG_FILE`	255

10. Start the slave threads:

    ```
    mysql> START SLAVE;
    ```

After you have performed this procedure, the slave should connect to the master and catch up on any updates that have occurred since the snapshot was taken.

If you have forgotten to set `server-id` for the master, slaves will not be able to connect to it.

If you have forgotten to set `server-id` for the slave, you will get the following error in its error log:

```
Warning: one should set server_id to a non-0 value if master_host is set.
The server will not act as a slave.
```

You will also find error messages in the slave's error log if it is not able to replicate for any other reason.

Once a slave is replicating, you will find in its data directory one file called '`master.info`' and another called '`relay-log.info`'. The slave uses these two files to keep track of how much of the master's binary log it has processed. **Do not** remove or edit these files, unless you really know what you are doing and understand the implications. Even in that case, it is preferred that you use `CHANGE MASTER TO` command.

NOTE: The content of '`master.info`' overrides some options specified on the command-line or in '`my.cnf`' See Section 4.11.6 [Replication Options], page 369 for more details.

Once you have a snapshot, you can use it to set up other slaves by following the slave portion of the procedure just described. You do not need to take another snapshot of the master.

4.11.5 Replication Features and Known Problems

Here is an explanation of what is supported and what is not:

- Replication will be done correctly with `AUTO_INCREMENT`, `LAST_INSERT_ID()`, and `TIMESTAMP` values.
- The `USER()` and `LOAD_FILE()` functions are replicated without changes and will thus not work reliably on the slave. This is also true for `CONNECTION_ID()` in slave versions older than 4.1.1. The **new** `PASSWORD()` function in MySQL 4.1, is well replicated since 4.1.1 masters; your slaves must be 4.1.0 or above to replicate it. If you have older slaves and need to replicate `PASSWORD()` from your 4.1.x master, you must start your master with option `--old-password`.
- The `SQL_MODE`, `UNIQUE_CHECKS`, `SQL_SELECT_LIMIT`, `SQL_AUTO_IS_NULL` and `TABLE_TYPE` variables are not replicated yet. `FOREIGN_KEY_CHECKS` is replicated since version 4.0.14.
- You must use the same character set (`--default-character-set`) on the master and the slave. Otherwise, you may get duplicate key errors on the slave, because a key that is regarded as unique in the master character set may not be unique in the slave character set.
- If you are using transactional tables on the master and non-transactional tables (for the same tables) on the slave, you will get problems if the slave is stopped in the middle of a `BEGIN/COMMIT` block, as the slave will later start at the beginning of the `BEGIN` block. This issue is on our TODO and will be fixed in the near future.
- Update queries that use user variables are badly replicated in 3.23 and 4.0. This is fixed in 4.1. Note that user variable names are case insensitive starting from version 5.0, so you should take this into account when setting up replication between 5.0 and a previous version.
- The slave can connect to the master using SSL, if the master and slave are both 4.1.1 or newer.
- Though we have never heard of it actually occurring, it is theoretically possible for the data on the master and slave to become different if a query is designed in such a way that the data modification is non-deterministic, that is, left to the will of the query optimiser (which generally is not a good practice, even outside of replication!). For a detailed explanation, see Section 1.7.6.2 [Open bugs], page 44.

- Before MySQL 4.1.1, `FLUSH`, `ANALYZE`, `OPTIMIZE`, `REPAIR` commands are not stored in the binary log and thus are not replicated to the slaves. This is not normally a problem as these commands don't change anything. However, it does mean that if you update the MySQL privilege tables directly without using the `GRANT` statement and you replicate the `mysql` privilege database, you must do a `FLUSH PRIVILEGES` on your slaves to put the new privileges into effect. Also if you use `FLUSH TABLES` when renaming a `MyISAM` table involved in a `MERGE` table, you will have to issue `FLUSH TABLES` manually on the slave. Since MySQL 4.1.1, these commands are written to the binary log (except `FLUSH LOGS`, `FLUSH MASTER`, `FLUSH SLAVE`, `FLUSH TABLES WITH READ LOCK`) unless you specify `NO_WRITE_TO_BINLOG` (or its alias `LOCAL`). For a syntax example, see Section 4.6.4 [`FLUSH`], page 282.
- MySQL only supports one master and many slaves. Later we will add a voting algorithm to automatically change master if something goes wrong with the current master. We will also introduce "agent" processes to help do load balancing by sending `SELECT` queries to different slaves.
- Temporary tables are replicated with the exception of the case that you shut down slave server (not just slave thread) and you have some replicated temporary tables that are used in update statements that have not yet been executed on the slave. (If you shut down the slave, the temporary tables needed by those updates no longer are available when the slave starts again.) To avoid this problem, do not shut down the slave while it has temporary tables open. Instead, use this procedure:
  1. Issue a `STOP SLAVE` statement.
  2. Use `SHOW STATUS` to check the value of the `Slave_open_temp_tables` variable.
  3. If the value is 0, issue a `mysqladmin shutdown` command to shut down the slave.
  4. If the value is not 0, restart the slave threads with `START SLAVE`.
  5. Repeat the procedure later to see if you have better luck next time.

  We have plans to fix this problem in the near future.
- It is safe to connect servers in a circular master/slave relationship with `log-slave-updates` enabled. Note, however, that many queries will not work correctly in this kind of setup unless your client code is written to take care of the potential problems that can happen from updates that occur in different sequence on different servers.

  This means that you can do a setup like the following:

  ```
  A -> B -> C -> A
  ```

  Server IDs are encoded in the binary log events. A will know when an event it reads had originally been created by A, so A will not execute it and there will be no infinite loop. But this circular setup will work only if you only if you perform no conflicting updates between the tables. In other words, if you insert data in A and C, you should never insert a row in A that may have a conflicting key with a row insert in C. You should also not update the same rows on two servers if the order in which the updates are applied matters.
- If a query on the slave gets an error, the slave SQL thread will terminate, and a message will appear in the slave error log. You should then connect to the slave manually, fix the cause of the error (for example, non-existent table), and then run `START SLAVE`.

- If the connection to the master is lost, the slave will try to reconnect immediately. If that fails, the slave will retry every `master-connect-retry` seconds (default 60). Because of this, it is safe to shut down the master, and then restart it after a while. The slave will also be able to deal with network connectivity outages. However, the slave will notice the network outage only after receiving no data from the master for `slave_net_timeout` seconds. So if your outages are short, you may want to decrease `slave_net_timeout`. See Section 4.6.8.4 [`SHOW VARIABLES`], page 290.
- Shutting down the slave (cleanly) is also safe, as it keeps track of where it left off. Unclean shutdowns might produce problems, especially if disk cache was not synced before the system died. Your system fault tolerance will be greatly increased if you have a good UPS.
- Due to the non-transactional nature of MyISAM tables, it is possible to have a query that will only partially update a table and return an error code. This can happen, for example, on a multi-row insert that has one row violating a key constraint, or if a long update query is killed after updating some of the rows. If that happens on the master, the slave thread will exit and wait for the DBA to decide what to do about it unless the error code is legitimate and the query execution results in the same error code. If this error code validation behaviour is not desirable, some (or all) errors can be masked out (ignored) with the `--slave-skip-errors` option. This option is available starting with MySQL Version 3.23.47.
- If you update transactional tables from non-transactional tables inside a `BEGIN/COMMIT` segment, updates to the binary log may be out of sync if some thread changes the non-transactional table before the transaction commits. This is because the transaction is written to the binary log only when it's commited.
- Before version 4.0.15, any update to a non-transactional table is written to the binary log at once when the update is made while transactional updates are written on `COMMIT` or not written at all if you use `ROLLBACK`; you have to take this into account when updating both transactional tables and non-transactional tables in the same transaction if you are using binary logging for backups or replication. In version 4.0.15, we changed the logging behaviour for transactions that mix updates to transactional and non-transactional tables, which solves the problems (order of queries is good in binlog, and all needed queries are written to the binlog even in case of `ROLLBACK`). The problem which remains is when a second connection updates the non-transactional table while the first connection's transaction is not finished yet (wrong order can still occur, because the second connection's update will be written immediately after it is done).

The following table lists problems in MySQL 3.23 that are fixed in MySQL 4.0:

- `LOAD DATA INFILE` is handled properly, as long as the data file still resides on the master server at the time of update propagation.
- `LOAD LOCAL DATA INFILE` will be skipped.
- In 3.23 `RAND()` in updates does not replicate properly. Use `RAND(some_non_rand_expr)` if you are replicating updates with `RAND()`. You can, for example, use `UNIX_TIMESTAMP()` for the argument to `RAND()`. This is fixed in 4.0.

4.11.6 Replication Startup Options

On both the master and the slave you need to use the `server-id` option to establish a unique replication ID for each server. You should pick a unique integer in the range from 1 to 2^32 - 1 for each master and slave. Example: `server-id=3`

The options that you can use on the master server for controlling binary logging are all described in Section 4.10.4 [Binary log], page 351.

The following table describes the options you can use on slave servers. You can specify them on the command line or in an option file.

NOTE: Replication handles the following options in a special way:

- `--master-host`
- `--master-user`
- `--master-password`
- `--master-port`
- `--master-connect-retry`

If no '`master.info`' file exists when the slave server starts, it uses values for those options that are specified in option files or on the command line. This will occur when you start the server as a replication slave for the very first time, or you have run `RESET SLAVE` and shut down and restarted the slave server.

However, if the '`master.info`' file exists when the slave server starts, it uses the values in the file and **IGNORES** any values specified for those options in option files or on the command line.

Suppose you specify this option in your '`my.cnf`' file:

```
[mysqld]
master-host=this_host
```

The first time you start the server as a replication slave, it will read and use that option from the '`my.cnf`' file. The server will then record that value in the '`master.info`' file. The next time you start the server, it will read the master host value from the '`master.info`' file only. If you modify the '`my.cnf`' file to specify a different master host, it will have no effect. You must use `CHANGE MASTER TO` instead.

As of MySQL 4.1.1, the following options also are handled specially:

- `--master-ssl`
- `--master-ssl-ca`
- `--master-ssl-capath`
- `--master-ssl-cert`
- `--master-ssl-cipher`
- `--master-ssl-key`

The '`master.info`' file includes the values corresponding to those options. In addition, the 4.1.1 file format includes as its first line the number of lines in the file. If you upgrade an older server to 4.1.1, the '`master.info`' will be upgraded to the new format automatically when the new server starts. (If you downgrade a 4.1.1 or newer server to a version older

than 4.1.1, you should manually remove the first line before starting the older server for the first time.)

Because the server gives an existing '`master.info`' file precedence over the startup options just described, you might prefer not to use startup options for these values at all, and instead specify them by using the `CHANGE MASTER TO` statement. See Section 4.11.8.1 [`CHANGE MASTER TO`], page 378.

This example shows a more extensive use of startup options to configure a slave server:

```
[mysqld]
server-id=2
master-host=db-master.mycompany.com
master-port=3306
master-user=pertinax
master-password=freitag
master-connect-retry=60
report-host=db-slave.mycompany.com
```

The following list describes startup options for controlling replication:

`--log-slave-updates`
: Tells the slave to log the updates performed by its SQL thread to the slave's own binary log. Off by default. Of course, for this option to have any effect, the slave must be started with binary logging enabled (`--log-bin` option). `--log-slave-updates` is used when you want to chain replication servers. For example, you might want a setup like this:

  ```
  A -> B -> C
  ```

  That is, A serves as the master for the slave B, and B serves as the master for the slave C. For this to work, where B is both a master and a slave, you must start B with the `--log-slave-updates` option. A and B must both be started with binary logging enabled.

`--log-warnings`
: Makes the slave print more messages about what it is doing. For example, it will warn you that it succeeded in reconnecting after a network/connection failure, and warn you about how each slave thread started.

  This option is not limited to replication use only. It produces warnings across a spectrum of server activities.

`--master-host=host`
: Specify the hostname or IP address of the master replication server. If this option is not given, the slave thread will not be started. The value in '`master.info`' takes precedence if it can be read. Probably a better name for this options would have been something like `--bootstrap-master-host`, but it is too late to change now.

`--master-user=username`
: The username of the account that the slave thread uses for authentication when connecting to the master. The account must have the `REPLICATION SLAVE` privilege (prior to MySQL 4.0.2, it must have the `FILE` privilege instead). If

the master user is not set, user `test` is assumed. The value in '`master.info`' takes precedence if it can be read.

`--master-password=password`
: The password of the account that the slave thread uses for authentication when connecting to the master. If not set, an empty password is assumed. The value in '`master.info`' takes precedence if it can be read.

`--master-port=port_number`
: The port the master is listening on. If not set, the compiled setting of `MYSQL_PORT` is assumed. If you have not tinkered with `configure` options, this should be 3306. The value in '`master.info`' takes precedence if it can be read.

`--master-connect-retry=seconds`
: The number of seconds the slave thread sleeps before retrying to connect to the master in case the master goes down or the connection is lost. Default is 60. The value in '`master.info`' takes precedence if it can be read.

`--master-info-file=filename`
: Specifies the name to use for the file in which the slave records information about the master. The default name is '`mysql.info`' in the data directory.

`--master-ssl`
`--master-ssl-ca=file_name`
`--master-ssl-capath=directory_name`
`--master-ssl-cert=file_name`
`--master-ssl-cipher=cipher_list`
`--master-ssl-key=file_name`
: These options are used for setting up a secure replication connection to the master server using SSL. Their meanings are the same as the corresponding `--ssl`, `--ssl-ca`, `--ssl-capath`, `--ssl-cert`, `--ssl-cipher`, `--ssl-key` options described in Section 4.4.10.5 [SSL options], page 259.

  These options are operational as of MySQL 4.1.1.

`--max-relay-log-size=#`
: To rotate the relay log automatically. See Section 4.6.8.4 [`SHOW VARIABLES`], page 290.

`--relay-log=filename`
: To specify the location and name that should be used for relay logs. You can use this to have hostname-independant relay log names, or if your relay logs tend to be big (and you don't want to decrease `max_relay_log_size`) and you need to put them on some area different from the data directory, or if you want to increase speed by balancing load between disks.

`--relay-log-index=filename`
: To specify the location and name that should be used for the relay logs index file.

`--relay-log-info-file=filename`
: To give '`relay-log.info`' another name and/or to put it in another directory than the data directory.

`--relay-log-purge=0|1`

Disables/enables automatic purging of relay logs as soon as they are not needed any more. This is a global variable that can be dynamically changed with `SET GLOBAL RELAY_LOG_PURGE=0|1`. The default value is 1.

This option is available as of MySQL 4.1.1.

`--relay-log-space-limit=#`

To put an upper limit on the total size of all relay logs on the slave (a value of 0 means "unlimited"). This is useful if you have a small hard disk on your slave machine. When the limit is reached, the I/O thread pauses (does not read the master's binlog) until the SQL thread has caught up and deleted some now unused relay logs. Note that this limit is not absolute: there are cases where the SQL thread needs more events to be able to delete; in that case the I/O thread will overgo the limit until deletion becomes possible. Not doing so would cause a deadlock (which happens before MySQL 4.0.13). Users should not set `--relay-log-space-limit` to less than twice the value of `--max-relay-log-size` (or `--max-binlog-size` if `--max-relay-log-size` is 0) because in that case there are chances that when the I/O thread waits for free space because `--relay-log-space-limit` is exceeded, the SQL thread has no relay log to purge and so cannot satisfy the I/O thread, forcing the I/O thread to temporarily ignore `--relay-log-space-limit`.

`--replicate-do-table=db_name.table_name`

Tells the slave thread to restrict replication to the specified table. To specify more than one table, use the directive multiple times, once for each table. This will work for cross-database updates, in contrast to `--replicate-do-db`. Please read the notes that follow this option list.

`--replicate-ignore-table=db_name.table_name`

Tells the slave thread to not replicate any command that updates the specified table (even if any other tables may be update by the same command). To specify more than one table to ignore, use the directive multiple times, once for each table. This will work for cross-database updates, in contrast to `--replicate-ignore-db`. Please read the notes that follow this option list.

`--replicate-wild-do-table=db_name.table_name`

Tells the slave thread to restrict replication to queries where any of the updated tables match the specified wildcard pattern. To specify more than one table, use the directive multiple times, once for each table. This will work for cross-database updates. Please read the notes that follow this option list.

Example: `--replicate-wild-do-table=foo%.bar%` will replicate only updates that uses a table in any databases that start with `foo` and whose table names start with `bar`.

Note that if you do `--replicate-wild-do-table=foo%.%` then the rule will be propagated to `CREATE DATABASE` and `DROP DATABASE`, that is, these two statements will be replicated if the database name matches the database pattern (`foo%` here) (this magic is triggered by `%` being the table pattern).

`--replicate-wild-ignore-table=db_name.table_name`

Tells the slave thread to not replicate a query where any table matches the given wildcard pattern. To specify more than one table to ignore, use the directive multiple times, once for each table. This will work for cross-database updates. Please read the notes that follow this option list.

Example: `--replicate-wild-ignore-table=foo%.bar%` will not do updates to tables in databases that start with `foo` and whose table names start with `bar`.

Note that if you do `--replicate-wild-ignore-table=foo%.%` then the rule will be propagated to `CREATE DATABASE` and `DROP DATABASE`, that is, these two statements will not be replicated if the database name matches the database pattern (`foo%` here) (this magic is triggered by `%` being the table pattern).

`--replicate-do-db=database_name`

Tells the slave to restrict replication to commands where the current database (that is, the one selected by `USE`) is `database_name`. To specify more than one database, use the directive multiple times, once for each database. Note that this will not replicate cross-database queries such as `UPDATE some_db.some_table SET foo='bar'` while having selected a different or no database. If you need cross database updates to work, make sure you have 3.23.28 or later, and use `--replicate-wild-do-table=db_name.%`. Please read the notes that follow this option list.

Example of what does not work as you could expect it: if the slave is started with `--replicate-do-db=sales`, and you do `USE prices; UPDATE sales.january SET amount=amount+1000;`, this query will not be replicated.

If you need cross database updates to work, use `--replicate-wild-do-table=db_name.%` instead.

The main reason for this "just-check-the-current-database" behaviour is that it's hard from the command alone to know if a query should be replicated or not; for example if you are using multi-table-delete or multi-table-update commands that go across multiple databases. It's also very fast to just check the current database.

`--replicate-ignore-db=database_name`

Tells the slave to not replicate any command where the current database (that is, the one selected by `USE`) is `database_name`. To specify more than one database to ignore, use the directive multiple times, once for each database. You should not use this directive if you are using cross table updates and you don't want these update to be replicated. Please read the notes that follow this option list.

Example of what does not work as you could expect it: if the slave is started with `--replicate-ignore-db=sales`, and you do `USE prices; UPDATE sales.january SET amount=amount+1000;`, this query will be replicated.

If you need cross database updates to work, use `--replicate-wild-ignore-table=db_name.%` instead.

`--replicate-rewrite-db=from_name->to_name`

Tells the slave to translate the current database (that is, the one selected by `USE`) to `to_name` if it was `from_name` on the master. Only statements involving tables may be affected (`CREATE DATABASE`, `DROP DATABASE` won't), and only if `from_name` was the current database on the master. This will not work for cross-database updates. Note that the translation is done before `--replicate-*` rules are tested.

Example: `replicate-rewrite-db=master_db_name->slave_db_name`

`--report-host=host`

The hostname or IP number of the slave to be reported to the master during slave registration. Will appear in the output of `SHOW SLAVE HOSTS`. Leave unset if you do not want the slave to register itself with the master. Note that it is not sufficient for the master to simply read the IP number of the slave from the TCP/IP socket once the slave connects. Due to `NAT` and other routing issues, that IP may not be valid for connecting to the slave from the master or other hosts.

This option is available as of MySQL 4.0.0.

`--report-port=port_number`

Port for connecting to slave reported to the master during slave registration. Set it only if the slave is listening on a non-default port or if you have a special tunnel from the master or other clients to the slave. If not sure, leave this option unset.

This option is available as of MySQL 4.0.0.

`--skip-slave-start`

Tells the slave server not to start the slave threads on server startup. The user can start them later with `START SLAVE`.

`--slave_compressed_protocol=#`

If 1, then use compression on the slave/client protocol if both slave and master support this.

`--slave-load-tmpdir=filename`

This option is by default equal to the value of the `tmpdir` variable. When the slave SQL thread replicates a `LOAD DATA INFILE` command, it extracts the to-be-loaded file from the relay log into temporary files, then loads these into the table. If the file loaded on the master was huge, the temporary files on the slave will be huge, too; therefore you may wish/have to tell the slave to put the temporary files on some large disk different from `tmpdir`, using this option. In that case, you may also use the `--relay-log` option, as relay logs will be huge, too. `--slave-load-tmpdir` should point to a disk-based filesystem; not a memory-based one. Because the slave needs the temporary files used to replicate `LOAD DATA INFILE`) to survive a machine's reboot.

`--slave-net-timeout=#`

Number of seconds to wait for more data from the master before aborting the read, considering the connection broken and retrying to connect. The first retry

occurs immediately after timeout. The interval between retries is controlled by the `--master-connect-retry` option.

`--slave-skip-errors= [err_code1,err_code2,... | all]`

Tells the slave SQL thread to continue replication when a query returns an error from the provided list. Normally, replication will discontinue when an error is encountered, giving the user a chance to resolve the inconsistency in the data manually. Do not use this option unless you fully understand why you are getting the errors. If there are no bugs in your replication setup and client programs, and no bugs in MySQL itself, you should never get an abort with error. Indiscriminate use of this option will result in slaves being hopelessly out of sync with the master and you having no idea how the problem happened.

For error codes, you should use the numbers provided by the error message in your slave error log and in the output of `SHOW SLAVE STATUS`. A full list of error messages can be found in the source distribution in '`Docs/mysqld_error.txt`'. The server error codes also are listed at Section 12.1 [Error-returns], page 825.

You can (but should not) also use a very non-recommended value of `all` which will ignore all error messages and keep barging along regardless. Needless to say, if you use it, we make no promises regarding your data integrity. Please do not complain if your data on the slave is not anywhere close to what it is on the master in this case — you have been warned.

Examples:

```
--slave-skip-errors=1062,1053
--slave-skip-errors=all
```

Some of these options, like all `--replicate-*` options, can only be set at the slave server's startup, not on-the-fly. We plan to fix this.

Here is the order of evaluation of the `r--eplicate-*` rules, to decide if the query is going to be executed by the slave or ignored by it:

1. Are there some `--replicate-do-db` or `--replicate-ignore-db` rules?
   - Yes: test them like for `--binlog-do-db` and `--binlog-ignore-db` (see Section 4.10.4 [Binary log], page 351). What is the result of the test?
     - ignore the query: ignore it and exit.
     - execute the query: don't execute it immediately, defer the decision, go to step below.
   - No: go to step below.
2. Are there some `--replicate-*-table` rules?
   - No: execute the query and exit.
   - Yes: go to step below. Only tables which are to be updated will be compared to rules (`INSERT INTO sales SELECT * from prices`: only `sales` will be compared to rules). If several tables are to be updated (multi-table statement), the first matching table (matching "do" or "ignore") wins (that is, the first table is compared to rules, then if no decision could be taken the second table is compared to rules, etc).
3. Are there some `--replicate-do-table` rules?

- Yes: does the table match any of them?
  - Yes: execute the query and exit.
  - No: go to step below.
- No: go to step below.

4. Are there some `--replicate-ignore-table` rules?
   - Yes: does the table match any of them?
     - Yes: ignore the query and exit.
     - No: go to step below.
   - No: go to step below.
5. Are there some `--replicate-wild-do-table` rules?
   - Yes: does the table match any of them?
     - Yes: execute the query and exit.
     - No: go to step below.
   - No: go to step below.
6. Are there some `--replicate-wild-ignore-table` rules?
   - Yes: does the table match any of them?
     - Yes: ignore the query and exit.
     - No: go to step below.
   - No: go to step below.
7. No `--replicate-*-table` rule was matched. Is there another table to test against these rules?
   - Yes: loop.
   - No: we have tested all tables to be updated, could not match any rule. Are there `--replicate-do-table` or `--replicate-wild-do-table` rules ?
     - Yes: ignore the query and exit.
     - No: execute the query and exit.

4.11.7 SQL Statements for Controlling Master Servers

Replication can be controlled through the SQL interface. This section discusses statements for managing master replication servers. Section 4.11.8 [Replication Slave SQL], page 378 discusses statements for managing slave servers.

4.11.7.1 PURGE MASTER LOGS

```
PURGE {MASTER|BINARY} LOGS TO 'log_name'
PURGE {MASTER|BINARY} LOGS BEFORE 'date'
```

Deletes all the binary logs listed in the log index that are strictly prior to the specified log or date. The logs also are removed from this list recorded in the log index file, so that the given log now becomes the first.

Example:

```
PURGE MASTER LOGS TO 'mysql-bin.010';
PURGE MASTER LOGS BEFORE '2003-04-02 22:46:26';
```

The `BEFORE` variant is available in MySQL 4.1; its date argument can be in `'YYYY-MM-DD hh:mm:ss'` format. `MASTER` and `BINARY` are synonyms, though `BINARY` can be used only as of MySQL 4.1.1.

If you have an active slave that is currently reading one of the logs you are trying to delete, this command does nothing and fails with an error. However, if you have a dormant slave, and happen to purge one of the logs it wants to read, the slave will be unable to replicate once it comes up. The command is safe to run while slaves are replicating. You do not need to stop them.

You must first check all the slaves with `SHOW SLAVE STATUS` to see which log they are reading, then do a listing of the logs on the master with `SHOW MASTER LOGS`, find the earliest log among all the slaves (if all the slaves are up to date, this will be the last log on the list), backup all the logs you are about to delete (optional) and purge up to the target log.

4.11.7.2 RESET MASTER

```
RESET MASTER
```

Deletes all binary logs listed in the index file, resetting the binlog index file to be empty.

This statement was named `FLUSH MASTER` before MySQL 3.23.26.

4.11.7.3 SET SQL_LOG_BIN

```
SET SQL_LOG_BIN = {0|1}
```

Disables or enables binary logging for the current connection (`SQL_LOG_BIN` is a session variable) if the client connects using an account that has the `SUPER` privilege. The statement is ignored if the client does not have that privilege.

4.11.7.4 SHOW BINLOG EVENTS

```
SHOW BINLOG EVENTS [ IN 'log_name' ] [ FROM pos ] [ LIMIT [offset,] row_count ]
```

Shows the events in the binary log. If you do not specify `'log_name'`, the first binary log will be displayed.

This statement is available as of MySQL 4.0

4.11.7.5 SHOW MASTER STATUS

```
SHOW MASTER STATUS
```

Provides status information on the binlog of the master.

4.11.7.6 SHOW MASTER LOGS

```
SHOW MASTER LOGS
```

Lists the binary logs on the master. You should use this command before using `PURGE MASTER LOGS` to find out how far you should go.

4.11.7.7 SHOW SLAVE HOSTS

```
SHOW SLAVE HOSTS
```

Displays a list of slaves currently registered with the master. Note that slaves not started with the `--report-host=slave_name` option will not be visible in that list.

4.11.8 SQL Statements for Controlling Slave Servers

Replication can be controlled through the SQL interface. This section discusses statements for managing slave replication servers. Section 4.11.7 [Replication Master SQL], page 376 discusses statements for managing master servers.

4.11.8.1 CHANGE MASTER TO

```
CHANGE MASTER TO master_def [, master_def] ...

master_def =
      MASTER_HOST = 'host_name'
    | MASTER_USER = 'user_name'
    | MASTER_PASSWORD = 'password'
    | MASTER_PORT = port_num
    | MASTER_CONNECT_RETRY = count
    | MASTER_LOG_FILE = 'master_log_name'
    | MASTER_LOG_POS = master_log_pos
    | RELAY_LOG_FILE = 'relay_log_name'
    | RELAY_LOG_POS = relay_log_pos
    | MASTER_SSL = {0|1}
    | MASTER_SSL_CA = 'ca_file_name'
    | MASTER_SSL_CAPATH = 'ca_directory_name'
    | MASTER_SSL_CERT = 'cert_file_name'
    | MASTER_SSL_KEY = 'key_file_name'
    | MASTER_SSL_CIPHER = 'cipher_list'
```

`CHANGE MASTER` is a "brutal" command. Before using it in production, you should read this entire description.

Changes the parameters that the slave server uses for connecting to and communicating with the master server. The possible `master_def` values are shown above.

The relay log options (`RELAY_LOG_FILE` and `RELAY_LOG_POS`) are available beginning with MySQL 4.0.

The SSL options (`MASTER_SSL`, `MASTER_SSL_CA`, `MASTER_SSL_CAPATH`, `MASTER_SSL_CERT`, `MASTER_SSL_KEY`, and `MASTER_SSL_CIPHER`) are available beginning with MySQL 4.1.1. You can change these options even on slaves that are compiled without SSL support. They will be saved to the '`master.info`' file but ignored until you use a server that has SSL support enabled.

For example:

```
mysql> CHANGE MASTER TO
    ->     MASTER_HOST='master2.mycompany.com',
    ->     MASTER_USER='replication',
    ->     MASTER_PASSWORD='bigs3cret',
    ->     MASTER_PORT=3306,
    ->     MASTER_LOG_FILE='master2-bin.001',
    ->     MASTER_LOG_POS=4,
    ->     MASTER_CONNECT_RETRY=10;
mysql> CHANGE MASTER TO
    ->     RELAY_LOG_FILE='slave-relay-bin.006',
    ->     RELAY_LOG_POS=4025;
```

You need to specify only the values that you want to change. The values that you omit will stay the same, with the exception that if you specify the master host or port, the slave will assume that the master server is different than before. (This is true even if you specify a host or port value value that is the same as the current value.) In this case, the old values of master binlog name and position are considered no longer applicable, so if you do not specify `MASTER_LOG_FILE` and `MASTER_LOG_POS` in the command, `MASTER_LOG_FILE=''` and `MASTER_LOG_POS=4` are silently appended to it.

`MASTER_LOG_FILE` and `MASTER_LOG_POS` are the coordinates at which the slave I/O thread should begin reading from the master the next time the thread starts. Because `CHANGE MASTER` deletes relay logs (see below), these are also the coordinates from which the slave SQL thread will begin executing the next time it starts.

`CHANGE MASTER` **deletes all relay logs** (and starts a new one), unless you specified `RELAY_LOG_FILE` or `RELAY_LOG_POS` (in that case relay logs will be kept; since MySQL 4.1.1 the `RELAY_LOG_PURGE` global variable will silently be set to 0). `CHANGE MASTER TO` updates '`master.info`' and '`relay-log.info`'.

Note: If the slave SQL thread is late by one or more queries compared to the I/O thread just before you issue `CHANGE MASTER` (a very common case when replication is running in high-load environments), then as `CHANGE MASTER` deletes relay logs containing these non-executed queries, and so replication then restarts **from the coordinates of the I/O thread**, **the SQL thread will have "leapt" over the non-executed queries**. Therefore, unless these queries were not important, you should do one of the following before issuing `CHANGE MASTER`:

- Ensure that the slave SQL thread has read all existing relay logs. You can achieve this by stopping only the slave I/O thread (`STOP SLAVE IO_THREAD`), then monitoring the progress of the running slave SQL thread with `SHOW SLAVE STATUS` and `SELECT MASTER_POS_WAIT()`, until it has caught up. This way there will be no leap for the slave SQL thread.
- Run `STOP SLAVE`, check where the slave SQL thread is in the master's binlog (using `SHOW SLAVE STATUS`, columns `Relay_Master_Log_File` and `Exec_master_log_pos`), and add a specification of these coordinates to the `CHANGE MASTER` command (`MASTER_LOG_FILE=..., MASTER_LOG_POS=...`). This way, you will instruct the slave I/O thread to start replication from the former coordinates of the slave SQL thread, so there will be no leap for the slave SQL thread.

If you don't take care of this issue, even a simple `STOP SLAVE; CHANGE MASTER TO MASTER_USER='repl'; START SLAVE;` run in the middle of a highly-loaded replication could break this replication and spoil the slave's data.

`CHANGE MASTER` is useful for setting up a slave when you have the snapshot of the master and have recorded the log and the offset on the master that the snapshot corresponds to. You can run `CHANGE MASTER TO MASTER_LOG_FILE='log_name_on_master', MASTER_LOG_POS=log_offset_on_master` on the slave after restoring the snapshot.

The first example above (`CHANGE MASTER TO MASTER_HOST='master2.mycompany.com'` etc) changes the master and master's binlog coordinates. This is when you want the slave to replicate the master. The second example, less frequently used, is when the slave has relay logs which, for some reason, you want the slave to execute again; to do this the master needn't be reachable, you just have to do `CHANGE MASTER TO` and start the SQL thread (`START SLAVE SQL_THREAD`). You can even use this out of a replication setup, on a standalone, slave-of-nobody server, to recover after a crash. Suppose your server has crashed and you have restored a backup. You want to replay the server's own binlogs (not relay logs, but regular binary logs), supposedly named '`myhost-bin.*`'. First make a backup copy of these binlogs in some safe place, in case you don't exactly follow the procedure below and accidentally have the server purge the binlogs. If using MySQL 4.1.1 or newer, do `SET GLOBAL RELAY_LOG_PURGE=0` for additional safety. Then start the server without `log-bin`, with a new (different from before) server ID, with `relay-log=myhost-bin` (to make the server believe that these regular binlogs are relay logs) and `skip-slave-start`, then issue these statements:

```
mysql> CHANGE MASTER TO
    ->     RELAY_LOG_FILE='myhost-bin.153',
    ->     RELAY_LOG_POS=410,
    ->     MASTER_HOST='some_dummy_string';
mysql> START SLAVE SQL_THREAD;
```

Then the server will read and execute its own binlogs, thus achieving crash recovery. Once the recovery is finished, run `STOP SLAVE`, shutdown the server, delete '`master.info`' and '`relay-log.info`', and restart the server with its original options. For the moment, specifying `MASTER_HOST` (even with a dummy value) is compulsory to make the server think it is a slave, and giving the server a new, different from before, server ID is also compulsory otherwise the server will see events with its ID and think it is in a circular replication setup and skip the events, which is unwanted. In the future we plan to add options to get rid of these small constraints.

4.11.8.2 LOAD DATA FROM MASTER

```
LOAD DATA FROM MASTER
```

Takes a snapshot of the master and copies it to the slave. Updates the values of `MASTER_LOG_FILE` and `MASTER_LOG_POS` so that the slave will start replicating from the correct position. Will honor table and database exclusion rules specified with `replicate-*` options.

Use of this statement is subject to the following conditions:

- It works only with `MyISAM` tables.

- It acquires a global read lock on the master while taking the snapshot, which prevents updates on the master during the load operation.

In the future, it is planned to make this statement work with `InnoDB` tables and to remove the need for global read lock by using the non-blocking online backup feature.

If you are loading big tables, you may have to increase the values of `net_read_timeout` and `net_write_timeout` on both your master and slave. See Section 4.6.8.4 [SHOW VARIABLES], page 290.

Note that `LOAD DATA FROM MASTER` does **NOT** copy any tables from the `mysql` database. This is to make it easy to have different users and privileges on the master and the slave.

This statement requires that the replication account that is used to connect to the master have `RELOAD` and `SUPER` privileges on the master, `SELECT` privileges on all master's tables you want to load. All master's tables on which the user has no `SELECT` privilege will be ignored by `LOAD DATA FROM MASTER`; this is because the master will hide them to the user: `LOAD DATA FROM MASTER` calls `SHOW DATABASES` to know the master databases to load, but `SHOW DATABASES` returns only databases on which the user has some privilege. See Section 4.6.8.1 [Show database info], page 285. On the slave's side, the user which issues `LOAD DATA FROM MASTER` should have grants to drop and create the involved databases and tables.

4.11.8.3 LOAD TABLE tbl_name FROM MASTER

```
LOAD TABLE tbl_name FROM MASTER
```

Downloads a copy of the table from master to the slave. This statement is mplemented mainly for debugging of `LOAD DATA FROM MASTER`. Requires that the account used for connecting to the master server have `RELOAD` and `SUPER` privileges on the master, and `SELECT` on the master table to load. On the slave's side, the user which issues `LOAD TABLE FROM MASTER` should have grants to drop and create the table. Please read the timeout notes in the description of `LOAD DATA FROM MASTER` above; they apply here, too. Please also read the limitations of `LOAD DATA FROM MASTER` above, they apply too (for example, `LOAD TABLE FROM MASTER` only works for `MyISAM` tables).

4.11.8.4 MASTER_POS_WAIT()

```
SELECT MASTER_POS_WAIT('master_log_file', master_log_pos)
```

This is a function, not a command. It is used to ensure that the slave has reached (read and executed up to) a given position in the master's binlog. See Section 6.3.6.2 [Miscellaneous functions], page 515 for a full description.

4.11.8.5 RESET SLAVE

```
RESET SLAVE
```

Makes the slave forget its replication position in the master's binlogs. This statement is meant to be used for a clean start: it deletes the '`master.info`' and '`relay-log.info`' files, all the relay logs, and starts a new relay log. **Note:** All relay logs are deleted, even if they had not been totally executed by the slave SQL thread. (This is a condition likely to exist on a replication slave that is highly-loaded, or if you have issued a `STOP SLAVE` statement.)

Connection information stored in the '`master.info`' file is immediately reset to the values specified in the corresponding startup options, if they were specified. This information includes values such as master host, master port, master user, and master password. If the slave SQL thread was in the middle of replicating temporary tables when it was stopped, and `RESET SLAVE` is issued, these replicated temporary tables are deleted on the slave.

This statement was named `FLUSH SLAVE` before MySQL 3.23.26.

4.11.8.6 SET GLOBAL SQL_SLAVE_SKIP_COUNTER

```
SET GLOBAL SQL_SLAVE_SKIP_COUNTER = n
```

Skip the next `n` events from the master. This is useful for recovering from replication stops caused by a statement.

This statement is valid only when the slave thread is not running. Otherwise, it produces an error.

Before MySQL 4.0, omit the `GLOBAL` keyword from the statement.

4.11.8.7 SHOW SLAVE STATUS

```
SHOW SLAVE STATUS
```

Provides status information on essential parameters of the slave threads. If you issue this statement using the `mysql` client, you can use a `\G` statement terminator rather than semicolon to get a more readable vertical layout:

```
mysql> SHOW SLAVE STATUS\G
*************************** 1. row ***************************
       Slave_IO_State: Waiting for master to send event
          Master_Host: localhost
          Master_User: root
          Master_Port: 3306
        Connect_retry: 3
      Master_Log_File: gbichot-bin.005
  Read_Master_Log_Pos: 79
       Relay_Log_File: gbichot-relay-bin.005
        Relay_Log_Pos: 548
Relay_Master_Log_File: gbichot-bin.005
     Slave_IO_Running: Yes
    Slave_SQL_Running: Yes
      Replicate_do_db:
  Replicate_ignore_db:
           Last_errno: 0
           Last_error:
         Skip_counter: 0
  Exec_master_log_pos: 79
      Relay_log_space: 552
      Until_condition: None
       Until_Log_File:
```

```
           Until_Log_pos: 0
       Master_SSL_Allowed: No
       Master_SSL_CA_File:
       Master_SSL_CA_Path:
          Master_SSL_Cert:
        Master_SSL_Cipher:
           Master_SSL_Key:
    Seconds_behind_master: 8
```

Depending on your version of MySQL, you may not see all the fields just shown. In particular, several fields are present only as of MySQL 4.1.1.

The fields displayed by `SHOW SLAVE STATUS` have the following meanings:

`Slave_IO_State`
: A copy of the `State` column of the output of `SHOW PROCESSLIST` for the slave I/O thread; will tell you if this thread is trying to connect to the master, waiting for events from the master, reconnecting to the master, etc. Possible states are listed in Section 4.11.2 [Replication Implementation], page 356. Looking at this column is necessary because, for example, the thread can be running but unsuccessfully trying to connect to the master: only this column will make you aware of the connection problem. On the opposite, the state of the SQL thread is not copied, because things are simpler for this thread: if it's running, there is no problem; if it's not, you will find the error in the `Last_error` column (described below).

  This field is present beginning with MySQL 4.1.1.

`Master_Host`
: The current master host.

`Master_User`
: The current user used to connect to the master.

`Master_Port`
: The current master port.

`Connect_Retry`
: The current value of `master-connect-retry`.

`Master_Log_File`
: The name of the master's binlog file from which the I/O thread is currently reading.

`Read_Master_Log_Pos`
: The position which the I/O thread has read up to in this master's binlog.

`Relay_Log_File`
: The name of the relay log file from which the SQL thread is currently reading and executing.

`Relay_Log_Pos`
: The position which the SQL thread has read and executed up to in this relay log.

`Relay_Master_Log_File`
: The name of the master's binlog file that contains the last event executed by the SQL thread.

`Slave_IO_Running`
: Tells whether or not the I/O thread is started.

`Slave_SQL_Running`
: Tells whether or not the SQL thread is started.

`Replicate_do_db, Replicate_ignore_db`
: The lists of the databases that were specified with the `--replicate-do-db` and `--replicate-ignore-db` options, if any

`Replicate_do_table, Replicate_ignore_table, Replicate_wild_do_table, Replicate_wild_ignore_table`
: The lists of tables that were specified with the `--replicate-do-table`, `--replicate-ignore-table`, `--replicate-wild-do-table`, and `--replicate-wild-ignore_table` options, if any

  These fields are present beginning with MySQL 4.1.1.

`Last_errno`
: The error number returned by the most recently executed query. A value of 0 means "no error".

`Last_error`
: The error message returned by the most recently executed query. For example:

```
Last_errno: 1051
Last_error: error 'Unknown table 'z'' on query 'drop table z'
```

  The message indicates that the table `z` existed on the master and was dropped there, but it did not exist on the slave, so `DROP TABLE` failed on the slave. (This might occur if you forgot to copy the table to the slave when setting up replication.)

  The empty string means "no error". If the `Last_error` value is not empty, it will also appear as a message in the slave's error log.

`Skip_counter`
: The last used value for `SQL_SLAVE_SKIP_COUNTER`.

`Exec_master_log_pos`
: The position in the master's binlog (`Relay_Master_Log_File`) of the last event executed by the SQL thread. (`Relay_Master_Log_File`,`Exec_master_log_pos`) in the master's binlog corresponds to (`Relay_Log_File`,`Relay_Log_Pos`) in the relay log).

`Relay_log_space`
: The total combined size of all existing relay logs.

`Until_condition, Until_Log_File, Until_Log_pos`
: The values specified in the `UNTIL` clause of the `START SLAVE` statement.

  `Until_condition` has these values:

- `None` if no `UNTIL` clause was specified
- `Master` if the slave is reading until a given position in the master's binlogs
- `Relay` if the slave is reading until a given position in its relay logs

`Until_Log_File` and `Until_Log_pos` indicate the log filename and position values that define the point at which the SQL thread will stop executing.

These fields are present beginning with MySQL 4.1.1.

`Master_SSL_Allowed, Master_SSL_CA_File, Master_SSL_CA_Path, Master_SSL_Cert, Master_SSL_Cipher, Master_SSL_Key`

These fields show the The SSL parameters used by the slave to connect to the master, if any.

`Master_SSL_Allowed` has these values:

- `Yes` if an SSL connection to the master is allowed
- `No` if an SSL connection to the master is not allowed
- `Ignored` if an SSL connection is allowed by the slave server does not have SSL support enabled

The values of the other fields correspond to the values of the `--master-ca`, `--master-capath`, `--master-cert`, `--master-cipher`, and `--master-key` options.

These fields are present beginning with MySQL 4.1.1.

`Seconds_behind_master`

The number of seconds that have elapsed since the timestamp of the last master's event executed by the slave SQL thread. Will be `NULL` when no event has been executed yet, or after `CHANGE MASTER` and `RESET SLAVE`. This column can be used to know how "late" your slave is. It will work even though your master and slave don't have identical clocks.

This field is present beginning with MySQL 4.1.1.

4.11.8.8 START SLAVE

```
START SLAVE [thread_name [, thread_name] ... ]
START SLAVE [SQL_THREAD] UNTIL
    MASTER_LOG_FILE = 'log_name', MASTER_LOG_POS = log_pos
START SLAVE [SQL_THREAD] UNTIL
    RELAY_LOG_FILE = 'log_name', RELAY_LOG_POS = log_pos

thread_name = IO_THREAD | SQL_THREAD
```

`START SLAVE` with no options starts both of the slave threads. The I/O thread reads queries from the master server and stores them in the relay log. The SQL thread reads the relay log and executes the queries. Note that if `START SLAVE` succeeds in starting the slave threads it will return without any error. But even in that case it might be that slave threads start and then later stop (because they don't manage to connect to the master or read his binlogs or any other problem). `START SLAVE` will not warn you about this. You must check your

slave's error log for error messages generated by the slave threads, or check that these are running fine with `SHOW SLAVE STATUS`.

As of MySQL 4.0.2, you can add `IO_THREAD` or `SQL_THREAD` options to the statement to name which of the threads to start.

As of MySQL 4.1.1, an `UNTIL` clause may be added to specify that the slave should start until the SQL thread reaches a given point in the master binlogs or in the slave relay logs. When the SQL thread reaches that point, it stops. If the `SQL_THREAD` option is specified in the statement, it starts only the SQL thread. Otherwise, it starts both slave threads. If the SQL thread is already running, the `UNTIL` clause is ignored and a warning is issued.

With an `UNTIL` clause, you must specify both a log filename and position. Do not mix master and relay log options.

Any `UNTIL` condition is reset by a subsequent `STOP SLAVE` statement, or a `START SLAVE` statement that includes no `UNTIL` clause, or a server restart.

The `UNTIL` clause can be useful for debugging replication, or to cause replication to proceed until just before the point where you want to avoid having the slave replicated a statement. For example, if an unwise `DROP TABLE` statement was executed on the master, you can use `UNTIL` to tell the slave to execute up to that point but no farther. To find what the event is, use `mysqlbinlog` with the master logs or relay logs, or by using a `SHOW BINLOG EVENTS` statement.

If you are using `UNTIL` to have the slave process replicated queries in sections, it is recommended that you start the slave with the `--skip-slave-start` option to prevent the SQL thread from running when the slave starts. It's probably best to use this option in an option file rather than on the command line, so that an unexpected server restart does not cause it to be forgotten.

The `SHOW SLAVE STATUS` statement includes output fields that display the current values of the `UNTIL` condition.

This command is called `SLAVE START` before MySQL 4.0.5. For the moment, `SLAVE START` is still accepted for backward compatibility, but is deprecated.

4.11.8.9 STOP SLAVE

```
STOP SLAVE [thread_name [, thread_name] ... ]

thread_name = IO_THREAD | SQL_THREAD
```

Stops the slave threads. Like `START SLAVE`, this statement may be used with the `IO_THREAD` and `SQL_THREAD` options to name the thread or threads to stop.

This command is called `SLAVE STOP` before MySQL 4.0.5. For the moment, `SLAVE STOP` is still accepted for backward compatibility, but is deprecated.

4.11.9 Replication FAQ

Q: How do I configure a slave if the master is already running and I do not want to stop it?

A: There are several options. If you have taken a backup of the master at some point and recorded the binlog name and offset (from the output of `SHOW MASTER STATUS`) corresponding to the snapshot, do the following:

1. Make sure the slave is assigned a unique server ID.
2. Execute the following statement on the slave, filling in appropriate values for each parameter:

```
mysql> CHANGE MASTER TO
    ->     MASTER_HOST='master_host-name',
    ->     MASTER_USER='master_user_name',
    ->     MASTER_PASSWORD='master_pass',
    ->     MASTER_LOG_FILE='recorded_log_name',
    ->     MASTER_LOG_POS=recorded_log_pos;
```

3. Execute `START SLAVE` on the slave.

If you do not have a backup of the master already, here is a quick way to do it consistently:

1. `FLUSH TABLES WITH READ LOCK`
2. `gtar zcf /tmp/backup.tar.gz /var/lib/mysql` (or a variation of this)
3. `SHOW MASTER STATUS` - make sure to record the output - you will need it later
4. `UNLOCK TABLES`

An alternative is taking an SQL dump of the master instead of a binary copy like above; for this you can use `mysqldump --master-data` on your master and later run this SQL dump into your slave. However, this is slower than makeing a binary copy.

No matter which of the two methods you use, afterwards follow the instructions for the case when you have a snapshot and have recorded the log name and offset. You can use the same snapshot to set up several slaves. As long as the binary logs of the master are left intact, you can wait as long as several days or in some cases maybe a month to set up a slave once you have the snapshot of the master. In theory the waiting gap can be infinite. The two practical limitations is the diskspace of the master getting filled with old logs, and the amount of time it will take the slave to catch up.

You can also use `LOAD DATA FROM MASTER`. This is a convenient command that takes a snapshot, restores it to the slave, and adjusts the log name and offset on the slave all at once. In the future, `LOAD DATA FROM MASTER` will be the recommended way to set up a slave. Be warned, howerver, that the read lock may be held for a long time if you use this command. It is not yet implemented as efficiently as we would like to have it. If you have large tables, the preferred method at this time is still with a local `tar` snapshot after executing `FLUSH TABLES WITH READ LOCK`.

Q: Does the slave need to be connected to the master all the time?

A: No, it does not. The slave can go down or stay disconnected for hours or even days, then reconnect and catch up on the updates. For example, you can set up a master/slave relationship over a dial-up link where the link is up only sporadically and for short periods of time. The implication of this is that at any given time the slave is not guaranteed to be in sync with the master unless you take some special measures. In the future, we will have the option to block the master until at least one slave is in sync.

Q: How do I know how late a slave is compared to the master? In other words, how do I know the date of the last query replicated by the slave?

A: If the slave is 4.1.1 or newer, read the `Seconds_behind_master` column in `SHOW SLAVE STATUS`. For older versions, the following applies. This is possible only if the slave SQL

thread exists (that is, if it shows up in `SHOW PROCESSLIST`, see Section 4.11.3 [Replication Implementation Details], page 357) (in MySQL 3.23: if the slave thread exists, that is, shows up in `SHOW PROCESSLIST`), and if it has executed at least one event from the master. Indeed, when the slave SQL thread executes an event read from the master, this thread modifies its own time to the event's timestamp (this is why `TIMESTAMP` is well replicated). So in the `Time` column in the output of `SHOW PROCESSLIST`, the number of seconds displayed for the slave SQL thread is the number of seconds between the timestamp of the last replicated event and the real time of the slave machine. You can use this to determine the date of the last replicated event. Note that if your slave has been disconnected from the master for one hour, then reconnects, you may immediately see `Time` values like 3600 for the slave SQL thread in `SHOW PROCESSLIST`... This would be because the slave is executing queries that are one hour old.

Q: How do I force the master to block updates until the slave catches up?

A: Use the following procedure:

1. On the master, execute these commands:

   ```
   mysql> FLUSH TABLES WITH READ LOCK;
   mysql> SHOW MASTER STATUS;
   ```

   Record the log name and the offset from the output of the `SHOW` statement.

2. On the slave, issue this command, where the replication coordinates that are the arguments to the `MASTER_POS_WAIT()` function are the values recorded in the previous step:

   ```
   mysql> SELECT MASTER_POS_WAIT('log_name', log_offset);
   ```

   The `SELECT` statement will block until the slave reaches the specified log file and offset. At that point, the slave will be in sync with the master and the statement will return.

3. On the master, issue the following statement to allow the master to begin processing updates again:

   ```
   mysql> UNLOCK TABLES;
   ```

Q: What issues should I be aware of when setting up two-way replication?

A: MySQL replication currently does not support any locking protocol between master and slave to guarantee the atomicity of a distributed (cross-server) update. In other words, it is possible for client A to make an update to co-master 1, and in the meantime, before it propagates to co-master 2, client B could make an update to co-master 2 that will make the update of client A work differently than it did on co-master 1. Thus, when the update of client A will make it to co-master 2, it will produce tables that are different than what you have on co-master 1, even after all the updates from co-master 2 have also propagated. So you should not co-chain two servers in a two-way replication relationship, unless you are sure that your updates can safely happen in any order, or unless you take care of mis-ordered updates somehow in the client code.

You must also realise that two-way replication actually does not improve performance very much (if at all), as far as updates are concerned. Both servers need to do the same amount of updates each, as you would have one server do. The only difference is that there will be a little less lock contention, because the updates originating on another server will be serialised in one slave thread. Even so, this benefit might be offset by network delays.

Q: How can I use replication to improve performance of my system?

A: You should set up one server as the master and direct all writes to it. Then configure as many slaves as you have the money and rackspace for, and distribute the reads among the master and the slaves. You can also start the slaves with `--skip-bdb`, `--low-priority-updates` and `--delay-key-write=ALL` to get speed improvements for the slave. In this case the slave will use non-transactional `MyISAM` tables instead of `BDB` tables to get more speed.

Q: What should I do to prepare client code in my own applications to use performance-enhancing replication?

A: If the part of your code that is responsible for database access has been properly abstracted/modularised, converting it to run with a replicated setup should be very smooth and easy. Just change the implementation of your database access to send all writes the the master, and to send reads to either the master or a slave. If your code does not have this level of abstraction, setting up a replicated system will give you the opportunity and motivation to it clean up. You should start by creating a wrapper library or module with the following functions:

- `safe_writer_connect()`
- `safe_reader_connect()`
- `safe_reader_query()`
- `safe_writer_query()`

`safe_` in each function name means that the function will take care of handling all the error conditions. You can, of course, use different names for the functions. The important thing is to have a unified interface for connecting for reads, connecting for writes, doing a read, and doing a write.

You should then convert your client code to use the wrapper library. This may be a painful and scary process at first, but it will pay off in the long run. All applications that use the approach just described will be able to take advantage of a master/slave configuration, even one involving multiple slaves. The code will be a lot easier to maintain, and adding troubleshooting options will be trivial. You will just need to modify one or two functions, for example, to log how long each query took, or which query, among your many thousands, gave you an error.

If you have written a lot of code already, you may want to automate the conversion task by using the `replace` utility that comes with the standard distribution of MySQL, or just write your own Perl script. Hopefully, your code follows some recognisable pattern. If not, then you are probably better off rewriting it anyway, or at least going through and manually beating it into a pattern.

Q: When and how much can MySQL replication improve the performance of my system?

A: MySQL replication is most beneficial for a system with frequent reads and infrequent writes. In theory, by using a single-master/multiple-slave setup, you can scale the system by adding more slaves until you either run out of network bandwidth, or your update load grows to the point that the master cannot handle it.

In order to determine how many slaves you can get before the added benefits begin to level out, and how much you can improve performance of your site, you need to know your query patterns, and empirically (by benchmarking) determine the relationship between the throughput on reads (reads per second, or `max_reads`) and on writes (`max_writes`) on a

typical master and a typical slave. The example here will show you a rather simplified calculation of what you can get with replication for a hypothetical system.

Let's say that system load consists of 10% writes and 90% reads, and we have determined `max_reads` to be 1200 - 2 * `max_writes`. In other words, the system can do 1200 reads per second with no writes, the average write is twice as slow as average read, and the relationship is linear. Let us suppose that the master and each slave have the same capacity, and that we have 1 master and N slaves. Then we have for each server (master or slave):

`reads = 1200 - 2 * writes` (from benchmarks)

`reads = 9* writes / (N + 1)` (reads split, but writes go to all servers)

`9*writes/(N+1) + 2 * writes = 1200`

`writes = 1200/(2 + 9/(N+1)`

This analysis yields the following conclusions:

- If N = 0 (which means we have no replication), our system can handle 1200/11, about 109 writes per second (which means we will have 9 times as many reads due to the nature of our application).
- If N = 1, we can get up to 184 writes per second.
- If N = 8, we get up to 400.
- If N = 17, 480 writes.
- Eventually, as N approaches infinity (and our budget negative infinity), we can get very close to 600 writes per second, increasing system throughput about 5.5 times. However, with only 8 servers, we increased it almost 4 times already.

Note that these computations assume infinite network bandwidth and neglect several other factors that could turn out to be significant on your system. In many cases, you may not be able to perform a computation similar to the one above that will accurately predict what will happen on your system if you add N replication slaves. However, answering the following questions should help you decide whether and how much replication will improve the performance of your system:

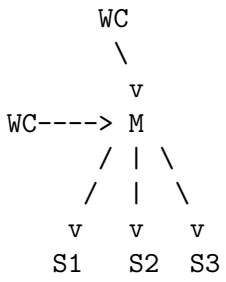
- What is the read/write ratio on your system?
- How much more write load can one server handle if you reduce the reads?
- How many slaves do you have bandwidth available for on your network?

Q: How can I use replication to provide redundancy/high availability?

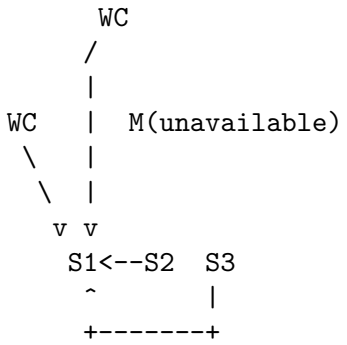
A: With the currently available features, you would have to set up a master and a slave (or several slaves), and write a script that will monitor the master to see if it is up, and instruct your applications and the slaves of the master change in case of failure. Some suggestions:

- To tell a slave to change the master, use the `CHANGE MASTER TO` command.
- A good way to keep your applications informed as to the location of the master is by having a dynamic DNS entry for the master. With `bind` you can use '`nsupdate`' to dynamically update your DNS.
- You should run your slaves with the `--log-bin` option and without `--log-slave-updates`. This way the slave will be ready to become a master as soon as you issue `STOP SLAVE`; `RESET MASTER`, and `CHANGE MASTER TO` on the other slaves. For example, consider you have the following setup ("M" means the master, "S" the slaves, "WC"

the clients that issue database writes and reads; clients that issue only database reads are not represented, because they need not switch):



S1 (like S2 and S3) is a slave running with `--log-bin` and without `--log-slave-updates`. As the only writes executed on S1 are those replicated from M, the binary log on S1 is **empty** (remember, S1 runs without `--log-slave-updates`). Then, for some reason, M becomes unavailable, and you want S1 to become the new master (that is, direct all WC to S1, and make S2 and S3 replicate S1). No WC accesses M. Instruct all WC to direct their queries to S1. From now on, all queries sent by WC to S1 are written to the binary log of S1. The binary log of S1 contains exactly every writing query sent to S1 since M died. On S2 (and S3) do `STOP SLAVE`, `CHANGE MASTER TO MASTER_HOST='S1'` (where `'S1'` is replaced by the real hostname of S1). To `CHANGE MASTER`, add all information about how to connect to S1 from S2 or S3 (user, password, port). In `CHANGE MASTER`, no need to specify the name of S1's binary log or binary log position to read from: we know it is the first binary log, from position 4, and these are the defaults of `CHANGE MASTER`. Finally do `START SLAVE` on S2 and S3, and now you have this:



When M is up again, you just have to issue on it the same `CHANGE MASTER` as the one issued on S2 and S3, so that M becomes a slave of S1 and picks all the WC writes it has missed while it was down. Now to make M a master again (because it is the most powerful machine, for example), follow the preceding procedure as if S1 was unavailable and M was to be the new master; then during the procedure don't forget to run `RESET MASTER` on M before making S1, S2, S3 slaves of M, or they may pick old WC writes from before M's unavailibility.

We are currently working on integrating an automatic master election system into MySQL, but until it is ready, you will have to create your own monitoring tools.

4.11.10 Troubleshooting Replication

If you have followed the instructions, and your replication setup is not working, first check the following:

- **Check the error log for messages**. Many users have lost time by not doing this early enough.
- Is the master logging to the binary log? Check with `SHOW MASTER STATUS`. If it is, `Position` will be non-zero. If not, verify that you have given the master `log-bin` option and have set `server-id`.
- Is the slave running? Do `SHOW SLAVE STATUS` and check that the `Slave_IO_Running` and `Slave_SQL_Running` values are both `Yes`. If not, verify slave options
- If the slave is running, did it establish a connection with the master? Do `SHOW PROCESSLIST`, find the I/O and SQL threads (see Section 4.11.3 [Replication Implementation Details], page 357 to see how they display), and check their `State` column. If it says `Connecting to master`, verify the privileges for the replication user on the master, master host name, your DNS setup, whether the master is actually running, whether it is reachable from the slave.
- If the slave was running before but now has stopped, the reason usually is that some query that succeeded on the master failed on the slave. This should never happen if you have taken a proper snapshot of the master, and never modify the data on the slave outside of the slave thread. If it does, it is a bug; read below on how to report it.
- If a query on that succeeded on the master refuses to run on the slave, and it does not feasible to do a full database resync (that is, to delete the slave's database and copy a new snapshot from the master), try the following:
  - First see if the slave's table was different from the master's. Understand how it happened (it may be a bug: read the Changelogs in the online MySQL manual as `http://www.mysql.com/documentation` to check if this is a known bug and if it is fixed yet). Then make the slave's table identical to the master's and run `START SLAVE`.
  - If the above does not work or does not apply, try to understand if it would be safe to make the update manually (if needed) and then ignore the next query from the master.
  - If you have decided you can skip the next query, issue the following statements:

    ```
    mysql> SET GLOBAL SQL_SLAVE_SKIP_COUNTER = n;
    mysql> START SLAVE;
    ```

    The value of `n` should be 1 if the query does not use `AUTO_INCREMENT` or `LAST_INSERT_ID()`. Otherwise, the value should be 2. The reason for using a value of 2 for queries that use `AUTO_INCREMENT` or `LAST_INSERT_ID()` is that they take two events in the binary log of the master.
  - Make sure you are not running into an old bug by upgrading to the most recent version.
  - If you are sure the slave started out perfectly in sync with the master, and no one has updated the tables involved outside of slave thread, report the bug.

4.11.11 Reporting Replication Bugs

When you have determined that there is no user error involved, and replication still either does not work at all or is unstable, it is time to send us a bug report. We need to get as much information as possible from you to be able to track down the bug. Please do spend some time and effort preparing a good bug report.

If you have a repeatable way to demonstrate the bug, please enter it into our bugs database at `http://bugs.mysql.com/`. If you have a phantom problem (one that you cannot duplicate "at will"), use the following procedure:

1. Verify that no user error is involved. For example, if you update the slave outside of the slave thread, the data will go out of sync, and you can have unique key violations on updates. In this case, the slave thread will stop and wait for you to clean up the tables manually to bring them in sync. This is not a replication problem; it is a problem of outside interference that causes replication to fail.
2. Run the slave with the `--log-slave-updates` and `--log-bin` options. They will cause the slave to log the updates that it receives in its own binlogs.
3. Save all evidence before resetting the replication state. If we have no information or only sketchy information, it will take us longer to track down the problem. The evidence you should collect is:
   - All binary logs from the master
   - All binary logs from the slave
   - The output of `SHOW MASTER STATUS` from the master at the time you have discovered the problem
   - The output of `SHOW SLAVE STATUS` from the master at the time you have discovered the problem
   - Error logs from the master and on the slave
4. Use `mysqlbinlog` to examine the binary logs. The following should be helpful to find the trouble query, for example:

```
mysqlbinlog -j pos_from_slave_status /path/to/log_from_slave_status | head
```

Once you have collected the evidence for the phantom problem, try hard to isolate it into a separate test case first. Then enter the problem into our bugs database at `http://bugs.mysql.com/` with as much information as possible.

5 MySQL Optimisation

Optimisation is a complicated task because it ultimately requires understanding of the whole system. While it may be possible to do some local optimisations with small knowledge of your system or application, the more optimal you want your system to become the more you will have to know about it.

This chapter will try to explain and give some examples of different ways to optimise MySQL. Remember, however, that there are always some (increasingly harder) additional ways to make the system even faster.

5.1 Optimisation Overview

The most important part for getting a system fast is of course the basic design. You also need to know what kinds of things your system will be doing, and what your bottlenecks are.

The most common bottlenecks are:

- Disk seeks. It takes time for the disk to find a piece of data. With modern disks in 1999, the mean time for this is usually lower than 10ms, so we can in theory do about 100 seeks a second. This time improves slowly with new disks and is very hard to optimise for a single table. The way to optimise this is to spread the data on more than one disk.
- Disk reading/writing. When the disk is at the correct position we need to read the data. With modern disks in 1999, one disk delivers something like 10-20 MB. This is easier to optimise than seeks because you can read in parallel from multiple disks.
- CPU cycles. When we have the data in main memory (or if it already were there) we need to process it to get to our result. Having small tables compared to the memory is the most common limiting factor. But then, with small tables speed is usually not the problem.
- Memory bandwidth. When the CPU needs more data than can fit in the CPU cache the main memory bandwidth becomes a bottleneck. This is an uncommon bottleneck for most systems, but one should be aware of it.

5.1.1 MySQL Design Limitations/Tradeoffs

When using the MyISAM storage engine, MySQL uses extremely fast table locking (multiple readers / single writers). The biggest problem with this table type is a if you have a mix of a steady stream of updates and slow selects on the same table. If this is a problem with some tables, you can use another table type for these. See Chapter 7 [Table types], page 594.

MySQL can work with both transactional and non-transactional tables. To be able to work smoothly with non-transactional tables (which can't rollback if something goes wrong), MySQL has the following rules:

- All columns have default values.
- If you insert a 'wrong' value in a column like a `NULL` in a `NOT NULL` column or a too big numerical value in a numerical column, MySQL will instead of giving an error instead

set the column to the 'best possible value'. For numerical values this is 0, the smallest possible values or the largest possible value. For strings this is either the empty string or the longest possible string that can be in the column.

- All calculated expressions returns a value that can be used instead of signaling an error condition. For example 1/0 returns `NULL`

For more information about this, see See Section 1.7.5 [Constraints], page 42.

The above means that one should not use MySQL to check fields content, but one should do this in the application.

5.1.2 Portability

Because all SQL servers implement different parts of SQL, it takes work to write portable SQL applications. For very simple selects/inserts it is very easy, but the more you need the harder it gets. If you want an application that is fast with many databases it becomes even harder!

To make a complex application portable you need to choose a number of SQL servers that it should work with.

You can use the MySQL `crash-me` program/web-page `http://www.mysql.com/information/crash-me.php` to find functions, types, and limits you can use with a selection of database servers. Crash-me now tests far from everything possible, but it is still comprehensive with about 450 things tested.

For example, you shouldn't have column names longer than 18 characters if you want to be able to use Informix or DB2.

Both the MySQL benchmarks and `crash-me` programs are very database-independent. By taking a look at how we have handled this, you can get a feeling for what you have to do to write your application database-independent. The benchmarks themselves can be found in the '`sql-bench`' directory in the MySQL source distribution. They are written in Perl with DBI database interface (which solves the access part of the problem).

See `http://www.mysql.com/information/benchmarks.html` for the results from this benchmark.

As you can see in these results, all databases have some weak points. That is, they have different design compromises that lead to different behaviour.

If you strive for database independence, you need to get a good feeling for each SQL server's bottlenecks. MySQL is very fast in retrieving and updating things, but will have a problem in mixing slow readers/writers on the same table. Oracle, on the other hand, has a big problem when you try to access rows that you have recently updated (until they are flushed to disk). Transaction databases in general are not very good at generating summary tables from log tables, as in this case row locking is almost useless.

To get your application *really* database-independent, you need to define an easy extendable interface through which you manipulate your data. As C++ is available on most systems, it makes sense to use a C++ classes interface to the databases.

If you use some specific feature for some database (like the `REPLACE` command in MySQL), you should code a method for the other SQL servers to implement the same feature (but slower). With MySQL you can use the `/*! */` syntax to add MySQL-specific keywords to

a query. The code inside `/**/` will be treated as a comment (ignored) by most other SQL servers.

If high performance is more important than exactness, as in some web applications, it is possibile to create an application layer that caches all results to give you even higher performance. By letting old results 'expire' after a while, you can keep the cache reasonably fresh. This provides a method to handle high load spikes, in which case you can dynamically increase the cache and set the expire timeout higher until things get back to normal.

In this case the table creation information should contain information of the initial size of the cache and how often the table should normally be refreshed.

5.1.3 What We Have Used MySQL For

During MySQL initial development, the features of MySQL were made to fit our largest customer. They handle data warehousing for a couple of the biggest retailers in Sweden.

From all stores, we get weekly summaries of all bonus card transactions, and we are expected to provide useful information for the store owners to help them find how their advertisement campaigns are affecting their customers.

The data is quite huge (about 7 million summary transactions per month), and we have data for 4-10 years that we need to present to the users. We got weekly requests from the customers that they want to get 'instant' access to new reports from this data.

We solved this by storing all information per month in compressed 'transaction' tables. We have a set of simple macros (script) that generates summary tables grouped by different criteria (product group, customer id, store ...) from the transactional tables. The reports are web pages that are dynamically generated by a small Perl script that parses a web page, executes the SQL statements in it, and inserts the results. We would have used PHP or mod_perl instead but they were not available at that time.

For graphical data we wrote a simple tool in `C` that can produce GIFs based on the result of an SQL query (with some processing of the result). This is also dynamically executed from the Perl script that parses the `HTML` files.

In most cases a new report can simply be done by copying an existing script and modifying the SQL query in it. In some cases, we will need to add more fields to an existing summary table or generate a new one, but this is also quite simple, as we keep all transactions tables on disk. (Currently we have at least 50G of transactions tables and 200G of other customer data.)

We also let our customers access the summary tables directly with ODBC so that the advanced users can themselves experiment with the data.

We haven't had any problems handling this with quite modest Sun Ultra SPARCstation (2x200 Mhz). We recently upgraded one of our servers to a 2 CPU 400 Mhz UltraSPARC, and we are now planning to start handling transactions on the product level, which would mean a ten-fold increase of data. We think we can keep up with this by just adding more disk to our systems.

We are also experimenting with Intel-Linux to be able to get more CPU power cheaper. Now that we have the binary portable database format (new in Version 3.23), we will start to use this for some parts of the application.

Our initial feelings are that Linux will perform much better on low-to-medium load and Solaris will perform better when you start to get a high load because of extreme disk IO, but we don't yet have anything conclusive about this. After some discussion with a Linux Kernel developer, this might be a side effect of Linux giving so much resources to the batch job that the interactive performance gets very low. This makes the machine feel very slow and unresponsive while big batches are going. Hopefully this will be better handled in future Linux Kernels.

5.1.4 The MySQL Benchmark Suite

This should contain a technical description of the MySQL benchmark suite (and `crash-me`), but that description is not written yet. Currently, you can get a good idea of the benchmark by looking at the code and results in the '`sql-bench`' directory in any MySQL source distributions.

This benchmark suite is meant to be a benchmark that will tell any user what things a given SQL implementation performs well or poorly at.

Note that this benchmark is single threaded, so it measures the minimum time for the operations. We plan to in the future add a lot of multi-threaded tests to the benchmark suite.

For example, (run on the same NT 4.0 machine):

Reading 2000000 rows by index	**Seconds**	**Seconds**
mysql	367	249
mysql_odbc	464	
db2_odbc	1206	
informix_odbc	121126	
ms-sql_odbc	1634	
oracle_odbc	20800	
solid_odbc	877	
sybase_odbc	17614	
Inserting (350768) rows	**Seconds**	**Seconds**
mysql	381	206
mysql_odbc	619	
db2_odbc	3460	
informix_odbc	2692	
ms-sql_odbc	4012	
oracle_odbc	11291	
solid_odbc	1801	
sybase_odbc	4802	

In the above test MySQL was run with a 8M index cache.

We have gathered some more benchmark results at `http://www.mysql.com/information/benchmarks.html`.

Note that Oracle is not included because they asked to be removed. All Oracle benchmarks have to be passed by Oracle! We believe that makes Oracle benchmarks **very** biased because the above benchmarks are supposed to show what a standard installation can do for a single client.

To run the benchmark suite, you have to download a MySQL source distribution, install the Perl DBI driver, the Perl DBD driver for the database you want to test and then do:

```
cd sql-bench
perl run-all-tests --server=#
```

where # is one of supported servers. You can get a list of all options and supported servers by doing `run-all-tests --help`.

`crash-me` tries to determine what features a database supports and what its capabilities and limitations are by actually running queries. For example, it determines:

- What column types are supported
- How many indexes are supported
- What functions are supported
- How big a query can be
- How big a `VARCHAR` column can be

We can find the result from `crash-me` on a lot of different databases at `http://www.mysql.com/information/crash-me.php`.

5.1.5 Using Your Own Benchmarks

You should definitely benchmark your application and database to find out where the bottlenecks are. By fixing it (or by replacing the bottleneck with a 'dummy module') you can then easily identify the next bottleneck (and so on). Even if the overall performance for your application is sufficient, you should at least make a plan for each bottleneck, and decide how to solve it if someday you really need the extra performance.

For an example of portable benchmark programs, look at the MySQL benchmark suite. See Section 5.1.4 [MySQL Benchmarks], page 397. You can take any program from this suite and modify it for your needs. By doing this, you can try different solutions to your problem and test which is really the fastest solution for you.

Another free benchmark suite is the `Open Source Database Benchmark` which may be found at `http://osdb.sourceforge.net/`.

It is very common that some problems only occur when the system is very heavily loaded. We have had many customers who contact us when they have a (tested) system in production and have encountered load problems. In every one of these cases so far, it has been problems with basic design (table scans are **not good** at high load) or OS/Library issues. Most of this would be a **lot** easier to fix if the systems were not already in production.

To avoid problems like this, you should put some effort into benchmarking your whole application under the worst possible load! You can use Super Smack for this, and it is available at: `http://www.mysql.com/Downloads/super-smack/super-smack-1.0.tar.gz`. As the name suggests, it can bring your system down to its knees if you ask it, so make sure to use it only on your development systems.

5.2 Optimising SELECTs and Other Queries

First, one thing that affects all queries: The more complex permission system setup you have, the more overhead you get.

If you do not have any GRANT statements done, MySQL will optimise the permission checking somewhat. So if you have a very high volume it may be worth the time to avoid grants. Otherwise, more permission check results in a larger overhead.

If your problem is with some explicit MySQL function, you can always time this in the MySQL client:

```
mysql> SELECT BENCHMARK(1000000,1+1);
+------------------------+
| BENCHMARK(1000000,1+1) |
+------------------------+
|                      0 |
+------------------------+
1 row in set (0.32 sec)
```

The above shows that MySQL can execute 1,000,000 + expressions in 0.32 seconds on a PentiumII 400MHz.

All MySQL functions should be very optimised, but there may be some exceptions, and the BENCHMARK(loop_count,expression) is a great tool to find out if this is a problem with your query.

5.2.1 EXPLAIN Syntax (Get Information About a SELECT)

```
    EXPLAIN tbl_name
or  EXPLAIN SELECT select_options
```

EXPLAIN tbl_name is a synonym for DESCRIBE tbl_name or SHOW COLUMNS FROM tbl_name.

When you precede a SELECT statement with the keyword EXPLAIN, MySQL explains how it would process the SELECT, providing information about how tables are joined and in which order.

With the help of EXPLAIN, you can see when you must add indexes to tables to get a faster SELECT that uses indexes to find the records.

You should frequently run ANALYZE TABLE to update table statistics such as cardinality of keys which can affect the choices the optimiser makes. See Section 4.6.2 [ANALYZE TABLE], page 281.

You can also see if the optimiser joins the tables in an optimal order. To force the optimiser to use a specific join order for a SELECT statement, add a STRAIGHT_JOIN clause.

For non-simple joins, EXPLAIN returns a row of information for each table used in the SELECT statement. The tables are listed in the order they would be read. MySQL resolves all joins using a single-sweep multi-join method. This means that MySQL reads a row from the first table, then finds a matching row in the second table, then in the third table and so on. When all tables are processed, it outputs the selected columns and backtracks through the table list until a table is found for which there are more matching rows. The next row is read from this table and the process continues with the next table.

In MySQL version 4.1 the `EXPLAIN` output was changed to work better with constructs like `UNION`s, subqueries and derived tables. Most notable is the addition of two new columns: `id` and `select_type`.

Output from `EXPLAIN` consists of the following columns:

`id` `SELECT` identifier, the sequential number of this `SELECT` within the query.

`select_type`
Type of `SELECT` clause, which can be any of the following:

- `SIMPLE` Simple `SELECT` (without `UNION`s or subqueries).
- `PRIMARY` Outermost `SELECT`.
- `UNION` Second and further `UNION` `SELECT`s.
- `DEPENDENT UNION` Second and further `UNION` `SELECTS`s, dependent on outer subquery.
- `SUBQUERY` First `SELECT` in subquery.
- `DEPENDENT SUBQUERY` First `SELECT`, dependent on outer subquery.
- `DERIVED` Derived table `SELECT` (subquery in `FROM` clause).

`table` The table to which the row of output refers.

`type` The join type. The different join types are listed here, ordered from best to worst type:

- `system` The table has only one row (= system table). This is a special case of the `const` join type.
- `const` The table has at most one matching row, which will be read at the start of the query. Because there is only one row, values from the column in this row can be regarded as constants by the rest of the optimiser. `const` tables are very fast as they are read only once!

  `const` is used when you compare all parts of a `PRIMARY/UNIQUE` key with constants:

```
SELECT * FROM const_table WHERE primary_key=1;

SELECT * FROM const_table WHERE primary_key_part1=1 and primary_ke
```

- `eq_ref` One row will be read from this table for each combination of rows from the previous tables. This is the best possible join type, other than the `const` types. It is used when all parts of an index are used by the join and the index is `UNIQUE` or a `PRIMARY KEY`.

  `eq_ref` can be used for indexed columns that is compared with `=`. The compared item may be a constant or an expression that uses columns from tables that are read before this table.

  In the following examples, `ref_table` will be able to use `eq_ref`

```
SELECT * FROM ref_table,other_table WHERE
ref_table.key_column=other_table.column;

SELECT * FROM ref_table,other_table WHERE
ref_table.key_column_part1=other_table.column AND
ref_table.key_column_part2=1;
```

`ref` All rows with matching index values will be read from this table for each combination of rows from the previous tables. `ref` is used if the join uses only a leftmost prefix of the key, or if the key is not `UNIQUE` or a `PRIMARY KEY` (in other words, if the join cannot select a single row based on the key value). If the key that is used matches only a few rows, this join type is good.

`ref` can be used for indexed columns that is compared with `=`.

In the following examples, `ref_table` will be able to use `ref`

```
SELECT * FROM ref_table WHERE key_column=expr;

SELECT * FROM ref_table,other_table WHERE
ref_table.key_column=other_table.column;

SELECT * FROM ref_table,other_table WHERE
ref_table.key_column_part1=other_table.column AND
ref_table.key_column_part2=1;
```

`ref_or_null`
Like `ref`, but with the addition that we will do an extra search for rows with `NULL`. See Section 5.2.5 [IS NULL optimisation], page 408.

```
SELECT * FROM ref_table WHERE key_column=expr OR key_column IS NUL
```

This optimisation is new for MySQL 4.1.1 and is mostly used when resolving sub queries.

`range` Only rows that are in a given range will be retrieved, using an index to select the rows. The `key` column indicates which index is used. The `key_len` contains the longest key part that was used. The `ref` column will be `NULL` for this type.

`range` can be used for when an key column is compared to a constant with `=`, `<>`, `>`, `>=`, `<`, `<=`, `IS NULL`, `<=>`, `BETWEEN` and `IN`.

```
SELECT * FROM range_table WHERE key_column = 10;

SELECT * FROM range_table WHERE key_column BETWEEN 10 and 20;

SELECT * FROM range_table WHERE key_column IN (10,20,30);

SELECT * FROM range_table WHERE key_part1= 10 and key_part2 IN (10
```

`index` This is the same as `ALL`, except that only the index tree is scanned. This is usually faster than `ALL`, as the index file is usually smaller than the datafile.

This can be used when the query only uses columns that are part of one index.

`ALL` A full table scan will be done for each combination of rows from the previous tables. This is normally not good if the table is the first table not marked `const`, and usually **very** bad in all other cases. You normally can avoid `ALL` by adding more indexes, so that the row can be retrieved based on constant values or column values from earlier tables.

`possible_keys`

The `possible_keys` column indicates which indexes MySQL could use to find the rows in this table. Note that this column is totally independent of the order of the tables. That means that some of the keys in `possible_keys` may not be usable in practice with the generated table order.

If this column is empty, there are no relevant indexes. In this case, you may be able to improve the performance of your query by examining the `WHERE` clause to see if it refers to some column or columns that would be suitable for indexing. If so, create an appropriate index and check the query with `EXPLAIN` again. See Section 6.5.4 [ALTER TABLE], page 573.

To see what indexes a table has, use `SHOW INDEX FROM tbl_name`.

`key` The `key` column indicates the key (index) that MySQL actually decided to use. The key is `NULL` if no index was chosen. To force MySQL to use an key listed in the `possible_keys` column, use `USE KEY/IGNORE KEY` in your query. See Section 6.4.1 [SELECT], page 530.

Also, running `myisamchk --analyze` (see Section 4.5.6.1 [myismchk syntax], page 265) or `ANALYZE TABLE` (see Section 4.6.2 [ANALYZE TABLE], page 281) on the table will help the optimiser choose better indexes.

`key_len` The `key_len` column indicates the length of the key that MySQL decided to use. The length is `NULL` if the `key` is `NULL`. Note that this tells us how many parts of a multi-part key MySQL will actually use.

`ref` The `ref` column shows which columns or constants are used with the `key` to select rows from the table.

`rows` The `rows` column indicates the number of rows MySQL believes it must examine to execute the query.

`Extra` This column contains additional information of how MySQL will resolve the query. Here is an explanation of the different text strings that can be found in this column:

`Distinct` MySQL will not continue searching for more rows for the current row combination after it has found the first matching row.

`Not exists`
: MySQL was able to do a `LEFT JOIN` optimisation on the query and will not examine more rows in this table for the previous row combination after it finds one row that matches the `LEFT JOIN` criteria.

  Here is an example for this:

  ```
  SELECT * FROM t1 LEFT JOIN t2 ON t1.id=t2.id WHERE t2.id IS NULL;
  ```

  Assume that `t2.id` is defined with `NOT NULL`. In this case MySQL will scan `t1` and look up the rows in `t2` through `t1.id`. If MySQL finds a matching row in `t2`, it knows that `t2.id` can never be `NULL`, and will not scan through the rest of the rows in `t2` that has the same `id`. In other words, for each row in `t1`, MySQL only needs to do a single lookup in `t2`, independent of how many matching rows there are in `t2`.

`range checked for each record (index map: #)`
: MySQL didn't find a real good index to use. It will, instead, for each row combination in the preceding tables, do a check on which index to use (if any), and use this index to retrieve the rows from the table. This isn't very fast but is faster than having to do a join without an index.

`Using filesort`
: MySQL will need to do an extra pass to find out how to retrieve the rows in sorted order. The sort is done by going through all rows according to the `join type` and storing the sort key `+` pointer to the row for all rows that match the `WHERE`. Then the keys are sorted. Finally the rows are retrieved in sorted order.

`Using index`
: The column information is retrieved from the table using only information in the index tree without having to do an additional seek to read the actual row. This can be done when all the used columns for the table are part of the same index.

`Using temporary`
: To resolve the query MySQL will need to create a temporary table to hold the result. This typically happens if you do an `ORDER BY` on a different column set than you did a `GROUP BY` on.

`Using where`
: A `WHERE` clause will be used to restrict which rows will be matched against the next table or sent to the client. If you don't have this information and the table is of type `ALL` or `index`, you may have something wrong in your query (if you don't intend to fetch/examine all rows from the table).

If you want to get your queries as fast as possible, you should look out for `Using filesort` and `Using temporary`.

You can get a good indication of how good a join is by multiplying all values in the `rows` column of the `EXPLAIN` output. This should tell you roughly how many rows MySQL must

examine to execute the query. This number is also used when you restrict queries with the `max_join_size` variable. See Section 5.5.2 [Server parameters], page 427.

The following example shows how a `JOIN` can be optimised progressively using the information provided by `EXPLAIN`.

Suppose you have the `SELECT` statement shown here, that you examine using `EXPLAIN`:

```
EXPLAIN SELECT tt.TicketNumber, tt.TimeIn,
            tt.ProjectReference, tt.EstimatedShipDate,
            tt.ActualShipDate, tt.ClientID,
            tt.ServiceCodes, tt.RepetitiveID,
            tt.CurrentProcess, tt.CurrentDPPerson,
            tt.RecordVolume, tt.DPPrinted, et.COUNTRY,
            et_1.COUNTRY, do.CUSTNAME
        FROM tt, et, et AS et_1, do
        WHERE tt.SubmitTime IS NULL
            AND tt.ActualPC = et.EMPLOYID
            AND tt.AssignedPC = et_1.EMPLOYID
            AND tt.ClientID = do.CUSTNMBR;
```

For this example, assume that:

- The columns being compared have been declared as follows:

Table	Column	Column type
tt	ActualPC	CHAR(10)
tt	AssignedPC	CHAR(10)
tt	ClientID	CHAR(10)
et	EMPLOYID	CHAR(15)
do	CUSTNMBR	CHAR(15)

- The tables have the indexes shown here:

Table	Index
tt	ActualPC
tt	AssignedPC
tt	ClientID
et	EMPLOYID (primary key)
do	CUSTNMBR (primary key)

- The `tt.ActualPC` values aren't evenly distributed.

Initially, before any optimisations have been performed, the `EXPLAIN` statement produces the following information:

```
table type possible_keys                key  key_len ref  rows  Extra
et    ALL  PRIMARY                      NULL NULL    NULL 74
do    ALL  PRIMARY                      NULL NULL    NULL 2135
et_1  ALL  PRIMARY                      NULL NULL    NULL 74
tt    ALL  AssignedPC,ClientID,ActualPC NULL NULL    NULL 3872
      range checked for each record (key map: 35)
```

Because `type` is `ALL` for each table, this output indicates that MySQL is generating a Cartesian product of all the tables! This will take quite a long time, as the product of the

number of rows in each table must be examined! For the case at hand, this is `74 * 2135 * 74 * 3872 = 45,268,558,720` rows. If the tables were bigger, you can only imagine how long it would take.

One problem here is that MySQL can't (yet) use indexes on columns efficiently if they are declared differently. In this context, `VARCHAR` and `CHAR` are the same unless they are declared as different lengths. Because `tt.ActualPC` is declared as `CHAR(10)` and `et.EMPLOYID` is declared as `CHAR(15)`, there is a length mismatch.

To fix this disparity between column lengths, use `ALTER TABLE` to lengthen `ActualPC` from 10 characters to 15 characters:

```
mysql> ALTER TABLE tt MODIFY ActualPC VARCHAR(15);
```

Now `tt.ActualPC` and `et.EMPLOYID` are both `VARCHAR(15)`. Executing the `EXPLAIN` statement again produces this result:

```
table type   possible_keys   key     key_len ref         rows    Extra
tt    ALL    AssignedPC,ClientID,ActualPC NULL NULL NULL 3872    Using where
do    ALL    PRIMARY         NULL    NULL    NULL        2135
      range checked for each record (key map: 1)
et_1  ALL    PRIMARY         NULL    NULL    NULL        74
      range checked for each record (key map: 1)
et    eq_ref PRIMARY         PRIMARY 15      tt.ActualPC 1
```

This is not perfect, but is much better (the product of the `rows` values is now less by a factor of 74). This version is executed in a couple of seconds.

A second alteration can be made to eliminate the column length mismatches for the `tt.AssignedPC = et_1.EMPLOYID` and `tt.ClientID = do.CUSTNMBR` comparisons:

```
mysql> ALTER TABLE tt MODIFY AssignedPC VARCHAR(15),
    ->                MODIFY ClientID   VARCHAR(15);
```

Now `EXPLAIN` produces the output shown here:

```
table type   possible_keys   key      key_len ref           rows Extra
et    ALL    PRIMARY         NULL     NULL    NULL          74
tt    ref    AssignedPC,     ActualPC 15      et.EMPLOYID   52   Using where
             ClientID,
             ActualPC
et_1  eq_ref PRIMARY         PRIMARY  15      tt.AssignedPC 1
do    eq_ref PRIMARY         PRIMARY  15      tt.ClientID   1
```

This is almost as good as it can get.

The remaining problem is that, by default, MySQL assumes that values in the `tt.ActualPC` column are evenly distributed, and that isn't the case for the `tt` table. Fortunately, it is easy to tell MySQL about this:

```
shell> myisamchk --analyze PATH_TO_MYSQL_DATABASE/tt
shell> mysqladmin refresh
```

Now the join is perfect, and `EXPLAIN` produces this result:

```
table type   possible_keys key     key_len ref           rows Extra
tt    ALL    AssignedPC    NULL    NULL    NULL          3872 Using where
             ClientID,
```

```
                ActualPC
et    eq_ref PRIMARY       PRIMARY 15      tt.ActualPC   1
et_1  eq_ref PRIMARY       PRIMARY 15      tt.AssignedPC 1
do    eq_ref PRIMARY       PRIMARY 15      tt.ClientID   1
```

Note that the `rows` column in the output from `EXPLAIN` is an educated guess from the MySQL join optimiser. To optimise a query, you should check if the numbers are even close to the truth. If not, you may get better performance by using `STRAIGHT_JOIN` in your `SELECT` statement and trying to list the tables in a different order in the `FROM` clause.

5.2.2 Estimating Query Performance

In most cases you can estimate the performance by counting disk seeks. For small tables, you can usually find the row in 1 disk seek (as the index is probably cached). For bigger tables, you can estimate that (using B++ tree indexes) you will need: `log(row_count) / log(index_block_length / 3 * 2 / (index_length + data_pointer_length)) + 1` seeks to find a row.

In MySQL an index block is usually 1024 bytes and the data pointer is usually 4 bytes. A 500,000 row table with an index length of 3 (medium integer) gives you: `log(500,000)/log(1024/3*2/(3+4)) + 1` = 4 seeks.

As the above index would require about 500,000 * 7 * 3/2 = 5.2M, (assuming that the index buffers are filled to 2/3, which is typical) you will probably have much of the index in memory and you will probably only need 1-2 calls to read data from the OS to find the row.

For writes, however, you will need 4 seek requests (as above) to find where to place the new index and normally 2 seeks to update the index and write the row.

Note that the above doesn't mean that your application will slowly degenerate by log N! As long as everything is cached by the OS or SQL server things will only go marginally slower while the table gets bigger. After the data gets too big to be cached, things will start to go much slower until your applications is only bound by disk-seeks (which increase by log N). To avoid this, increase the index cache as the data grows. See Section 5.5.2 [Server parameters], page 427.

5.2.3 Speed of `SELECT` Queries

In general, when you want to make a slow `SELECT ... WHERE` faster, the first thing to check is whether you can add an index. See Section 5.4.3 [MySQL indexes], page 421. All references between different tables should usually be done with indexes. You can use the `EXPLAIN` command to determine which indexes are used for a `SELECT`. See Section 5.2.1 [`EXPLAIN`], page 399.

Some general tips:

- To help MySQL optimise queries better, run `myisamchk --analyze` on a table after it has been loaded with relevant data. This updates a value for each index part that indicates the average number of rows that have the same value. (For unique indexes, this is always 1, of course.) MySQL will use this to decide which index to choose when you connect two tables with 'a non-constant expression'. You can check the

result from the `analyze` run by doing `SHOW INDEX FROM table_name` and examining the `Cardinality` column.

- To sort an index and data according to an index, use `myisamchk --sort-index --sort-records=1` (if you want to sort on index 1). If you have a unique index from which you want to read all records in order according to that index, this is a good way to make that faster. Note, however, that this sorting isn't written optimally and will take a long time for a large table!

5.2.4 How MySQL Optimises `WHERE` Clauses

The `WHERE` optimisations are put in the `SELECT` part here because they are mostly used with `SELECT`, but the same optimisations apply for `WHERE` in `DELETE` and `UPDATE` statements.

Also note that this section is incomplete. MySQL does many optimisations, and we have not had time to document them all.

Some of the optimisations performed by MySQL are listed here:

- Removal of unnecessary parentheses:

```
   ((a AND b) AND c OR (((a AND b) AND (c AND d))))
-> (a AND b AND c) OR (a AND b AND c AND d)
```

- Constant folding:

```
   (a<b AND b=c) AND a=5
-> b>5 AND b=c AND a=5
```

- Constant condition removal (needed because of constant folding):

```
   (B>=5 AND B=5) OR (B=6 AND 5=5) OR (B=7 AND 5=6)
-> B=5 OR B=6
```

- Constant expressions used by indexes are evaluated only once.
- `COUNT(*)` on a single table without a `WHERE` is retrieved directly from the table information for `MyISAM` and `HEAP` tables. This is also done for any `NOT NULL` expression when used with only one table.
- Early detection of invalid constant expressions. MySQL quickly detects that some `SELECT` statements are impossible and returns no rows.
- `HAVING` is merged with `WHERE` if you don't use `GROUP BY` or group functions (`COUNT()`, `MIN()`...).
- For each sub-join, a simpler `WHERE` is constructed to get a fast `WHERE` evaluation for each sub-join and also to skip records as soon as possible.
- All constant tables are read first, before any other tables in the query. A constant table is:
  - An empty table or a table with 1 row.
  - A table that is used with a `WHERE` clause on a `UNIQUE` index, or a `PRIMARY KEY`, where all index parts are used with constant expressions and the index parts are defined as `NOT NULL`.

  All the following tables are used as constant tables:

```
mysql> SELECT * FROM t WHERE primary_key=1;
mysql> SELECT * FROM t1,t2
    ->          WHERE t1.primary_key=1 AND t2.primary_key=t1.id;
```

- The best join combination to join the tables is found by trying all possibilities. If all columns in `ORDER BY` and in `GROUP BY` come from the same table, then this table is preferred first when joining.
- If there is an `ORDER BY` clause and a different `GROUP BY` clause, or if the `ORDER BY` or `GROUP BY` contains columns from tables other than the first table in the join queue, a temporary table is created.
- If you use `SQL_SMALL_RESULT`, MySQL will use an in-memory temporary table.
- Each table index is queried, and the best index that spans fewer than 30% of the rows is used. If no such index can be found, a quick table scan is used.
- In some cases, MySQL can read rows from the index without even consulting the datafile. If all columns used from the index are numeric, then only the index tree is used to resolve the query.
- Before each record is output, those that do not match the `HAVING` clause are skipped.

Some examples of queries that are very fast:

```
mysql> SELECT COUNT(*) FROM tbl_name;
mysql> SELECT MIN(key_part1),MAX(key_part1) FROM tbl_name;
mysql> SELECT MAX(key_part2) FROM tbl_name
    ->        WHERE key_part_1=constant;
mysql> SELECT ... FROM tbl_name
    ->        ORDER BY key_part1,key_part2,... LIMIT 10;
mysql> SELECT ... FROM tbl_name
    ->        ORDER BY key_part1 DESC,key_part2 DESC,... LIMIT 10;
```

The following queries are resolved using only the index tree (assuming the indexed columns are numeric):

```
mysql> SELECT key_part1,key_part2 FROM tbl_name WHERE key_part1=val;
mysql> SELECT COUNT(*) FROM tbl_name
    ->        WHERE key_part1=val1 AND key_part2=val2;
mysql> SELECT key_part2 FROM tbl_name GROUP BY key_part1;
```

The following queries use indexing to retrieve the rows in sorted order without a separate sorting pass:

```
mysql> SELECT ... FROM tbl_name
    ->            ORDER BY key_part1,key_part2,... ;
mysql> SELECT ... FROM tbl_name
    ->            ORDER BY key_part1 DESC,key_part2 DESC,... ;
```

5.2.5 How MySQL Optimises `IS NULL`

MySQL can do the same optimisation on `column IS NULL` as it can do with `column = constant_value`. For example, MySQL can use indexes and ranges to search for `NULL` with `IS NULL`.

```
SELECT * FROM table_name WHERE key_col IS NULL;

SELECT * FROM table_name WHERE key_col <=> NULL;

SELECT * FROM table_name WHERE key_col=# OR key_col=# OR key_col IS NULL
```

If you use `column_name IS NULL` on a `NOT NULL` in a WHERE clause on table that is not used `OUTER JOIN` that expression will be optimised away.

MySQL 4.1.1 can additionally optimise the combination `column = expr AND column IS NULL`, an form that is common in resolved sub queries. `EXPLAIN` will show `ref_or_null` when this optimisation is used.

This optimisation can handle one `IS NULL` for any key part.

Some examples of queries that are optimised (assuming key on t2 (a,b)):

```
SELECT * FROM t1 WHERE t1.a=expr OR t1.a IS NULL;

SELECT * FROM t1,t2 WHERE t1.a=t2.a OR t2.a IS NULL;

SELECT * FROM t1,t2 WHERE (t1.a=t2.a OR t2.a IS NULL) AND t2.b=t1.b;

SELECT * FROM t1,t2 WHERE t1.a=t2.a AND (t2.b=t1.b OR t2.b IS NULL);

SELECT * FROM t1,t2 WHERE (t1.a=t2.a AND t2.a IS NULL AND ...) OR (t1.a=t2.a AND t2.a
```

`ref_or_null` works by first doing a read on the reference key and after that a separate search after rows with NULL key.

Note that the optimisation can only handle one `IS NULL` level.

```
SELECT * FROM t1,t2 where (t1.a=t2.a AND t2.a IS NULL) OR (t1.b=t2.b AND t2.b IS NULL)
```

Int the above case MySQL will only use key lookups on the part `(t1.a=t2.a AND t2.a IS NULL)` and not be able to use the key part on `b`.

5.2.6 How MySQL Optimises `DISTINCT`

`DISTINCT` combined with `ORDER BY` will in many cases need a temporary table.

Note that as `DISTINCT` may use `GROUP BY`, you should be aware of how MySQL works with in fields in `ORDER BY` or `HAVING` that are not part of the selected fields. See Section 6.3.7.3 [GROUP-BY-hidden-fields], page 529.

When combining `LIMIT row_count` with `DISTINCT`, MySQL will stop as soon as it finds `row_count` unique rows.

If you don't use columns from all used tables, MySQL will stop the scanning of the not used tables as soon as it has found the first match.

```
SELECT DISTINCT t1.a FROM t1,t2 where t1.a=t2.a;
```

In the case, assuming `t1` is used before `t2` (check with `EXPLAIN`), then MySQL will stop reading from `t2` (for that particular row in `t1`) when the first row in `t2` is found.

5.2.7 How MySQL Optimises LEFT JOIN and RIGHT JOIN

A LEFT JOIN B join_condition in MySQL is implemented as follows:

- The table B is set to be dependent on table A and all tables that A is dependent on.
- The table A is set to be dependent on all tables (except B) that are used in the LEFT JOIN condition.
- The LEFT JOIN condition is used to decide how we should retrieve rows from table B. (In other words, any condition in the WHERE clause is not used).
- All standard join optimisations are done, with the exception that a table is always read after all tables it is dependent on. If there is a circular dependence then MySQL will issue an error.
- All standard WHERE optimisations are done.
- If there is a row in A that matches the WHERE clause, but there wasn't any row in B that matched the ON condition, then an extra B row is generated with all columns set to NULL.
- If you use LEFT JOIN to find rows that don't exist in some table and you have the following test: column_name IS NULL in the WHERE part, where column_name is a column that is declared as NOT NULL, then MySQL will stop searching after more rows (for a particular key combination) after it has found one row that matches the LEFT JOIN condition.

RIGHT JOIN is implemented analogously to LEFT JOIN.

The table read order forced by LEFT JOIN and STRAIGHT JOIN will help the join optimiser (which calculates in which order tables should be joined) to do its work much more quickly, as there are fewer table permutations to check.

Note that the above means that if you do a query of type:

```
SELECT * FROM a,b LEFT JOIN c ON (c.key=a.key) LEFT JOIN d (d.key=a.key)
        WHERE b.key=d.key
```

MySQL will do a full scan on b as the LEFT JOIN will force it to be read before d.

The fix in this case is to change the query to:

```
SELECT * FROM b,a LEFT JOIN c ON (c.key=a.key) LEFT JOIN d (d.key=a.key)
        WHERE b.key=d.key
```

Starting from 4.0.14 MySQL does the following left join optimisation:

If the WHERE condition is always be false for the generated NULL row, the LEFT JOIN is changed to a normal join.

For example, in the following query the WHERE clause would be false if t2.column would be NULL so it's safe to convert to a normal join.

```
SELECT * FROM t1 LEFT t2 ON (column) WHERE t2.column2 =5;
->
SELECT * FROM t1,t2 WHERE t2.column2=5 AND t1.column=t2.column;
```

this can be made faster as MySQL can now use table t2 before table t1 if this would result in a better query plan. To force a specific table order one should use STRAIGHT JOIN.

5.2.8 How MySQL Optimises ORDER BY

In some cases MySQL can uses index to satisfy an ORDER BY or GROUP BY request without doing any extra sorting.

The index can also be used even if the ORDER BY doesn't match the index exactly, as long as all the unused index parts and all the extra are ORDER BY columns are constants in the WHERE clause. The following queries will use the index to resolve the ORDER BY / GROUP BY part:

```
SELECT * FROM t1 ORDER BY key_part1,key_part2,...
SELECT * FROM t1 WHERE key_part1=constant ORDER BY key_part2
SELECT * FROM t1 WHERE key_part1=constant GROUP BY key_part2
SELECT * FROM t1 ORDER BY key_part1 DESC,key_part2 DESC
SELECT * FROM t1 WHERE key_part1=1 ORDER BY key_part1 DESC,key_part2 DESC
```

Some cases where MySQL can **not** use indexes to resolve the ORDER BY: (Note that MySQL will still use indexes to find the rows that matches the WHERE clause):

- You are doing an ORDER BY on different keys:

  ```
  SELECT * FROM t1 ORDER BY key1,key2
  ```

- You are doing an ORDER BY using non-consecutive key parts.

  ```
  SELECT * FROM t1 WHERE key2=constant ORDER BY key_part2
  ```

- You are mixing ASC and DESC.

  ```
  SELECT * FROM t1 ORDER BY key_part1 DESC,key_part2 ASC
  ```

- The key used to fetch the rows are not the same one that is used to do the ORDER BY:

  ```
  SELECT * FROM t1 WHERE key2=constant ORDER BY key1
  ```

- You are joining many tables and the columns you are doing an ORDER BY on are not all from the first not-const table that is used to retrieve rows (This is the first table in the EXPLAIN output which doesn't use a const row fetch method).
- You have different ORDER BY and GROUP BY expressions.
- The used table index is an index type that doesn't store rows in order. (Like the HASH index in HEAP tables).

In the cases where MySQL have to sort the result, it uses the following algorithm:

- Read all rows according to key or by table scanning. Rows that don't match the WHERE clause are skipped.
- Store the sort-key in a buffer (of size sort_buffer).
- When the buffer gets full, run a qsort on it and store the result in a temporary file. Save a pointer to the sorted block. (In the case where all rows fits into the sort buffer, no temporary file is created)
- Repeat the above until all rows have been read.
- Do a multi-merge of up to MERGEBUFF (7) regions to one block in another temporary file. Repeat until all blocks from the first file are in the second file.
- Repeat the following until there is less than MERGEBUFF2 (15) blocks left.
- On the last multi-merge, only the pointer to the row (last part of the sort-key) is written to a result file.

- Now the code in '`sql/records.cc`' will be used to read through them in sorted order by using the row pointers in the result file. To optimise this, we read in a big block of row pointers, sort these and then we read the rows in the sorted order into a row buffer (`read_rnd_buffer_size`) .

You can with `EXPLAIN SELECT ... ORDER BY` check if MySQL can use indexes to resolve the query. If you get `Using filesort` in the `extra` column, then MySQL can't use indexes to resolve the `ORDER BY`. See Section 5.2.1 [EXPLAIN], page 399.

If you want to have a higher `ORDER BY` speed, you should first see if you can get MySQL to use indexes instead of having to do an extra sorting phase. If this is not possible, then you can do:

- Increase the size of the `sort_buffer_size` variable.
- Increase the size of the `read_rnd_buffer_size` variable.
- Change `tmpdir` to point to a dedicated disk with lots of empty space. If you use MySQL 4.1 or later you can spread load between several physical disks by setting `tmpdir` to a list of paths separated by colon `:` (semicolon `;` on Windows). They will be used in round-robin fashion. **Note:** These paths should end up on different **physical** disks, not different partitions of the same disk.

By default, MySQL sorts all `GROUP BY x,y[,...]` queries as if you specified `ORDER BY x,y[,...]` in the query as well. If you include the `ORDER BY` clause explicitly, MySQL optimises it away without any speed penalty, though the sorting still occurs. If a query includes `GROUP BY` but you want to avoid the overhead of sorting the result, you can supress sorting by specifying `ORDER BY NULL`:

```
INSERT INTO foo SELECT a,COUNT(*) FROM bar GROUP BY a ORDER BY NULL;
```

5.2.9 How MySQL Optimises `LIMIT`

In some cases MySQL will handle the query differently when you are using `LIMIT row_count` and not using `HAVING`:

- If you are selecting only a few rows with `LIMIT`, MySQL will use indexes in some cases when it normally would prefer to do a full table scan.
- If you use `LIMIT row_count` with `ORDER BY`, MySQL will end the sorting as soon as it has found the first `row_count` lines instead of sorting the whole table.
- When combining `LIMIT row_count` with `DISTINCT`, MySQL will stop as soon as it finds `row_count` unique rows.
- In some cases a `GROUP BY` can be resolved by reading the key in order (or do a sort on the key) and then calculate summaries until the key value changes. In this case `LIMIT row_count` will not calculate any unnecessary `GROUP BY`s.
- As soon as MySQL has sent the first `#` rows to the client, it will abort the query (if you are not using `SQL_CALC_FOUND_ROWS`).
- `LIMIT 0` will always quickly return an empty set. This is useful to check the query and to get the column types of the result columns.
- When the server uses temporary tables to resolve the query, the `LIMIT row_count` is used to calculate how much space is required.

5.2.10 Speed of `INSERT` Queries

The time to insert a record consists approximately of:

- Connect: (3)
- Sending query to server: (2)
- Parsing query: (2)
- Inserting record: (1 x size of record)
- Inserting indexes: (1 x number of indexes)
- Close: (1)

where the numbers are somewhat proportional to the overall time. This does not take into consideration the initial overhead to open tables (which is done once for each concurrently running query).

The size of the table slows down the insertion of indexes by log N (B-trees).

Some ways to speed up inserts:

- If you are inserting many rows from the same client at the same time, use multiple value lists `INSERT` statements. This is much faster (many times in some cases) than using separate `INSERT` statements. If you are adding data to non-empty table, you may tune up the `bulk_insert_buffer_size` variable to make it even faster. See Section 4.6.8.4 [`bulk_insert_buffer_size`], page 290.
- If you are inserting a lot of rows from different clients, you can get higher speed by using the `INSERT DELAYED` statement. See Section 6.4.3 [`INSERT`], page 546.
- Note that with `MyISAM` tables you can insert rows at the same time `SELECT`s are running if there are no deleted rows in the tables.
- When loading a table from a text file, use `LOAD DATA INFILE`. This is usually 20 times faster than using a lot of `INSERT` statements. See Section 6.4.8 [`LOAD DATA`], page 555.
- It is possible with some extra work to make `LOAD DATA INFILE` run even faster when the table has many indexes. Use the following procedure:
  1. Optionally create the table with `CREATE TABLE`. For example, using `mysql` or Perl-DBI.
  2. Execute a `FLUSH TABLES` statement or the shell command `mysqladmin flush-tables`.
  3. Use `myisamchk --keys-used=0 -rq /path/to/db/tbl_name`. This will remove all usage of all indexes from the table.
  4. Insert data into the table with `LOAD DATA INFILE`. This will not update any indexes and will therefore be very fast.
  5. If you are going to only read the table in the future, run `myisampack` on it to make it smaller. See Section 7.1.2.3 [Compressed format], page 599.
  6. Re-create the indexes with `myisamchk -r -q /path/to/db/tbl_name`. This will create the index tree in memory before writing it to disk, which is much faster because it avoids lots of disk seeks. The resulting index tree is also perfectly balanced.

7. Execute a `FLUSH TABLES` statement or the shell command `mysqladmin flush-tables`.

Note that `LOAD DATA INFILE` also does the above optimisation if you insert into an empty table; the main difference with the above procedure is that you can let `myisamchk` allocate much more temporary memory for the index creation that you may want MySQL to allocate for every index recreation.

Since MySQL 4.0 you can also use `ALTER TABLE tbl_name DISABLE KEYS` instead of `myisamchk --keys-used=0 -rq /path/to/db/tbl_name` and `ALTER TABLE tbl_name ENABLE KEYS` instead of `myisamchk -r -q /path/to/db/tbl_name`. This way you can also skip `FLUSH TABLES` steps.

- You can speed up insertions that is done over multiple statements by locking your tables:

```
mysql> LOCK TABLES a WRITE;
mysql> INSERT INTO a VALUES (1,23),(2,34),(4,33);
mysql> INSERT INTO a VALUES (8,26),(6,29);
mysql> UNLOCK TABLES;
```

The main speed difference is that the index buffer is flushed to disk only once, after all `INSERT` statements have completed. Normally there would be as many index buffer flushes as there are different `INSERT` statements. Locking is not needed if you can insert all rows with a single statement.

For transactional tables, you should use `BEGIN/COMMIT` instead of `LOCK TABLES` to get a speedup.

Locking will also lower the total time of multi-connection tests, but the maximum wait time for some threads will go up (because they wait for locks). For example:

```
thread 1 does 1000 inserts
thread 2, 3, and 4 does 1 insert
thread 5 does 1000 inserts
```

If you don't use locking, 2, 3, and 4 will finish before 1 and 5. If you use locking, 2, 3, and 4 probably will not finish before 1 or 5, but the total time should be about 40% faster.

As `INSERT`, `UPDATE`, and `DELETE` operations are very fast in MySQL, you will obtain better overall performance by adding locks around everything that does more than about 5 inserts or updates in a row. If you do very many inserts in a row, you could do a `LOCK TABLES` followed by an `UNLOCK TABLES` once in a while (about each 1000 rows) to allow other threads access to the table. This would still result in a nice performance gain.

Of course, `LOAD DATA INFILE` is much faster for loading data.

To get some more speed for both `LOAD DATA INFILE` and `INSERT`, enlarge the key buffer. See Section 5.5.2 [Server parameters], page 427.

5.2.11 Speed of `UPDATE` Queries

Update queries are optimised as a `SELECT` query with the additional overhead of a write. The speed of the write is dependent on the size of the data that is being updated and the number of indexes that are updated. Indexes that are not changed will not be updated.

Also, another way to get fast updates is to delay updates and then do many updates in a row later. Doing many updates in a row is much quicker than doing one at a time if you lock the table.

Note that, with dynamic record format, updating a record to a longer total length may split the record. So if you do this often, it is very important to `OPTIMIZE TABLE` sometimes. See Section 4.6.1 [`OPTIMIZE TABLE`], page 281.

5.2.12 Speed of `DELETE` Queries

If you want to delete all rows in the table, you should use `TRUNCATE TABLE table_name`. See Section 6.4.6 [TRUNCATE], page 554.

The time to delete a record is exactly proportional to the number of indexes. To delete records more quickly, you can increase the size of the index cache. See Section 5.5.2 [Server parameters], page 427.

5.2.13 Other Optimisation Tips

Unsorted tips for faster systems:

- Use persistent connections to the database to avoid the connection overhead. If you can't use persistent connections and you are doing a lot of new connections to the database, you may want to change the value of the `thread_cache_size` variable. See Section 5.5.2 [Server parameters], page 427.
- Always check that all your queries really use the indexes you have created in the tables. In MySQL you can do this with the `EXPLAIN` command. See Section 5.2.1 [Explain], page 399.
- Try to avoid complex `SELECT` queries on `MyISAM` tables that are updated a lot. This is to avoid problems with table locking.
- The new `MyISAM` tables can insert rows in a table without deleted rows at the same time another table is reading from it. If this is important for you, you should consider methods where you don't have to delete rows or run `OPTIMIZE TABLE` after you have deleted a lot of rows.
- Use `ALTER TABLE ... ORDER BY expr1,expr2...` if you mostly retrieve rows in `expr1,expr2...` order. By using this option after big changes to the table, you may be able to get higher performance.
- In some cases it may make sense to introduce a column that is 'hashed' based on information from other columns. If this column is short and reasonably unique it may be much faster than a big index on many columns. In MySQL it's very easy to use this extra column: `SELECT * FROM table_name WHERE hash=MD5(CONCAT(col1,col2)) AND col_1='constant' AND col_2='constant'`

- For tables that change a lot you should try to avoid all `VARCHAR` or `BLOB` columns. You will get dynamic row length as soon as you are using a single `VARCHAR` or `BLOB` column. See Chapter 7 [Table types], page 594.
- It's not normally useful to split a table into different tables just because the rows gets 'big'. To access a row, the biggest performance hit is the disk seek to find the first byte of the row. After finding the data most new disks can read the whole row fast enough for most applications. The only cases where it really matters to split up a table is if it's a dynamic row size table (see above) that you can change to a fixed row size, or if you very often need to scan the table and don't need most of the columns. See Chapter 7 [Table types], page 594.
- If you very often need to calculate things based on information from a lot of rows (like counts of things), it's probably much better to introduce a new table and update the counter in real time. An update of type `UPDATE table SET count=count+1 WHERE index_column=constant` is very fast!

  This is really important when you use MySQL table types like MyISAM and ISAM that only have table locking (multiple readers / single writers). This will also give better performance with most databases, as the row locking manager in this case will have less to do.
- If you need to collect statistics from big log tables, use summary tables instead of scanning the whole table. Maintaining the summaries should be much faster than trying to do statistics 'live'. It's much faster to regenerate new summary tables from the logs when things change (depending on business decisions) than to have to change the running application!
- If possible, one should classify reports as 'live' or 'statistical', where data needed for statistical reports are only generated based on summary tables that are generated from the actual data.
- Take advantage of the fact that columns have default values. Insert values explicitly only when the value to be inserted differs from the default. This reduces the parsing that MySQL need to do and improves the insert speed.
- In some cases it's convenient to pack and store data into a blob. In this case you have to add some extra code in your application to pack/unpack things in the blob, but this may save a lot of accesses at some stage. This is practical when you have data that doesn't conform to a static table structure.
- Normally you should try to keep all data non-redundant (what is called 3rd normal form in database theory), but you should not be afraid of duplicating things or creating summary tables if you need these to gain more speed.
- Stored procedures or UDF (user-defined functions) may be a good way to get more performance. In this case you should, however, always have a way to do this some other (slower) way if you use some database that doesn't support this.
- You can always gain something by caching queries/answers in your application and trying to do many inserts/updates at the same time. If your database supports lock tables (like MySQL and Oracle), this should help to ensure that the index cache is only flushed once after all updates.
- Use `INSERT /*! DELAYED */` when you do not need to know when your data is written. This speeds things up because many records can be written with a single disk write.

- Use `INSERT /*! LOW_PRIORITY */` when you want your selects to be more important.
- Use `SELECT /*! HIGH_PRIORITY */` to get selects that jump the queue. That is, the select is done even if there is somebody waiting to do a write.
- Use the multi-line `INSERT` statement to store many rows with one SQL command (many SQL servers supports this).
- Use `LOAD DATA INFILE` to load bigger amounts of data. This is faster than normal inserts and will be even faster when `myisamchk` is integrated in `mysqld`.
- Use `AUTO_INCREMENT` columns to make unique values.
- Use `OPTIMIZE TABLE` once in a while to avoid fragmentation when using a dynamic table format. See Section 4.6.1 [`OPTIMIZE TABLE`], page 281.
- Use `HEAP` tables to get more speed when possible. See Chapter 7 [Table types], page 594.
- When using a normal web server setup, images should be stored as files. That is, store only a file reference in the database. The main reason for this is that a normal web server is much better at caching files than database contents. So it it's much easier to get a fast system if you are using files.
- Use in memory tables for non-critical data that are accessed often (like information about the last shown banner for users that don't have cookies).
- Columns with identical information in different tables should be declared identical and have identical names. Before Version 3.23 you got slow joins otherwise.

  Try to keep the names simple (use `name` instead of `customer_name` in the customer table). To make your names portable to other SQL servers you should keep them shorter than 18 characters.
- If you need really high speed, you should take a look at the low-level interfaces for data storage that the different SQL servers support! For example, by accessing the MySQL `MyISAM` directly, you could get a speed increase of 2-5 times compared to using the SQL interface. To be able to do this the data must be on the same server as the application, and usually it should only be accessed by one process (because external file locking is really slow). One could eliminate the above problems by introducing low-level `MyISAM` commands in the MySQL server (this could be one easy way to get more performance if needed). By carefully designing the database interface, it should be quite easy to support this types of optimisation.
- In many cases it's faster to access data from a database (using a live connection) than accessing a text file, just because the database is likely to be more compact than the text file (if you are using numerical data), and this will involve fewer disk accesses. You will also save code because you don't have to parse your text files to find line and column boundaries.
- You can also use replication to speed things up. See Section 4.11 [Replication], page 355.
- Declaring a table with `DELAY_KEY_WRITE=1` will make the updating of indexes faster, as these are not logged to disk until the file is closed. The downside is that you should run `myisamchk` on these tables before you start `mysqld` to ensure that they are okay if something killed `mysqld` in the middle. As the key information can always be generated from the data, you should not lose anything by using `DELAY_KEY_WRITE`.

5.3 Locking Issues

5.3.1 How MySQL Locks Tables

You can find a discussion about different locking methods in the appendix. See Section E.4 [Locking methods], page 1014.

All locking in MySQL is deadlock-free, except for `InnoDB` and `BDB` type tables. This is managed by always requesting all needed locks at once at the beginning of a query and always locking the tables in the same order.

`InnoDB` type tables automatically acquire their row locks and `BDB` type tables their page locks during the processing of SQL statements, not at the start of the transaction.

The locking method MySQL uses for `WRITE` locks works as follows:

- If there are no locks on the table, put a write lock on it.
- Otherwise, put the lock request in the write lock queue.

The locking method MySQL uses for `READ` locks works as follows:

- If there are no write locks on the table, put a read lock on it.
- Otherwise, put the lock request in the read lock queue.

When a lock is released, the lock is made available to the threads in the write lock queue, then to the threads in the read lock queue.

This means that if you have many updates on a table, `SELECT` statements will wait until there are no more updates.

To work around this for the case where you want to do many `INSERT` and `SELECT` operations on a table, you can insert rows in a temporary table and update the real table with the records from the temporary table once in a while.

This can be done with the following code:

```
mysql> LOCK TABLES real_table WRITE, insert_table WRITE;
mysql> INSERT INTO real_table SELECT * FROM insert_table;
mysql> TRUNCATE TABLE insert_table;
mysql> UNLOCK TABLES;
```

You can use the `LOW_PRIORITY` options with `INSERT`, `UPDATE` or `DELETE` or `HIGH_PRIORITY` with `SELECT` if you want to prioritise retrieval in some specific cases. You can also start `mysqld` with `--low-priority-updates` to get the same behaveour.

Using `SQL_BUFFER_RESULT` can also help making table locks shorter. See Section 6.4.1 [SELECT], page 530.

You could also change the locking code in '`mysys/thr_lock.c`' to use a single queue. In this case, write locks and read locks would have the same priority, which might help some applications.

5.3.2 Table Locking Issues

The table locking code in MySQL is deadlock free.

MySQL uses table locking (instead of row locking or column locking) on all table types, except `InnoDB` and `BDB` tables, to achieve a very high lock speed. For large tables, table locking is much better than row locking for most applications, but there are, of course, some pitfalls.

For `InnoDB` and `BDB` tables, MySQL only uses table locking if you explicitly lock the table with `LOCK TABLES`. For these table types we recommend you to not use `LOCK TABLES` at all, because `InnoDB` uses automatic row level locking and `BDB` uses page level locking to ensure transaction isolation.

In MySQL Version 3.23.7 and above, you can insert rows into `MyISAM` tables at the same time other threads are reading from the table. Note that currently this only works if there are no holes after deleted rows in the table at the time the insert is made. When all holes has been filled with new data, concurrent inserts will automatically be enabled again.

Table locking enables many threads to read from a table at the same time, but if a thread wants to write to a table, it must first get exclusive access. During the update, all other threads that want to access this particular table will wait until the update is ready.

As updates on tables normally are considered to be more important than `SELECT`, all statements that update a table have higher priority than statements that retrieve information from a table. This should ensure that updates are not 'starved' because one issues a lot of heavy queries against a specific table. (You can change this by using `LOW_PRIORITY` with the statement that does the update or `HIGH_PRIORITY` with the `SELECT` statement.)

Starting from MySQL Version 3.23.7 one can use the `max_write_lock_count` variable to force MySQL to temporary give all `SELECT` statements, that wait for a table, a higher priority after a specific number of inserts on a table.

Table locking is, however, not very good under the following senario:

- A client issues a `SELECT` that takes a long time to run.
- Another client then issues an `UPDATE` on a used table. This client will wait until the `SELECT` is finished.
- Another client issues another `SELECT` statement on the same table. As `UPDATE` has higher priority than `SELECT`, this `SELECT` will wait for the `UPDATE` to finish. It will also wait for the first `SELECT` to finish!
- A thread is waiting for something like `full disk`, in which case all threads that wants to access the problem table will also be put in a waiting state until more disk space is made available.

Some possible solutions to this problem are:

- Try to get the `SELECT` statements to run faster. You may have to create some summary tables to do this.
- Start `mysqld` with `--low-priority-updates`. This will give all statements that update (modify) a table lower priority than a `SELECT` statement. In this case the last `SELECT` statement in the previous scenario would execute before the `INSERT` statement.

- You can give a specific `INSERT`, `UPDATE`, or `DELETE` statement lower priority with the `LOW_PRIORITY` attribute.
- Start `mysqld` with a low value for `max_write_lock_count` to give `READ` locks after a certain number of `WRITE` locks.
- You can specify that all updates from a specific thread should be done with low priority by using the SQL command: `SET LOW_PRIORITY_UPDATES=1`. See Section 5.5.6 [SET], page 432.
- You can specify that a specific `SELECT` is very important with the `HIGH_PRIORITY` attribute. See Section 6.4.1 [SELECT], page 530.
- If you have problems with `INSERT` combined with `SELECT`, switch to use the new `MyISAM` tables as these support concurrent `SELECT`s and `INSERT`s.
- If you mainly mix `INSERT` and `SELECT` statements, the `DELAYED` attribute to `INSERT` will probably solve your problems. See Section 6.4.3 [INSERT], page 546.
- If you have problems with `SELECT` and `DELETE`, the `LIMIT` option to `DELETE` may help. See Section 6.4.5 [DELETE], page 552.

5.4 Optimising Database Structure

5.4.1 Design Choices

MySQL keeps row data and index data in separate files. Many (almost all) other databases mix row and index data in the same file. We believe that the MySQL choice is better for a very wide range of modern systems.

Another way to store the row data is to keep the information for each column in a separate area (examples are SDBM and Focus). This will cause a performance hit for every query that accesses more than one column. Because this degenerates so quickly when more than one column is accessed, we believe that this model is not good for general purpose databases.

The more common case is that the index and data are stored together (as in Oracle/Sybase et al). In this case you will find the row information at the leaf page of the index. The good thing with this layout is that it, in many cases, depending on how well the index is cached, saves a disk read. The bad things with this layout are:

- Table scanning is much slower because you have to read through the indexes to get at the data.
- You can't use only the index table to retrieve data for a query.
- You lose a lot of space, as you must duplicate indexes from the nodes (as you can't store the row in the nodes).
- Deletes will degenerate the table over time (as indexes in nodes are usually not updated on delete).
- It's harder to cache only the index data.

5.4.2 Get Your Data as Small as Possible

One of the most basic optimisation is to get your data (and indexes) to take as little space on the disk (and in memory) as possible. This can give huge improvements because disk reads are faster and normally less main memory will be used. Indexing also takes less resources if done on smaller columns.

MySQL supports a lot of different table types and row formats. Choosing the right table format may give you a big performance gain. See Chapter 7 [Table types], page 594.

You can get better performance on a table and minimise storage space using the techniques listed here:

- Use the most efficient (smallest) types possible. MySQL has many specialised types that save disk space and memory.
- Use the smaller integer types if possible to get smaller tables. For example, `MEDIUMINT` is often better than `INT`.
- Declare columns to be `NOT NULL` if possible. It makes everything faster and you save one bit per column. Note that if you really need `NULL` in your application you should definitely use it. Just avoid having it on all columns by default.
- If you don't have any variable-length columns (`VARCHAR`, `TEXT`, or `BLOB` columns), a fixed-size record format is used. This is faster but unfortunately may waste some space. See Section 7.1.2 [`MyISAM` table formats], page 597.
- The primary index of a table should be as short as possible. This makes identification of one row easy and efficient.
- For each table, you have to decide which storage/index method to use. See Chapter 7 [Table types], page 594.
- Only create the indexes that you really need. Indexes are good for retrieval but bad when you need to store things fast. If you mostly access a table by searching on a combination of columns, make an index on them. The first index part should be the most used column. If you are **always** using many columns, you should use the column with more duplicates first to get better compression of the index.
- If it's very likely that a column has a unique prefix on the first number of characters, it's better to only index this prefix. MySQL supports an index on a part of a character column. Shorter indexes are faster not only because they take less disk space but also because they will give you more hits in the index cache and thus fewer disk seeks. See Section 5.5.2 [Server parameters], page 427.
- In some circumstances it can be beneficial to split into two a table that is scanned very often. This is especially true if it is a dynamic format table and it is possible to use a smaller static format table that can be used to find the relevant rows when scanning the table.

5.4.3 How MySQL Uses Indexes

Indexes are used to find rows with a specific value of one column fast. Without an index MySQL has to start with the first record and then read through the whole table until it finds the relevant rows. The bigger the table, the more this costs. If the table has an index

for the columns in question, MySQL can quickly get a position to seek to in the middle of the datafile without having to look at all the data. If a table has 1000 rows, this is at least 100 times faster than reading sequentially. Note that if you need to access almost all 1000 rows it is faster to read sequentially because we then avoid disk seeks.

All MySQL indexes (`PRIMARY`, `UNIQUE`, and `INDEX`) are stored in B-trees. Strings are automatically prefix- and end-space compressed. See Section 6.5.7 [`CREATE INDEX`], page 578.

Indexes are used to:

- Quickly find the rows that match a `WHERE` clause.
- Retrieve rows from other tables when performing joins.
- Find the `MAX()` or `MIN()` value for a specific indexed column. This is optimised by a preprocessor that checks if you are using `WHERE` key_part_# = constant on all key parts < N. In this case MySQL will do a single key lookup and replace the `MIN()` expression with a constant. If all expressions are replaced with constants, the query will return at once:

  ```
  SELECT MIN(key_part2),MAX(key_part2) FROM table_name where key_part1=10
  ```

- Sort or group a table if the sorting or grouping is done on a leftmost prefix of a usable key (for example, `ORDER BY key_part_1,key_part_2`). The key is read in reverse order if all key parts are followed by `DESC`. See Section 5.2.8 [ORDER BY optimisation], page 411.
- In some cases a query can be optimised to retrieve values without consulting the datafile. If all used columns for some table are numeric and form a leftmost prefix for some key, the values may be retrieved from the index tree for greater speed:

  ```
  SELECT key_part3 FROM table_name WHERE key_part1=1
  ```

Suppose you issue the following `SELECT` statement:

```
mysql> SELECT * FROM tbl_name WHERE col1=val1 AND col2=val2;
```

If a multiple-column index exists on `col1` and `col2`, the appropriate rows can be fetched directly. If separate single-column indexes exist on `col1` and `col2`, the optimiser tries to find the most restrictive index by deciding which index will find fewer rows and using that index to fetch the rows.

If the table has a multiple-column index, any leftmost prefix of the index can be used by the optimiser to find rows. For example, if you have a three-column index on `(col1,col2,col3)`, you have indexed search capabilities on `(col1)`, `(col1,col2)`, and `(col1,col2,col3)`.

MySQL can't use a partial index if the columns don't form a leftmost prefix of the index. Suppose you have the `SELECT` statements shown here:

```
mysql> SELECT * FROM tbl_name WHERE col1=val1;
mysql> SELECT * FROM tbl_name WHERE col2=val2;
mysql> SELECT * FROM tbl_name WHERE col2=val2 AND col3=val3;
```

If an index exists on `(col1,col2,col3)`, only the first of the preceding queries uses the index. The second and third queries do involve indexed columns, but `(col2)` and `(col2,col3)` are not leftmost prefixes of `(col1,col2,col3)`.

MySQL also uses indexes for `LIKE` comparisons if the argument to `LIKE` is a constant string that doesn't start with a wildcard character. For example, the following `SELECT` statements use indexes:

```
mysql> SELECT * FROM tbl_name WHERE key_col LIKE "Patrick%";
mysql> SELECT * FROM tbl_name WHERE key_col LIKE "Pat%_ck%";
```

In the first statement, only rows with `"Patrick" <= key_col < "Patricl"` are considered. In the second statement, only rows with `"Pat" <= key_col < "Pau"` are considered.

The following `SELECT` statements will not use indexes:

```
mysql> SELECT * FROM tbl_name WHERE key_col LIKE "%Patrick%";
mysql> SELECT * FROM tbl_name WHERE key_col LIKE other_col;
```

In the first statement, the `LIKE` value begins with a wildcard character. In the second statement, the `LIKE` value is not a constant.

MySQL 4.0 does another optimisation on `LIKE`. If you use `... LIKE "%string%"` and `string` is longer than 3 characters, MySQL will use the `Turbo Boyer-Moore` algorithm to initialise the pattern for the string and then use this pattern to perform the search quicker.

Searching using `column_name IS NULL` will use indexes if column_name is an index.

MySQL normally uses the index that finds the least number of rows. An index is used for columns that you compare with the following operators: `=`, `>`, `>=`, `<`, `<=`, `BETWEEN`, and a `LIKE` with a non-wildcard prefix like `'something%'`.

Any index that doesn't span all `AND` levels in the `WHERE` clause is not used to optimise the query. In other words: To be able to use an index, a prefix of the index must be used in every `AND` group.

The following `WHERE` clauses use indexes:

```
... WHERE index_part1=1 AND index_part2=2 AND other_column=3
... WHERE index=1 OR A=10 AND index=2      /* index = 1 OR index = 2 */
... WHERE index_part1='hello' AND index_part_3=5
          /* optimised like "index_part1='hello'" */
... WHERE index1=1 and index2=2 or index1=3 and index3=3;
          /* Can use index on index1 but not on index2 or index 3 */
```

These `WHERE` clauses do **NOT** use indexes:

```
... WHERE index_part2=1 AND index_part3=2  /* index_part_1 is not used */
... WHERE index=1 OR A=10                  /* Index is not used in
                                                        both AND parts */
... WHERE index_part1=1 OR index_part2=10  /* No index spans all rows  */
```

Note that in some cases MySQL will not use an index, even if one would be available. Some of the cases where this happens are:

- If the use of the index would require MySQL to access more than 30% of the rows in the table. (In this case a table scan is probably much faster, as this will require us to do much fewer seeks.) Note that if such a query uses `LIMIT` to only retrieve part of the rows, MySQL will use an index anyway, as it can much more quickly find the few rows to return in the result.

5.4.4 Column Indexes

All MySQL column types can be indexed. Use of indexes on the relevant columns is the best way to improve the performance of `SELECT` operations.

The maximum number of keys and the maximum index length is defined per storage engine. See Chapter 7 [Table types], page 594. You can with all storage engines have at least 16 keys and a total index length of at least 256 bytes.

For `CHAR` and `VARCHAR` columns, you can index a prefix of a column. This is much faster and requires less disk space than indexing the whole column. The syntax to use in the `CREATE TABLE` statement to index a column prefix looks like this:

```
KEY index_name (col_name(length))
```

The example here creates an index for the first 10 characters of the `name` column:

```
mysql> CREATE TABLE test (
    ->        name CHAR(200) NOT NULL,
    ->        KEY index_name (name(10)));
```

For `BLOB` and `TEXT` columns, you must index a prefix of the column. The prefix may be up to 255 bytes long.

In MySQL Version 3.23.23 or later, you can also create special `FULLTEXT` indexes. They are used for full-text search. Only the `MyISAM` table type supports `FULLTEXT` indexes. They can be created only from `CHAR`, `VARCHAR`, and `TEXT` columns. Indexing always happens over the entire column and partial indexing is not supported. See Section 6.8 [Fulltext Search], page 584 for details.

5.4.5 Multiple-Column Indexes

MySQL can create indexes on multiple columns. An index may consist of up to 15 columns. (On `CHAR` and `VARCHAR` columns you can also use a prefix of the column as a part of an index.)

A multiple-column index can be considered a sorted array containing values that are created by concatenating the values of the indexed columns.

MySQL uses multiple-column indexes in such a way that queries are fast when you specify a known quantity for the first column of the index in a `WHERE` clause, even if you don't specify values for the other columns.

Suppose a table is created using the following specification:

```
mysql> CREATE TABLE test (
    ->       id INT NOT NULL,
    ->       last_name CHAR(30) NOT NULL,
    ->       first_name CHAR(30) NOT NULL,
    ->       PRIMARY KEY (id),
    ->       INDEX name (last_name,first_name));
```

Then the index `name` is an index over `last_name` and `first_name`. The index will be used for queries that specify values in a known range for `last_name`, or for both `last_name` and `first_name`. Therefore, the `name` index will be used in the following queries:

```
mysql> SELECT * FROM test WHERE last_name="Widenius";

mysql> SELECT * FROM test WHERE last_name="Widenius"
    ->                    AND first_name="Michael";
```

```
mysql> SELECT * FROM test WHERE last_name="Widenius"
    ->                    AND (first_name="Michael" OR first_name="Monty");

mysql> SELECT * FROM test WHERE last_name="Widenius"
    ->                    AND first_name >="M" AND first_name < "N";
```

However, the `name` index will NOT be used in the following queries:

```
mysql> SELECT * FROM test WHERE first_name="Michael";

mysql> SELECT * FROM test WHERE last_name="Widenius"
    ->                    OR first_name="Michael";
```

For more information on the manner in which MySQL uses indexes to improve query performance, see Section 5.4.3 [MySQL indexes], page 421.

5.4.6 How MySQL Counts Open Tables

When you run `mysqladmin status`, you'll see something like this:

```
Uptime: 426 Running threads: 1 Questions: 11082 Reloads: 1 Open tables: 12
```

This can be somewhat perplexing if you only have 6 tables.

MySQL is multi-threaded, so it may have many queries on the same table simultaneously. To minimise the problem with two threads having different states on the same file, the table is opened independently by each concurrent thread. This takes some memory but will normally increase performance. With `ISAM` and `MyISAM` tables this also requires one extra file descriptor for the datafile. With these table types the index file descriptor is shared between all threads.

You can read more about this topic in the next section. See Section 5.4.7 [Table cache], page 425.

5.4.7 How MySQL Opens and Closes Tables

`table_cache`, `max_connections`, and `max_tmp_tables` affect the maximum number of files the server keeps open. If you increase one or both of these values, you may run up against a limit imposed by your operating system on the per-process number of open file descriptors. However, you can increase the limit on many systems. Consult your OS documentation to find out how to do this, because the method for changing the limit varies widely from system to system.

`table_cache` is related to `max_connections`. For example, for 200 concurrent running connections, you should have a table cache of at least `200 * n`, where `n` is the maximum number of tables in a join. You also need to reserve some extra file descriptors for temporary tables and files.

Make sure that your operating system can handle the number of open file descriptors implied by the `table_cache` setting. If `table_cache` is set too high, MySQL may run out of file descriptors and refuse connections, fail to perform queries, and be very unreliable. You also have to take into account that the `MyISAM` storage engine needs two file descriptors for each unique open table. You can in increase the number of file descriptors available for

MySQL with the `--open-files-limit=#` startup option. See Section A.2.17 [Not enough file handles], page 856.

The cache of open tables will be kept at a level of `table_cache` entries. The default value is 64; this can be changed with the `-O table_cache=#` option to `mysqld`). Note that MySQL may temporarily open even more tables to be able to execute queries.

A not used table is closed and removed from the table cache under the following circumstances:

- When the cache is full and a thread tries to open a table that is not in the cache.
- When the cache contains more than `table_cache` entries and a thread is no longer using a table.
- When someone executes `mysqladmin refresh` or `mysqladmin flush-tables`.
- When someone executes a `FLUSH TABLES` statement.

When the table cache fills up, the server uses the following procedure to locate a cache entry to use:

- Tables that are not currently in use are released, in least-recently-used order.
- If the cache is full and no tables can be released, but a new table needs to be opened, the cache is temporarily extended as necessary.
- If the cache is in a temporarily extended state and a table goes from in-use to not-in-use state, the table is closed and released from the cache.

A table is opened for each concurrent access. This means that if you have two threads accessing the same table or access the table twice in the same query (with `AS`) the table needs to be opened twice. The first open of any table takes two file descriptors; each additional use of the table takes only one file descriptor. The extra descriptor for the first open is used for the index file; this descriptor is shared among all threads.

If you are opening a table with the `HANDLER table_name OPEN` statement, a dedicated table object is allocated for the thread. This table object is not shared by other threads an will not be closed until the thread calls `HANDLER table_name CLOSE` or the thread dies. See Section 6.4.9 [`HANDLER`], page 562. When this happens, the table is put back in the table cache (if it isn't full).

You can check if your table cache is too small by checking the `mysqld` variable `Opened_tables`. If this is quite big, even if you haven't done a lot of `FLUSH TABLES`, you should increase your table cache. See Section 4.6.8.3 [`Opened_tables`], page 287.

5.4.8 Drawbacks to Creating Large Numbers of Tables in the Same Database

If you have many files in a directory, open, close, and create operations will be slow. If you execute `SELECT` statements on many different tables, there will be a little overhead when the table cache is full, because for every table that has to be opened, another must be closed. You can reduce this overhead by making the table cache larger.

5.5 Optimising the MySQL Server

5.5.1 System/Compile Time and Startup Parameter Tuning

We start with the system level things since some of these decisions have to be made very early. In other cases a fast look at this part may suffice because it not that important for the big gains. However, it is always nice to have a feeling about how much one could gain by changing things at this level.

The default OS to use is really important! To get the most use of multiple-CPU machines one should use Solaris (because the threads works really nice) or Linux (because the 2.2 kernel has really good SMP support). Also on 32-bit machines Linux has a 2G file-size limit by default. Hopefully this will be fixed soon when new filesystems are released (XFS/Reiserfs). If you have a desperate need for files bigger than 2G on Linux-intel 32 bit, you should get the LFS patch for the ext2 filesystem.

Because we have not run MySQL in production on that many platforms, we advice you to test your intended platform before choosing it, if possible.

Other tips:

- If you have enough RAM, you could remove all swap devices. Some operating systems will use a swap device in some contexts even if you have free memory.
- Use the `--skip-external-locking` MySQL option to avoid external locking. Note that this will not impact MySQL's functionality as long as you only run one server. Just remember to take down the server (or lock relevant parts) before you run `myisamchk`. On some system this switch is mandatory because the external locking does not work in any case.

  The `--skip-external-locking` option is on by default when compiling with MIT-pthreads, because `flock()` isn't fully supported by MIT-pthreads on all platforms. It's also on default for Linux as Linux file locking are not yet safe.

  The only case when you can't use `--skip-external-locking` is if you run multiple MySQL *servers* (not clients) on the same data, or run `myisamchk` on the table without first flushing and locking the `mysqld` server tables first.

  You can still use `LOCK TABLES`/`UNLOCK TABLES` even if you are using `--skip-external-locking`

5.5.2 Tuning Server Parameters

You can get the default buffer sizes used by the `mysqld` server with this command:

```
shell> mysqld --help
```

This command produces a list of all `mysqld` options and configurable variables. The output includes the default values and looks something like this:

```
Possible variables for option --set-variable (-O) are:
back_log                current value: 5
bdb_cache_size          current value: 1048540
binlog_cache_size       current value: 32768
```

```
connect_timeout          current value: 5
delayed_insert_timeout   current value: 300
delayed_insert_limit     current value: 100
delayed_queue_size       current value: 1000
flush_time               current value: 0
interactive_timeout      current value: 28800
join_buffer_size         current value: 131072
key_buffer_size          current value: 1048540
lower_case_table_names   current value: 0
long_query_time          current value: 10
max_allowed_packet       current value: 1048576
max_binlog_cache_size    current value: 4294967295
max_connections          current value: 100
max_connect_errors       current value: 10
max_delayed_threads      current value: 20
max_heap_table_size      current value: 16777216
max_join_size            current value: 4294967295
max_sort_length          current value: 1024
max_tmp_tables           current value: 32
max_write_lock_count     current value: 4294967295
myisam_sort_buffer_size  current value: 8388608
net_buffer_length        current value: 16384
net_retry_count          current value: 10
net_read_timeout         current value: 30
net_write_timeout        current value: 60
read_buffer_size         current value: 131072
read_rnd_buffer_size     current value: 262144
slow_launch_time         current value: 2
sort_buffer              current value: 2097116
table_cache              current value: 64
thread_concurrency       current value: 10
tmp_table_size           current value: 1048576
thread_stack             current value: 131072
wait_timeout             current value: 28800
```

Please note that `--set-variable` is deprecated since MySQL 4.0, just use `--var=option` on its own.

If there is a `mysqld` server currently running, you can see what values it actually is using for the variables by executing this command:

```
shell> mysqladmin variables
```

You can find a full description for all variables in the `SHOW VARIABLES` section in this manual. See Section 4.6.8.4 [SHOW VARIABLES], page 290.

You can also see some statistics from a running server by issuing the command `SHOW STATUS`. See Section 4.6.8.3 [SHOW STATUS], page 287.

MySQL uses algorithms that are very scalable, so you can usually run with very little memory. If you, however, give MySQL more memory, you will normally also get better performance.

When tuning a MySQL server, the two most important variables to use are `key_buffer_size` and `table_cache`. You should first feel confident that you have these right before trying to change any of the other variables.

If you have much memory (>=256M) and many tables and want maximum performance with a moderate number of clients, you should use something like this:

```
shell> mysqld_safe -O key_buffer=64M -O table_cache=256 \
           -O sort_buffer=4M -O read_buffer_size=1M &
```

If you have only 128M and only a few tables, but you still do a lot of sorting, you can use something like:

```
shell> mysqld_safe -O key_buffer=16M -O sort_buffer=1M
```

If you have little memory and lots of connections, use something like this:

```
shell> mysqld_safe -O key_buffer=512k -O sort_buffer=100k \
           -O read_buffer_size=100k &
```

or even:

```
shell> mysqld_safe -O key_buffer=512k -O sort_buffer=16k \
           -O table_cache=32 -O read_buffer_size=8k -O net_buffer_length=1K &
```

If you are doing a `GROUP BY` or `ORDER BY` on files that are much bigger than your available memory you should increase the value of `read_rnd_buffer_size` to speed up the reading of rows after the sorting is done.

When you have installed MySQL, the '`support-files`' directory will contain some different '`my.cnf`' example files, '`my-huge.cnf`', '`my-large.cnf`', '`my-medium.cnf`', and '`my-small.cnf`', you can use as a base to optimise your system.

If there are very many connections, "swapping problems" may occur unless `mysqld` has been configured to use very little memory for each connection. `mysqld` performs better if you have enough memory for all connections, of course.

Note that if you change an option to `mysqld`, it remains in effect only for that instance of the server.

To see the effects of a parameter change, do something like this:

```
shell> mysqld -O key_buffer=32m --help
```

Make sure that the `--help` option is last; otherwise, the effect of any options listed after it on the command-line will not be reflected in the output.

5.5.3 How Compiling and Linking Affects the Speed of MySQL

Most of the following tests are done on Linux with the MySQL benchmarks, but they should give some indication for other operating systems and workloads.

You get the fastest executable when you link with `-static`.

On Linux, you will get the fastest code when compiling with `pgcc` and `-O3`. To compile '`sql_yacc.cc`' with these options, you need about 200M memory because `gcc/pgcc` needs a lot of memory to make all functions inline. You should also set `CXX=gcc` when configuring MySQL to avoid inclusion of the `libstdc++` library (it is not needed). Note that with some versions of `pgcc`, the resulting code will only run on true Pentium processors, even if you

use the compiler option that you want the resulting code to be working on all x586 type processors (like AMD).

By just using a better compiler and/or better compiler options you can get a 10-30% speed increase in your application. This is particularly important if you compile the SQL server yourself!

We have tested both the Cygnus CodeFusion and Fujitsu compilers, but when we tested them, neither was sufficiently bug free to allow MySQL to be compiled with optimisations on.

When you compile MySQL you should only include support for the character sets that you are going to use. (Option `--with-charset=xxx`.) The standard MySQL binary distributions are compiled with support for all character sets.

Here is a list of some measurements that we have done:

- If you use `pgcc` and compile everything with `-O6`, the `mysqld` server is 1% faster than with `gcc` 2.95.2.
- If you link dynamically (without `-static`), the result is 13% slower on Linux. Note that you still can use a dynamic linked MySQL library. It is only the server that is critical for performance.
- If you strip your `mysqld` binary with `strip libexec/mysqld`, the resulting binary can be up to 4% faster.
- If you connect using TCP/IP rather than Unix sockets, the result is 7.5% slower on the same computer. (If you are connection to `localhost`, MySQL will, by default, use sockets.)
- If you connect using TCP/IP from another computer over a 100M Ethernet, things will be 8-11% slower.
- When running our benchmark tests using secure connections (all data encrypted with internal SSL support) things were 55% slower.
- If you compile with `--with-debug=full`, you will lose 20% for most queries. Some queries may take substantially longer (for example, the MySQL benchmarks ran 35% slower). If you use `--with-debug`, then you will only lose 15%. For a `mysqld` version that has been compiled with `--with-debug=full`, you can disable memory checking at runtime by starting it with the `--skip-safemalloc` option. The end result in this case should be close to when configuring with `--with-debug`.
- On a Sun UltraSPARC-IIe, Forte 5.0 is 4% faster than `gcc` 3.2
- On a Sun UltraSPARC-IIe, Forte 5.0 is 4% faster in 32 bit mode than in 64 bit mode.
- Compiling with `gcc` 2.95.2 for UltraSPARC with the option `-mcpu=v8 -Wa,-xarch=v8plusa` gives 4% more performance.
- On Solaris 2.5.1, MIT-pthreads is 8-12% slower than Solaris native threads on a single processor. With more load/CPUs the difference should get bigger.
- Running with `--log-bin` makes mysqld 1% slower.
- Compiling on Linux-x86 using gcc without frame pointers `-fomit-frame-pointer` or `-fomit-frame-pointer -ffixed-ebp` makes `mysqld` 1-4% faster.

The MySQL-Linux distribution provided by MySQL AB used to be compiled with `pgcc`, but we had to go back to regular gcc because of a bug in `pgcc` that would generate the

code that does not run on AMD. We will continue using gcc until that bug is resolved. In the meantime, if you have a non-AMD machine, you can get a faster binary by compiling with `pgcc`. The standard MySQL Linux binary is linked statically to get it faster and more portable.

5.5.4 How MySQL Uses Memory

The following list indicates some of the ways that the `mysqld` server uses memory. Where applicable, the name of the server variable relevant to the memory use is given:

- The key buffer (variable `key_buffer_size`) is shared by all threads; other buffers used by the server are allocated as needed. See Section 5.5.2 [Server parameters], page 427.
- Each connection uses some thread-specific space: A stack (default 64K, variable `thread_stack`), a connection buffer (variable `net_buffer_length`), and a result buffer (variable `net_buffer_length`). The connection buffer and result buffer are dynamically enlarged up to `max_allowed_packet` when needed. When a query is running, a copy of the current query string is also allocated.
- All threads share the same base memory.
- Only the compressed `ISAM` / `MyISAM` tables are memory mapped. This is because the 32-bit memory space of 4 GB is not large enough for most big tables. When systems with a 64-bit address space become more common we may add general support for memory mapping.
- Each request doing a sequential scan over a table allocates a read buffer (variable `record_buffer`).
- When reading rows in 'random' order (for example after a sort) a random-read buffer is allocated to avoid disk seeks. (variable `read_rnd_buffer_size`).
- All joins are done in one pass, and most joins can be done without even using a temporary table. Most temporary tables are memory-based (`HEAP`) tables. Temporary tables with a big record length (calculated as the sum of all column lengths) or that contain `BLOB` columns are stored on disk.

  One problem in MySQL versions before Version 3.23.2 is that if a `HEAP` table exceeds the size of `tmp_table_size`, you get the error `The table tbl_name is full`. In newer versions this is handled by automatically changing the in-memory (`HEAP`) table to a disk-based (`MyISAM`) table as necessary. To work around this problem, you can increase the temporary table size by setting the `tmp_table_size` option to `mysqld`, or by setting the SQL option `BIG_TABLES` in the client program. See Section 5.5.6 [`SET` Syntax], page 432. In MySQL Version 3.20, the maximum size of the temporary table was `record_buffer*16`, so if you are using this version, you have to increase the value of `record_buffer`. You can also start `mysqld` with the `--big-tables` option to always store temporary tables on disk. However, this will affect the speed of many complicated queries.
- Most requests doing a sort allocates a sort buffer and 0-2 temporary files depending on the result set size. See Section A.4.4 [Temporary files], page 863.
- Almost all parsing and calculating is done in a local memory store. No memory overhead is needed for small items and the normal slow memory allocation and freeing is

avoided. Memory is allocated only for unexpectedly large strings (this is done with `malloc()` and `free()`).

- Each index file is opened once and the datafile is opened once for each concurrently running thread. For each concurrent thread, a table structure, column structures for each column, and a buffer of size `3 * n` is allocated (where `n` is the maximum row length, not counting `BLOB` columns). A `BLOB` uses 5 to 8 bytes plus the length of the `BLOB` data. The `ISAM`/`MyISAM` storage engines will use one extra row buffer for internal usage.
- For each table having `BLOB` columns, a buffer is enlarged dynamically to read in larger `BLOB` values. If you scan a table, a buffer as large as the largest `BLOB` value is allocated.
- Storage engines for all in-use tables are saved in a cache and managed as a FIFO. Normally the cache has 64 entries. If a table has been used by two running threads at the same time, the cache contains two entries for the table. See Section 5.4.7 [Table cache], page 425.
- A `mysqladmin flush-tables` command closes all tables that are not in use and marks all in-use tables to be closed when the currently executing thread finishes. This will effectively free most in-use memory.

`ps` and other system status programs may report that `mysqld` uses a lot of memory. This may be caused by thread-stacks on different memory addresses. For example, the Solaris version of `ps` counts the unused memory between stacks as used memory. You can verify this by checking available swap with `swap -s`. We have tested `mysqld` with commercial memory-leakage detectors, so there should be no memory leaks.

5.5.5 How MySQL uses DNS

When a new thread connects to `mysqld`, `mysqld` will spawn a new thread to handle the request. This thread will first check if the hostname is in the hostname cache. If not the thread will call `gethostbyaddr_r()` and `gethostbyname_r()` to resolve the hostname.

If the operating system doesn't support the above thread-safe calls, the thread will lock a mutex and call `gethostbyaddr()` and `gethostbyname()` instead. Note that in this case no other thread can resolve other hostnames that is not in the hostname cache until the first thread is ready.

You can disable DNS host lookup by starting `mysqld` with `--skip-name-resolve`. In this case you can however only use IP names in the MySQL privilege tables.

If you have a very slow DNS and many hosts, you can get more performance by either disabling DNS lookop with `--skip-name-resolve` or by increasing the `HOST_CACHE_SIZE` define (default: 128) and recompile `mysqld`.

You can disable the hostname cache with `--skip-host-cache`. You can clear the hostname cache with `FLUSH HOSTS` or `mysqladmin flush-hosts`.

If you don't want to allow connections over `TCP/IP`, you can do this by starting `mysqld` with `--skip-networking`.

5.5.6 `SET` Syntax

```
SET [GLOBAL | SESSION] sql_variable=expression,
```

```
[[GLOBAL | SESSION] sql_variable=expression] ...
```

`SET` sets various options that affect the operation of the server or your client.

The following examples shows the different syntaxes one can use to set variables:

In old MySQL versions we allowed the use of the `SET OPTION` syntax, but this syntax is now deprecated.

In MySQL 4.0.3 we added the `GLOBAL` and `SESSION` options and access to most important startup variables.

`LOCAL` can be used as a synonym for `SESSION`.

If you set several variables on the same command line, the last used `GLOBAL | SESSION` mode is used.

```
SET sort_buffer_size=10000;
SET @@local.sort_buffer_size=10000;
SET GLOBAL sort_buffer_size=1000000, SESSION sort_buffer_size=1000000;
SET @@sort_buffer_size=1000000;
SET @@global.sort_buffer_size=1000000, @@local.sort_buffer_size=1000000;
```

The `@@variable_name` syntax is supported to make MySQL syntax compatible with some other databases.

The different system variables one can set are described in the system variable section of this manual. See Section 6.1.5 [System Variables], page 447.

If you are using `SESSION` (the default) the option you set remains in effect until the current session ends, or until you set the option to a different value. If you use `GLOBAL`, which require the `SUPER` privilege, the option is remembered and used for new connections until the server restarts. If you want to make an option permanent, you should set it in one of the MySQL option files. See Section 4.1.2 [Option files], page 203.

To avoid incorrect usage, MySQL will produce an error if you use `SET GLOBAL` with a variable that can only be used with `SET SESSION` or if you are not using `SET GLOBAL` with a global variable.

If you want to set a `SESSION` variable to the `GLOBAL` value or a `GLOBAL` value to the MySQL default value, you can set it to `DEFAULT`.

```
SET max_join_size=DEFAULT;
```

This is identical to:

```
SET @@session.max_join_size=@@global.max_join_size;
```

If you want to restrict the maximum value a startup option can be set to with the `SET` command, you can specify this by using the `--maximum-variable-name` command line option. See Section 4.1.1 [Command-line options], page 195.

You can get a list of most variables with `SHOW VARIABLES`. See Section 4.6.8.4 [SHOW VARIABLES], page 290. You can get the value for a specific value with the `@@[global.|local.]variable_name` syntax:

```
SHOW VARIABLES like "max_join_size";
SHOW GLOBAL VARIABLES like "max_join_size";
SELECT @@max_join_size, @@global.max_join_size;
```

Here follows a description of the variables that uses a the variables that uses a non-standard `SET` syntax and some of the other variables. The other variable definitions can be found

in the system variable section, among the startup options or in the description of `SHOW VARIABLES`. See Section 6.1.5 [System Variables], page 447. See Section 4.1.1 [Command-line options], page 195. See Section 4.6.8.4 [SHOW VARIABLES], page 290.

`CHARACTER SET character_set_name | DEFAULT`
: This maps all strings from and to the client with the given mapping. Currently the only option for `character_set_name` is `cp1251_koi8`, but you can easily add new mappings by editing the '`sql/convert.cc`' file in the MySQL source distribution. The default mapping can be restored by using a `character_set_name` value of `DEFAULT`.

  Note that the syntax for setting the `CHARACTER SET` option differs from the syntax for setting the other options.

`PASSWORD = PASSWORD('some password')`
: Set the password for the current user. Any non-anonymous user can change his own password!

`PASSWORD FOR user = PASSWORD('some password')`
: Set the password for a specific user on the current server host. Only a user with access to the `mysql` database can do this. The user should be given in `user@hostname` format, where `user` and `hostname` are exactly as they are listed in the `User` and `Host` columns of the `mysql.user` table entry. For example, if you had an entry with `User` and `Host` fields of `'bob'` and `'%.loc.gov'`, you would write:

```
mysql> SET PASSWORD FOR bob@"%.loc.gov" = PASSWORD("newpass");
```

  Which is equivalent to:

```
mysql> UPDATE mysql.user SET password=PASSWORD("newpass")
    ->                   WHERE user="bob" AND host="%.loc.gov";
```

`SQL_AUTO_IS_NULL = 0 | 1`
: If set to `1` (default) then one can find the last inserted row for a table with an `AUTO_INCREMENT` column with the following construct: `WHERE auto_increment_column IS NULL`. This is used by some ODBC programs like Access.

`AUTOCOMMIT= 0 | 1`
: If set to `1` all changes to a table will be done at once. To start a multi-command transaction, you have to use the `BEGIN` statement. See Section 6.7.1 [COMMIT], page 580. If set to `0` you have to use `COMMIT` / `ROLLBACK` to accept/revoke that transaction. See Section 6.7.1 [COMMIT], page 580. Note that when you change from not `AUTOCOMMIT` mode to `AUTOCOMMIT` mode, MySQL will do an automatic `COMMIT` on any open transactions.

`BIG_TABLES = 0 | 1`
: If set to `1`, all temporary tables are stored on disk rather than in memory. This will be a little slower, but you will not get the error `The table tbl_name is full` for big `SELECT` operations that require a large temporary table. The default value for a new connection is `0` (that is, use in-memory temporary tables). This option was before named `SQL_BIG_TABLES`. In MySQL 4.0 you

should normally never need this flag as MySQL will automatically convert in memory tables to disk based ones if need.

`SQL_BIG_SELECTS = 0 | 1`

If set to `0`, MySQL will abort if a `SELECT` is attempted that probably will take a very long time, which is defined as if the number of examined rows is probably going to be bigger than `MAX_JOIN_SIZE`. This is useful when an inadvisable `WHERE` statement has been issued. A big query is defined as a `SELECT` that probably will have to examine more than `max_join_size` rows. The default value for a new connection is `1` (which will allow all `SELECT` statements).

If you set `MAX_JOIN_SIZE` to another value than `DEFAULT SQL_BIG_SELECTS` will be set to 0.

`SQL_BUFFER_RESULT = 0 | 1`

`SQL_BUFFER_RESULT` will force the result from `SELECT`s to be put into a temporary table. This will help MySQL free the table locks early and will help in cases where it takes a long time to send the result set to the client.

`LOW_PRIORITY_UPDATES = 0 | 1`

If set to `1`, all `INSERT`, `UPDATE`, `DELETE`, and `LOCK TABLE WRITE` statements wait until there is no pending `SELECT` or `LOCK TABLE READ` on the affected table. This option was before named `SQL_LOW_PRIORITY_UPDATES`.

`MAX_JOIN_SIZE = value | DEFAULT`

Don't allow `SELECT`s that will probably need to examine more than `value` row combinations or is likely to do more than `value` disk seeks. By setting this value, you can catch `SELECT`s where keys are not used properly and that would probably take a long time. Setting this to a value other than `DEFAULT` will reset the `SQL_BIG_SELECTS` flag. If you set the `SQL_BIG_SELECTS` flag again, the `SQL_MAX_JOIN_SIZE` variable will be ignored. You can set a default value for this variable by starting `mysqld` with `-O max_join_size=#`. This option was before named `SQL_MAX_JOIN_SIZE`.

Note that if the result of the query is already in the query cache, the above check will not be made. Instead, MySQL will send the result to the client. Since the query result is already computed and it will not burden the server to send the result to the client.

`QUERY_CACHE_TYPE = OFF | ON | DEMAND`
`QUERY_CACHE_TYPE = 0 | 1 | 2`

Set query cache setting for this thread.

Option	**Description**
0 or OFF	Don't cache or retrieve results.
1 or ON	Cache all results except `SELECT SQL_NO_CACHE ...` queries.
2 or DEMAND	Cache only `SELECT SQL_CACHE ...` queries.

`SQL_SAFE_UPDATES = 0 | 1`

If set to `1`, MySQL will abort if an `UPDATE` or `DELETE` is attempted that doesn't use a key or `LIMIT` in the `WHERE` clause. This makes it possible to catch wrong updates when creating SQL commands by hand.

`SQL_SELECT_LIMIT = value | DEFAULT`
: The maximum number of records to return from `SELECT` statements. If a `SELECT` has a `LIMIT` clause, the `LIMIT` takes precedence over the value of `SQL_SELECT_LIMIT`. The default value for a new connection is "unlimited." If you have changed the limit, the default value can be restored by using a `SQL_SELECT_LIMIT` value of `DEFAULT`.

`SQL_LOG_OFF = 0 | 1`
: If set to `1`, no logging is done to the standard log for this client, if the client has the `SUPER` privilege.

`SQL_LOG_BIN = 0 | 1`
: If set to `0`, no logging is done to the binary log for the client, if the client has the `SUPER` privilege.

`SQL_LOG_UPDATE = 0 | 1`
: If set to `0`, no logging is done to the update log for the client, if the client has the `SUPER` privilege. This variable is deprecated starting from version 5.0.

`SQL_QUOTE_SHOW_CREATE = 0 | 1`
: If set to `1`, `SHOW CREATE TABLE` quotes table and column names. This is **on** by default, for replication of tables with fancy column names to work. Section 4.6.8.8 [`SHOW CREATE TABLE`], page 303.

`TIMESTAMP = timestamp_value | DEFAULT`
: Set the time for this client. This is used to get the original timestamp if you use the binary log to restore rows. `timestamp_value` should be a Unix epoch timestamp, not a MySQL timestamp.

`LAST_INSERT_ID = #`
: Set the value to be returned from `LAST_INSERT_ID()`. This is stored in the binary log when you use `LAST_INSERT_ID()` in a command that updates a table.

`INSERT_ID = #`
: Set the value to be used by the following `INSERT` or `ALTER TABLE` command when inserting an `AUTO_INCREMENT` value. This is mainly used with the binary log.

`DATE_FORMAT = format_str`
: Determines how the server converts DATE values to strings. This variable is available as a global, local, or command-line option. `format_str` can be specified conveniently using the `GET_FORMAT()` function. See See Section 6.3.4 [Date and time functions], page 499.

`TIME_FORMAT = format_str`
: Determines how the server converts TIME values to strings. This variable is available as a global, local, or command-line option. `format_str` can be specified conveniently using the `GET_FORMAT()` function. See See Section 6.3.4 [Date and time functions], page 499.

`DATETIME_FORMAT = format_str`

Determines how the server converts DATETIME values to strings. This variable is available as a global, local, or command-line option. `format_str` can be specified conveniently using the `GET_FORMAT()` function. See See Section 6.3.4 [Date and time functions], page 499.

5.6 Disk Issues

- As mentioned before, disks seeks are a big performance bottleneck. This problems gets more and more apparent when the data starts to grow so large that effective caching becomes impossible. For large databases, where you access data more or less randomly, you can be sure that you will need at least one disk seek to read and a couple of disk seeks to write things. To minimise this problem, use disks with low seek times.
- Increase the number of available disk spindles (and thereby reduce the seek overhead) by either symlink files to different disks or striping the disks.

  Using symbolic links

  This means that you symlink the index and/or datafile(s) from the normal data directory to another disk (that may also be striped). This makes both the seek and read times better (if the disks are not used for other things). See Section 5.6.1 [Symbolic links], page 438.

  Striping Striping means that you have many disks and put the first block on the first disk, the second block on the second disk, and the Nth on the (N mod number_of_disks) disk, and so on. This means if your normal data size is less than the stripe size (or perfectly aligned) you will get much better performance. Note that striping is very dependent on the OS and stripe-size. So benchmark your application with different stripe-sizes. See Section 5.1.5 [Custom Benchmarks], page 398.

  Note that the speed difference for striping is **very** dependent on the parameters. Depending on how you set the striping parameters and number of disks you may get a difference in orders of magnitude. Note that you have to choose to optimise for random or sequential access.
- For reliability you may want to use RAID 0+1 (striping + mirroring), but in this case you will need 2*N drives to hold N drives of data. This is probably the best option if you have the money for it! You may, however, also have to invest in some volume-management software to handle it efficiently.
- A good option is to have semi-important data (that can be regenerated) on RAID 0 disk while storing really important data (like host information and logs) on a RAID 0+1 or RAID N disk. RAID N can be a problem if you have many writes because of the time to update the parity bits.
- You may also set the parameters for the filesystem that the database uses. One easy change is to mount the filesystem with the noatime option. That makes it skip the updating of the last access time in the inode and by this will avoid some disk seeks.
- On Linux, you can get much more performance (up to 100% under load is not uncommon) by using `hdparm` to configure your disk's interface! The following should be quite good `hdparm` options for MySQL (and probably many other applications):

```
hdparm -m 16 -d 1
```

Note that the performance/reliability when using the above depends on your hardware, so we strongly suggest that you test your system thoroughly after using `hdparm`! Please consult the `hdparm` man page for more information! If `hdparm` is not used wisely, filesystem corruption may result. Backup everything before experimenting!

- On many operating systems you can mount the disks with the `-o async` option to set the filesystem to be updated asynchronously. If your computer is reasonably stable, this should give you more performance without sacrificing too much reliability. (This flag is on by default on Linux.)
- If you don't need to know when a file was last accessed (which is not really useful on a database server), you can mount your filesystems with the `-o noatime` option.

5.6.1 Using Symbolic Links

You can move tables and databases from the database directory to other locations and replace them with symbolic links to the new locations. You might want to do this, for example, to move a database to a file system with more free space or increase the speed of your system by spreading your tables to different disk.

The recommended way to do this, is to just symlink databases to a different disk and only symlink tables as a last resort.

5.6.1.1 Using Symbolic Links for Databases

The way to symlink a database is to first create a directory on some disk where you have free space and then create a symlink to it from the MySQL database directory.

```
shell> mkdir /dr1/databases/test
shell> ln -s /dr1/databases/test mysqld-datadir
```

MySQL doesn't support that you link one directory to multiple databases. Replacing a database directory with a symbolic link will work fine as long as you don't make a symbolic link between databases. Suppose you have a database `db1` under the MySQL data directory, and then make a symlink `db2` that points to `db1`:

```
shell> cd /path/to/datadir
shell> ln -s db1 db2
```

Now, for any table `tbl_a` in `db1`, there also appears to be a table `tbl_a` in `db2`. If one thread updates `db1.tbl_a` and another thread updates `db2.tbl_a`, there will be problems.

If you really need this, you must change the following code in '`mysys/mf_format.c`':

```
if (flag & 32 || (!lstat(to,&stat_buff) && S_ISLNK(stat_buff.st_mode)))
```

to

```
if (1)
```

On Windows you can use internal symbolic links to directories by compiling MySQL with `-DUSE_SYMDIR`. This allows you to put different databases on different disks. See Section 2.6.1.2 [Windows symbolic links], page 122.

5.6.1.2 Using Symbolic Links for Tables

Before MySQL 4.0 you should not symlink tables, if you are not very careful with them. The problem is that if you run `ALTER TABLE`, `REPAIR TABLE` or `OPTIMIZE TABLE` on a symlinked table, the symlinks will be removed and replaced by the original files. This happens because the above command works by creating a temporary file in the database directory and when the command is complete, replace the original file with the temporary file.

You should not symlink tables on systems that don't have a fully working `realpath()` call. (At least Linux and Solaris support `realpath()`)

In MySQL 4.0 symlinks are fully supported only for `MyISAM` tables. For other table types you will probably get strange problems when doing any of the above mentioned commands.

The handling of symbolic links in MySQL 4.0 works the following way (this is mostly relevant only for `MyISAM` tables).

- In the data directory you will always have the table definition file and the data and index files.
- You can symlink the index file and the datafile to different directories independently of the other.
- The symlinking can be done from the operating system (if `mysqld` is not running) or with the `INDEX/DATA DIRECTORY="path-to-dir"` command in `CREATE TABLE`. See Section 6.5.3 [CREATE TABLE], page 564.
- `myisamchk` will not replace a symlink with the data or index file but work directly on the file the symlink points to. Any temporary files will be created in the same directory where the data or index file is located.
- When you drop a table that is using symlinks, both the symlink and the file the symlink points to are dropped. This is a good reason to why you should **not** run `mysqld` as `root` or allow persons to have write access to the MySQL database directories.
- If you rename a table with `ALTER TABLE RENAME` and you don't move the table to another database, the symlinks in the database directory will be renamed to the new names and the data and index files will be renamed accordingly.
- If you use `ALTER TABLE RENAME` to move a table to another database, the table will be moved to the other database directory and the old symlinks and the files they pointed to will be deleted. (In other words, the new table will not be symlinked.)
- If you are not using symlinks, you should use the `--skip-symlink` option to `mysqld` to ensure that no one can drop or rename a file outside of the `mysqld` data directory.

Things that are not yet supported:

- `ALTER TABLE` ignores the `DATA DIRECTORY` and `INDEX DIRECTORY` table options.
- `CREATE TABLE` doesn't report if the table has symbolic links.
- `mysqldump` doesn't include the symbolic link information in the output.
- `BACKUP TABLE` and `RESTORE TABLE` don't respect symbolic links.
- The `frm` file must **never** be a symbolic link (as said previously, only the data and index files can be symbolic links). Doing this (for example to make synonyms), will produce wrong results. Suppose you have a database `db1` under the MySQL data directory, a

table `tbl1` in this database, and in the `db1` directory you make a symlink `tbl2` that points to `tbl1`:

```
shell> cd /path/to/datadir/db1
shell> ln -s tbl1.frm tbl2.frm
shell> ln -s tbl1.MYD tbl2.MYD
shell> ln -s tbl1.MYI tbl2.MYI
```

Now if one thread reads `db1.tbl1` and another thread updates `db1.tbl2`, there will be problems: the query cache will be fooled (it will believe `tbl1` has not been updated so will return out-of-date results), the `ALTER` commands on `tbl2` will also fail.

6 MySQL Language Reference

MySQL has a very complex, but intuitive and easy to learn SQL interface. This chapter describes the various commands, types, and functions you will need to know in order to use MySQL efficiently and effectively. This chapter also serves as a reference to all functionality included in MySQL. In order to use this chapter effectively, you may find it useful to refer to the various indexes.

6.1 Language Structure

6.1.1 Literals: How to Write Strings and Numbers

This section describes the various ways to write strings and numbers in MySQL. It also covers the various nuances and "gotchas" that you may run into when dealing with these basic types in MySQL.

6.1.1.1 Strings

A string is a sequence of characters, surrounded by either single quote (`'`) or double quote (`"`) characters (only the single quote if you run in ANSI mode). Examples:

```
'a string'
"another string"
```

Within a string, certain sequences have special meaning. Each of these sequences begins with a backslash (`\`), known as the *escape character*. MySQL recognises the following escape sequences:

`\0` An ASCII 0 (`NUL`) character.

`\'` A single quote (`'`) character.

`\"` A double quote (`"`) character.

`\b` A backspace character.

`\n` A newline character.

`\r` A carriage return character.

`\t` A tab character.

`\z` ASCII(26) (Control-Z). This character can be encoded to allow you to work around the problem that ASCII(26) stands for END-OF-FILE on Windows. (ASCII(26) will cause problems if you try to use `mysql database < filename`.)

`\\` A backslash (`\`) character.

`\%` A `%` character. This is used to search for literal instances of `%` in contexts where `%` would otherwise be interpreted as a wildcard character. See Section 6.3.2.1 [String comparison functions], page 489.

`\_` A '_' character. This is used to search for literal instances of '_' in contexts where '_' would otherwise be interpreted as a wildcard character. See Section 6.3.2.1 [String comparison functions], page 489.

Note that if you use '\%' or '_' in some string contexts, these will return the strings '\%' and '_' and not '%' and '_'.

There are several ways to include quotes within a string:

- A ''' inside a string quoted with ''' may be written as '''''.
- A '"' inside a string quoted with '"' may be written as '""'.
- You can precede the quote character with an escape character ('\').
- A ''' inside a string quoted with '"' needs no special treatment and need not be doubled or escaped. In the same way, '"' inside a string quoted with ''' needs no special treatment.

The `SELECT` statements shown here demonstrate how quoting and escaping work:

```
mysql> SELECT 'hello', '"hello"', '""hello""', 'hel''lo', '\'hello';
+-------+---------+-----------+--------+--------+
| hello | "hello" | ""hello"" | hel'lo | 'hello |
+-------+---------+-----------+--------+--------+

mysql> SELECT "hello", "'hello'", "''hello''", "hel""lo", "\"hello";
+-------+---------+-----------+--------+--------+
| hello | 'hello' | ''hello'' | hel"lo | "hello |
+-------+---------+-----------+--------+--------+

mysql> SELECT "This\nIs\nFour\nlines";
+--------------------+
| This
Is
Four
lines |
+--------------------+
```

If you want to insert binary data into a string column (such as a `BLOB`), the following characters must be represented by escape sequences:

`NUL` ASCII 0. You should represent this by '\0' (a backslash and an ASCII '0' character).

`\` ASCII 92, backslash. Represent this by '\\'.

`'` ASCII 39, single quote. Represent this by '\''.

`"` ASCII 34, double quote. Represent this by '\"'.

If you write C code, you can use the C API function `mysql_real_escape_string()` to escape characters for the `INSERT` statement. See Section 11.1.2 [C API function overview], page 719. In Perl, you can use the `quote` method of the `DBI` package to convert special characters to the proper escape sequences. See Section 11.5.2 [Perl `DBI` Class], page 817.

You should use an escape function on any string that might contain any of the special characters listed above!

Alternatively, many MySQL APIs provide some sort of placeholder capability that allows you to insert special markers into a query string, and then bind data values to them when you issue the query. In this case, the API takes case of escaping special characters in the values for you automatically.

6.1.1.2 Numbers

Integers are represented as a sequence of digits. Floats use '`.`' as a decimal separator. Either type of number may be preceded by '`-`' to indicate a negative value.

Examples of valid integers:

```
1221
0
-32
```

Examples of valid floating-point numbers:

```
294.42
-32032.6809e+10
148.00
```

An integer may be used in a floating-point context; it is interpreted as the equivalent floating-point number.

From version 4.1.0, the constant `TRUE` evaluates to `1` and the constant `FALSE` evaluates to `0`.

6.1.1.3 Hexadecimal Values

MySQL supports hexadecimal values. In numeric context these act like an integer (64-bit precision). In string context these act like a binary string where each pair of hex digits is converted to a character:

```
mysql> SELECT x'4D7953514C';
         -> MySQL
mysql> SELECT 0xa+0;
         -> 10
mysql> SELECT 0x5061756c;
         -> Paul
```

In MySQL 4.1 (and in MySQL 4.0 when using the `--new` option) the default type of of a hexadecimal value is a string. If you want to be sure that the string is threated as a number, you can use `CAST( ... AS UNSIGNED)` on the hexadecimal value.

The `x'hexstring'` syntax (new in 4.0) is based on standard SQL and the `0x` syntax is based on ODBC. Hexadecimal strings are often used by ODBC to supply values for `BLOB` columns. You can convert a string or a number to string in hexadecimal format with the `HEX()` function.

6.1.1.4 NULL Values

The NULL value means "no data" and is different from values such as 0 for numeric types or the empty string for string types. See Section A.5.3 [Problems with NULL], page 866.

NULL may be represented by \N when using the text file import or export formats (LOAD DATA INFILE, SELECT ... INTO OUTFILE). See Section 6.4.8 [LOAD DATA], page 555.

6.1.2 Database, Table, Index, Column, and Alias Names

Database, table, index, column, and alias names all follow the same rules in MySQL.

Note that the rules changed starting with MySQL Version 3.23.6 when we introduced quoting of identifiers (database, table, and column names) with '`'. '"' will also work to quote identifiers if you run in ANSI mode. See Section 1.7.2 [ANSI mode], page 33.

Identifier	Max length (bytes)	Allowed characters
Database	64	Any character that is allowed in a directory name except '/', '\' or '.'.
Table	64	Any character that is allowed in a file name, except '/' or '.'.
Column	64	All characters.
Alias	255	All characters.

Note that in addition to the above, you can't have ASCII(0) or ASCII(255) or the quoting character in an identifier.

You may, however, enclose table names with quoting characters, if you are running MySQL in MAXDB or ANSI_QUOTES mode:

```
mysql> CREATE TABLE "test" (col INT);
ERROR 1064: You have an error in your SQL syntax. (...)
mysql> SET SQL_MODE="ANSI_QUOTES";
mysql> CREATE TABLE "test" (col INT);
Query OK, 0 rows affected (0.00 sec)
```

See Section 4.1.1 [Command-line options], page 195.

Note that if the identifier is a restricted word or contains special characters you must always quote it with a ` (backtick) when you use it:

```
mysql> SELECT * FROM `select` WHERE `select`.id > 100;
```

See Section 6.1.7 [Reserved words], page 451.

In MySQL versions prior to 3.23.6, the name rules are as follows:

- A name may consist of alphanumeric characters from the current character set and also '_' and '$'. The default character set is ISO-8859-1 Latin1; this may be changed with the --default-character-set option to mysqld. See Section 4.7.1 [Character sets], page 306.
- A name may start with any character that is legal in a name. In particular, a name may start with a digit (this differs from many other database systems!). However, a name cannot consist *only* of digits.

- You cannot use the '.' character in names because it is used to extend the format by which you can refer to columns (see immediately below).

It is recommended that you do not use names like `1e`, because an expression like `1e+1` is ambiguous. It may be interpreted as the expression `1e + 1` or as the number `1e+1`.

In MySQL you can refer to a column using any of the following forms:

Column reference	Meaning
`col_name`	Column `col_name` from whichever table used in the query contains a column of that name.
`tbl_name.col_name`	Column `col_name` from table `tbl_name` of the current database.
`db_name.tbl_name.col_name`	Column `col_name` from table `tbl_name` of the database `db_name`. This form is available in MySQL Version 3.22 or later.
`'column_name'`	A column that is a keyword or contains special characters.

You need not specify a `tbl_name` or `db_name.tbl_name` prefix for a column reference in a statement unless the reference would be ambiguous. For example, suppose tables `t1` and `t2` each contain a column `c`, and you retrieve `c` in a `SELECT` statement that uses both `t1` and `t2`. In this case, `c` is ambiguous because it is not unique among the tables used in the statement, so you must indicate which table you mean by writing `t1.c` or `t2.c`. Similarly, if you are retrieving from a table `t` in database `db1` and from a table `t` in database `db2`, you must refer to columns in those tables as `db1.t.col_name` and `db2.t.col_name`.

The syntax `.tbl_name` means the table `tbl_name` in the current database. This syntax is accepted for ODBC compatibility, because some ODBC programs prefix table names with a '.' character.

6.1.3 Case Sensitivity in Names

In MySQL, databases and tables correspond to directories and files within those directories. Consequently, the case-sensitivity of the underlying operating system determines the case-sensitivity of database and table names. This means database and table names are case-insensitive in Windows, and case-sensitive in most varieties of Unix. One prominent exception here is Mac OS X, when the default HFS+ file system is being used. However Mac OS X also supports UFS volumes, those are case sensitive on Mac OS X just like they are on any Unix. See Section 1.7.3 [Extensions to ANSI], page 34.

Note: although database and table names are case-insensitive for Windows, you should not refer to a given database or table using different cases within the same query. The following query would not work because it refers to a table both as `my_table` and as `MY_TABLE`:

```
mysql> SELECT * FROM my_table WHERE MY_TABLE.col=1;
```

Column names and column aliases are case-insensitive in all cases.

Aliases on tables are case-sensitive. The following query would not work because it refers to the alias both as `a` and as `A`:

```
mysql> SELECT col_name FROM tbl_name AS a
    ->                 WHERE a.col_name = 1 OR A.col_name = 2;
```

If you have trouble remembering the lettercase for database and table names, adopt a consistent convention, such as always creating databases and tables using lowercase names.

One way to avoid this problem is to start `mysqld` with `-O lower_case_table_names=1`. By default this option is 1 on Windows and 0 on Unix.

If `lower_case_table_names` is 1 MySQL will convert all table names to lowercase on storage and lookup. (From version 4.0.2, this option also applies to database names. From 4.1.1 this also applies for table alias).

Note that if you change this option, you need to first convert your old table names to lower case before starting `mysqld`.

If you move `MyISAM` files from a Windows to a Unix disk, you may in some cases need to use the '`mysql_fix_extensions`' tool to fix-up the case of the file extensions in each specified database directory (lowercase '`.frm`', uppercase '`.MYI`' and '`.MYD`'). '`mysql_fix_extensions`' can be found in the '`scripts`' subdirectory.

6.1.4 User Variables

MySQL supports connection-specific user variables with the `@variablename` syntax. A variable name may consist of alphanumeric characters from the current character set and also '`_`', '`$`', and '`.`' . The default character set is ISO-8859-1 Latin1; this may be changed with the `--default-character-set` option to `mysqld`. See Section 4.7.1 [Character sets], page 306. User variable names are case insensitive in versions >= 5.0, case sensitive in versions < 5.0.

Variables don't have to be initialised. They contain `NULL` by default and can store an integer, real, or string value. All variables for a thread are automatically freed when the thread exits.

You can set a variable with the `SET` syntax:

```
SET @variable= { integer expression | real expression | string expression }
[,@variable= ...].
```

You can also assign a value to a variable in statements other than `SET`. However, in this case the assignment operator is `:=` rather than `=`, because `=` is reserved for comparisons in non-`SET` statements:

```
mysql> SET @t1=0, @t2=0, @t3=0;
mysql> SELECT @t1:=(@t2:=1)+@t3:=4,@t1,@t2,@t3;
+----------------------+------+------+------+
| @t1:=(@t2:=1)+@t3:=4 | @t1  | @t2  | @t3  |
+----------------------+------+------+------+
|                    5 |    5 |    1 |    4 |
+----------------------+------+------+------+
```

User variables may be used where expressions are allowed. Note that this does not currently include contexts where a number is explicitly required, such as in the `LIMIT` clause of a `SELECT` statement, or the `IGNORE number LINES` clause of a `LOAD DATA` statement.

Note: in a `SELECT` statement, each expression is evaluated only when it's sent to the client. This means that in the `HAVING`, `GROUP BY`, or `ORDER BY` clause, you can't refer to an expression that involves variables that are set in the `SELECT` part. For example, the following statement will NOT work as expected:

```
mysql> SELECT (@aa:=id) AS a, (@aa+3) AS b FROM table_name HAVING b=5;
```

The reason is that `@aa` will not contain the value of the current row, but the value of `id` for the previous accepted row.

The general rule is to never assign **and** use the same variable in the same statement.

Another issue with setting a variable and using it in the same statement is that the default result type of a variable is based on the type of the variable at the start of the statement. (A not assigned variable is assumed to have value `NULL` and to be of type STRING). The following example illustrates this:

```
mysql> SET @a="test";
mysql> SELECT @a,(@a:=20) FROM table_name;
```

In this case MySQL will report to the client that column 1 is a string and convert all accesses of `@a` to strings, even if `@a` will be set to a number for the second row. After the statement is executed `@a` will be regarded as a number.

If you have any problems with this, either avoid to set and use the same variable in the same statement or set the variable to 0, 0.0 or `""` before you use it.

6.1.5 System Variables

Starting from MySQL 4.0.3 we provide better access to a lot of system and connection variables. One can change most of them without having to take down the server.

There are two kind of system variables: Thread-specific (or connection-specific) variables that are unique to the current connection and global variables that are used to configure global events. Global variables also are used to set up the initial values of the corresponding thread-specific variables for new connections.

When `mysqld` starts, all global variables are initialised from command line arguments and option files. You can change the value with the `SET GLOBAL` command. When a new thread is created, the thread-specific variables are initialised from the global variables and they will not change even if you issue a new `SET GLOBAL` command.

To set the value for a `GLOBAL` variable, you should use one of the following syntaxes: (Here we use `sort_buffer_size` as an example variable)

```
SET GLOBAL sort_buffer_size=value;
SET @@global.sort_buffer_size=value;
```

To set the value for a `SESSION` variable, you can use one of the following syntaxes:

```
SET SESSION sort_buffer_size=value;
SET @@session.sort_buffer_size=value;
SET sort_buffer_size=value;
```

If you don't specify `GLOBAL` or `SESSION` then `SESSION` is used. See Section 5.5.6 [SET OPTION], page 432.

`LOCAL` is a synonym for `SESSION`.

To retrieve the value for a `GLOBAL` variable you can use one of the following commands:

```
SELECT @@global.sort_buffer_size;
SHOW GLOBAL VARIABLES like 'sort_buffer_size';
```

To retrieve the value for a `SESSION` variable you can use one of the following commands:

```
SELECT @@session.sort_buffer_size;
SHOW SESSION VARIABLES like 'sort_buffer_size';
```

When you **retrieve** a variable value with the `@@variable_name` syntax and you don't specify `GLOBAL` or `SESSION` then MySQL will return the thread-specific (`SESSION`) value if it exists. If not, MySQL will return the global value.

The reason for requiring `GLOBAL` for setting `GLOBAL` only variables but not for retrieving them is to ensure that we don't later run into problems if we later would introduce a thread-specific variable with the same name or remove a thread-specific variable. In this case, you could accidentally change the state for the server as a whole, rather than just for your own connection.

The following is a full list of all variables that you change and retrieve and if you can use `GLOBAL` or `SESSION` with them.

Variable name	Value type	Type
autocommit	bool	SESSION
big_tables	bool	SESSION
binlog_cache_size	num	GLOBAL
bulk_insert_buffer_size	num	GLOBAL | SESSION
concurrent_insert	bool	GLOBAL
connect_timeout	num	GLOBAL
convert_character_set	string	SESSION
delay_key_write	OFF | ON | ALL	GLOBAL
delayed_insert_limit	num	GLOBAL
delayed_insert_timeout	num	GLOBAL
delayed_queue_size	num	GLOBAL
error_count	num	SESSION
flush	bool	GLOBAL
flush_time	num	GLOBAL
foreign_key_checks	bool	SESSION
identity	num	SESSION
insert_id	bool	SESSION
interactive_timeout	num	GLOBAL | SESSION
join_buffer_size	num	GLOBAL | SESSION
key_buffer_size	num	GLOBAL
last_insert_id	bool	SESSION
local_infile	bool	GLOBAL
log_warnings	bool	GLOBAL
long_query_time	num	GLOBAL | SESSION
low_priority_updates	bool	GLOBAL | SESSION
max_allowed_packet	num	GLOBAL | SESSION
max_binlog_cache_size	num	GLOBAL
max_binlog_size	num	GLOBAL
max_connect_errors	num	GLOBAL

max_connections	num	GLOBAL
max_error_count	num	GLOBAL | SESSION
max_delayed_threads	num	GLOBAL
max_heap_table_size	num	GLOBAL | SESSION
max_join_size	num	GLOBAL | SESSION
max_relay_log_size	num	GLOBAL
max_sort_length	num	GLOBAL | SESSION
max_tmp_tables	num	GLOBAL
max_user_connections	num	GLOBAL
max_write_lock_count	num	GLOBAL
myisam_max_extra_sort_file_size	num	GLOBAL | SESSION
myisam_repair_threads	num	GLOBAL | SESSION
myisam_max_sort_file_size	num	GLOBAL | SESSION
myisam_sort_buffer_size	num	GLOBAL | SESSION
net_buffer_length	num	GLOBAL | SESSION
net_read_timeout	num	GLOBAL | SESSION
net_retry_count	num	GLOBAL | SESSION
net_write_timeout	num	GLOBAL | SESSION
query_cache_limit	num	GLOBAL
query_cache_size	num	GLOBAL
query_cache_type	enum	GLOBAL
read_buffer_size	num	GLOBAL | SESSION
read_rnd_buffer_size	num	GLOBAL | SESSION
rpl_recovery_rank	num	GLOBAL
safe_show_database	bool	GLOBAL
server_id	num	GLOBAL
slave_compressed_protocol	bool	GLOBAL
slave_net_timeout	num	GLOBAL
slow_launch_time	num	GLOBAL
sort_buffer_size	num	GLOBAL | SESSION
sql_auto_is_null	bool	SESSION
sql_big_selects	bool	SESSION
sql_big_tables	bool	SESSION
sql_buffer_result	bool	SESSION
sql_log_binlog	bool	SESSION
sql_log_off	bool	SESSION
sql_log_update	bool	SESSION

sql_low_priority_updates	bool	GLOBAL | SESSION
sql_max_join_size	num	GLOBAL | SESSION
sql_quote_show_create	bool	SESSION
sql_safe_updates	bool	SESSION
sql_select_limit	bool	SESSION
sql_slave_skip_counter	num	GLOBAL
sql_warnings	bool	SESSION
table_cache	num	GLOBAL
table_type	enum	GLOBAL | SESSION
thread_cache_size	num	GLOBAL
timestamp	bool	SESSION
tmp_table_size	enum	GLOBAL | SESSION
tx_isolation	enum	GLOBAL | SESSION
wait_timeout	num	GLOBAL | SESSION
warning_count	num	SESSION
unique_checks	bool	SESSION

Variables that are marked with `num` can be given a numerical value. Variables that are marked with `bool` can be set to 0, 1, `ON` or `OFF`. Variables that are of type `enum` should normally be set to one of the available values for the variable, but can also be set to the number that correspond to the enum value. (The first enum value is 0).

Here is a description of some of the variables:

Variable	**Description**
identity	Alias for last_insert_id (Sybase compatiblity)
sql_low_priority_updates	Alias for low_priority_updates
sql_max_join_size	Alias for max_join_size
version	Alias for VERSION() (Sybase (?) compatability)

A description of the other variable definitions can be found in the startup options section, the description of `SHOW VARIABLES` and in the `SET` section. See Section 4.1.1 [Command-line options], page 195. See Section 4.6.8.4 [SHOW VARIABLES], page 290. See Section 5.5.6 [SET OPTION], page 432.

6.1.6 Comment Syntax

The MySQL server supports the `# to end of line`, `-- to end of line` and `/* in-line or multiple-line */` comment styles:

```
mysql> SELECT 1+1;     # This comment continues to the end of line
mysql> SELECT 1+1;     -- This comment continues to the end of line
mysql> SELECT 1 /* this is an in-line comment */ + 1;
mysql> SELECT 1+
/*
this is a
multiple-line comment
```

```
*/
1;
```

Note that the `--` (double-dash) comment style requires you to have at least one space after the second dash!

Although the server understands the comment syntax just described, there are some limitations on the way that the `mysql` client parses `/* ... */` comments:

- Single-quote and double-quote characters are taken to indicate the beginning of a quoted string, even within a comment. If the quote is not matched by a second quote within the comment, the parser doesn't realise the comment has ended. If you are running `mysql` interactively, you can tell that it has gotten confused like this because the prompt changes from `mysql>` to `'>` or `">`.
- A semicolon is taken to indicate the end of the current SQL statement and anything following it to indicate the beginning of the next statement.

These limitations apply both when you run `mysql` interactively and when you put commands in a file and tell `mysql` to read its input from that file with `mysql < some-file`.

MySQL supports the '`--`' SQL-99 comment style only if the second dash is followed by a space. See Section 1.7.4.7 [ANSI diff comments], page 42.

6.1.7 Treatment of Reserved Words in MySQL

A common problem stems from trying to create a table with column names that use the names of datatypes or functions built into MySQL, such as `TIMESTAMP` or `GROUP`. You're allowed to do it (for example, `ABS` is allowed as a column name). However, by default, in function invocations no whitespace is allowed between the function name and the following '`(`' character, so that a function call can be distinguished from a reference to a column name.

If you start the server with the `--ansi` or `--sql-mode=IGNORE_SPACE` option, the server allows function invocations to have whitespace between a function name and the following '`(`' character. This causes function names to be treated as reserved words; as a result, column names that are the same as function names must be quoted as described in Section 6.1.2 [Legal names], page 444.

The following words are explicitly reserved in MySQL. Most of them are forbidden by SQL-92 as column and/or table names (for example, `GROUP`). A few are reserved because MySQL needs them and is (currently) using a `yacc` parser:

Word	**Word**	**Word**
ADD	ALL	ALTER
ANALYZE	AND	AS
ASC	ASENSITIVE	AUTO_INCREMENT
BDB	BEFORE	BERKELEYDB
BETWEEN	BIGINT	BINARY
BLOB	BOTH	BTREE
BY	CALL	CASCADE
CASE	CHANGE	CHAR
CHARACTER	CHECK	COLLATE

COLUMN	COLUMNS	CONNECTION
CONSTRAINT	CREATE	CROSS
CURRENT_DATE	CURRENT_TIME	CURRENT_TIMESTAMP
CURSOR	DATABASE	DATABASES
DAY_HOUR	DAY_MICROSECOND	DAY_MINUTE
DAY_SECOND	DEC	DECIMAL
DECLARE	DEFAULT	DELAYED
DELETE	DESC	DESCRIBE
DISTINCT	DISTINCTROW	DIV
DOUBLE	DROP	ELSE
ELSEIF	ENCLOSED	ERRORS
ESCAPED	EXISTS	EXPLAIN
FALSE	FIELDS	FLOAT
FOR	FORCE	FOREIGN
FROM	FULLTEXT	GRANT
GROUP	HASH	HAVING
HIGH_PRIORITY	HOUR_MICROSECOND	HOUR_MINUTE
HOUR_SECOND	IF	IGNORE
IN	INDEX	INFILE
INNER	INNODB	INOUT
INSENSITIVE	INSERT	INT
INTEGER	INTERVAL	INTO
IO_THREAD	IS	ITERATE
JOIN	KEY	KEYS
KILL	LEADING	LEAVE
LEFT	LIKE	LIMIT
LINES	LOAD	LOCALTIME
LOCALTIMESTAMP	LOCK	LONG
LONGBLOB	LONGTEXT	LOOP
LOW_PRIORITY	MASTER_SERVER_ID	MATCH
MEDIUMBLOB	MEDIUMINT	MEDIUMTEXT
MIDDLEINT	MINUTE_MICROSECOND	MINUTE_SECOND
MOD	MRG_MYISAM	NATURAL
NOT	NO_WRITE_TO_BINLOG	NULL
NUMERIC	ON	OPTIMIZE
OPTION	OPTIONALLY	OR
ORDER	OUT	OUTER
OUTFILE	PRECISION	PRIMARY
PRIVILEGES	PROCEDURE	PURGE
READ	REAL	REFERENCES
REGEXP	RENAME	REPEAT
REPLACE	REQUIRE	RESTRICT
RETURN	RETURNS	REVOKE
RIGHT	RLIKE	RTREE
SECOND_MICROSECOND	SELECT	SENSITIVE
SEPARATOR	SET	SHOW
SMALLINT	SOME	SONAME

SPATIAL	SPECIFIC	SQL_BIG_RESULT
SQL_CALC_FOUND_ROWS	SQL_SMALL_RESULT	SSL
STARTING	STRAIGHT_JOIN	STRIPED
TABLE	TABLES	TERMINATED
THEN	TINYBLOB	TINYINT
TINYTEXT	TO	TRAILING
TRUE	TYPES	UNION
UNIQUE	UNLOCK	UNSIGNED
UNTIL	UPDATE	USAGE
USE	USER_RESOURCES	USING
UTC_DATE	UTC_TIME	UTC_TIMESTAMP
VALUES	VARBINARY	VARCHAR
VARCHARACTER	VARYING	WARNINGS
WHEN	WHERE	WHILE
WITH	WRITE	XOR
YEAR_MONTH	ZEROFILL	

The following symbols (from the table above) are disallowed by SQL-99 but allowed by MySQL as column/table names. This is because some of these names are very natural names and a lot of people have already used them.

- ACTION
- BIT
- DATE
- ENUM
- NO
- TEXT
- TIME
- TIMESTAMP

6.2 Column Types

MySQL supports a number of column types, which may be grouped into three categories: numeric types, date and time types, and string (character) types. This section first gives an overview of the types available and summarises the storage requirements for each column type, then provides a more detailed description of the properties of the types in each category. The overview is intentionally brief. The more detailed descriptions should be consulted for additional information about particular column types, such as the allowable formats in which you can specify values.

The column types supported by MySQL are listed below. The following code letters are used in the descriptions:

`M` Indicates the maximum display size. The maximum legal display size is 255.

`D` Applies to floating-point types and indicates the number of digits following the decimal point. The maximum possible value is 30, but should be no greater than `M`-2.

Square brackets ('[' and ']') indicate parts of type specifiers that are optional.

Note that if you specify ZEROFILL for a column, MySQL will automatically add the UNSIGNED attribute to the column.

Warning: you should be aware that when you use subtraction between integer values where one is of type UNSIGNED, the result will be unsigned! See Section 6.3.5 [Cast Functions], page 513.

`TINYINT[(M)] [UNSIGNED] [ZEROFILL]`
: A very small integer. The signed range is -128 to 127. The unsigned range is 0 to 255.

`BIT`
`BOOL`
`BOOLEAN`
: These are synonyms for TINYINT(1). The BOOLEAN synonym was added in version 4.1.0

  Full boolean type handling will be introduced in accordance with SQL-99.

`SMALLINT[(M)] [UNSIGNED] [ZEROFILL]`
: A small integer. The signed range is -32768 to 32767. The unsigned range is 0 to 65535.

`MEDIUMINT[(M)] [UNSIGNED] [ZEROFILL]`
: A medium-size integer. The signed range is -8388608 to 8388607. The unsigned range is 0 to 16777215.

`INT[(M)] [UNSIGNED] [ZEROFILL]`
: A normal-size integer. The signed range is -2147483648 to 2147483647. The unsigned range is 0 to 4294967295.

`INTEGER[(M)] [UNSIGNED] [ZEROFILL]`
: This is a synonym for INT.

`BIGINT[(M)] [UNSIGNED] [ZEROFILL]`
: A large integer. The signed range is -9223372036854775808 to 9223372036854775807. The unsigned range is 0 to 18446744073709551615. Some things you should be aware of with respect to BIGINT columns:

  - All arithmetic is done using signed BIGINT or DOUBLE values, so you shouldn't use unsigned big integers larger than 9223372036854775807 (63 bits) except with bit functions! If you do that, some of the last digits in the result may be wrong because of rounding errors when converting the BIGINT to a DOUBLE.

    MySQL 4.0 can handle BIGINT in the following cases:

    - Use integers to store big unsigned values in a BIGINT column.
    - In MIN(big_int_column) and MAX(big_int_column).
    - When using operators (+, -, *, etc.) where both operands are integers.
  - You can always store an exact integer value in a BIGINT column by storing it as a string. In this case, MySQL will perform a string-to-number conversion that involves no intermediate double representation.

- '-', '+', and '*' will use BIGINT arithmetic when both arguments are integer values! This means that if you multiply two big integers (or results from functions that return integers) you may get unexpected results when the result is larger than 9223372036854775807.

FLOAT(precision) [UNSIGNED] [ZEROFILL]
: A floating-point number. precision can be <=24 for a single-precision floating-point number and between 25 and 53 for a double-precision floating-point number. These types are like the FLOAT and DOUBLE types described immediately below. FLOAT(X) has the same range as the corresponding FLOAT and DOUBLE types, but the display size and number of decimals are undefined.

  In MySQL Version 3.23, this is a true floating-point value. In earlier MySQL versions, FLOAT(precision) always has 2 decimals.

  Note that using FLOAT may give you some unexpected problems as all calculations in MySQL are done with double precision. See Section A.5.6 [No matching rows], page 867.

  This syntax is provided for ODBC compatibility.

FLOAT[(M,D)] [UNSIGNED] [ZEROFILL]
: A small (single-precision) floating-point number. Allowable values are -3.402823466E+38 to -1.175494351E-38, 0, and 1.175494351E-38 to 3.402823466E+38. If UNSIGNED is specified, negative values are disallowed. The M is the display width and D is the number of decimals. FLOAT without arguments or FLOAT(X) where X <= 24 stands for a single-precision floating-point number.

DOUBLE[(M,D)] [UNSIGNED] [ZEROFILL]
: A normal-size (double-precision) floating-point number. Allowable values are -1.7976931348623157E+308 to -2.2250738585072014E-308, 0, and 2.2250738585072014E-308 to 1.7976931348623157E+308. If UNSIGNED is specified, negative values are disallowed. The M is the display width and D is the number of decimals. DOUBLE without arguments or FLOAT(X) where 25 <= X <= 53 stands for a double-precision floating-point number.

DOUBLE PRECISION[(M,D)] [UNSIGNED] [ZEROFILL]
REAL[(M,D)] [UNSIGNED] [ZEROFILL]
: These are synonyms for DOUBLE.

DECIMAL[(M[,D])] [UNSIGNED] [ZEROFILL]
: An unpacked floating-point number. Behaves like a CHAR column: "unpacked" means the number is stored as a string, using one character for each digit of the value. The decimal point and, for negative numbers, the '-' sign, are not counted in M (but space for these is reserved). If D is 0, values will have no decimal point or fractional part. The maximum range of DECIMAL values is the same as for DOUBLE, but the actual range for a given DECIMAL column may be constrained by the choice of M and D. If UNSIGNED is specified, negative values are disallowed.

  If D is omitted, the default is 0. If M is omitted, the default is 10.

Prior to MySQL Version 3.23, the `M` argument must include the space needed for the sign and the decimal point.

`DEC[(M[,D])] [UNSIGNED] [ZEROFILL]`
`NUMERIC[(M[,D])] [UNSIGNED] [ZEROFILL]`
`FIXED[(M[,D])] [UNSIGNED] [ZEROFILL]`

These are synonyms for `DECIMAL`.

The `FIXED` alias was added in version 4.1.0 for compatibility with other servers.

`DATE`

A date. The supported range is `'1000-01-01'` to `'9999-12-31'`. MySQL displays `DATE` values in `'YYYY-MM-DD'` format, but allows you to assign values to `DATE` columns using either strings or numbers. See Section 6.2.2.2 [DATETIME], page 462.

`DATETIME`

A date and time combination. The supported range is `'1000-01-01 00:00:00'` to `'9999-12-31 23:59:59'`. MySQL displays `DATETIME` values in `'YYYY-MM-DD HH:MM:SS'` format, but allows you to assign values to `DATETIME` columns using either strings or numbers. See Section 6.2.2.2 [DATETIME], page 462.

`TIMESTAMP[(M)]`

A timestamp. The range is `'1970-01-01 00:00:00'` to sometime in the year `2037`.

In MySQL 4.0 and earlier, `TIMESTAMP` values are displayed in `YYYYMMDDHHMMSS`, `YYMMDDHHMMSS`, `YYYYMMDD`, or `YYMMDD` format, depending on whether `M` is `14` (or missing), `12`, `8`, or `6`, but allows you to assign values to `TIMESTAMP` columns using either strings or numbers.

From MySQL 4.1, `TIMESTAMP` is returned as a string with the format `'YYYY-MM-DD HH:MM:SS'`. If you want to have this as a number you should add `+0` to the timestamp column. Different timestamp lengths are not supported. From version 4.0.12, the `--new` option can be used to make the server behave as in version 4.1.

A `TIMESTAMP` column is useful for recording the date and time of an `INSERT` or `UPDATE` operation because it is automatically set to the date and time of the most recent operation if you don't give it a value yourself. You can also set it to the current date and time by assigning it a `NULL` value. See Section 6.2.2 [Date and time types], page 460.

The `M` argument affects only how a `TIMESTAMP` column is displayed; its values always are stored using 4 bytes each.

Note that `TIMESTAMP(M)` columns where `M` is 8 or 14 are reported to be numbers while other `TIMESTAMP(M)` columns are reported to be strings. This is just to ensure that one can reliably dump and restore the table with these types! See Section 6.2.2.2 [DATETIME], page 462.

`TIME`

A time. The range is `'-838:59:59'` to `'838:59:59'`. MySQL displays `TIME` values in `'HH:MM:SS'` format, but allows you to assign values to `TIME` columns using either strings or numbers. See Section 6.2.2.3 [TIME], page 466.

`YEAR[(2|4)]`
: A year in 2- or 4-digit format (default is 4-digit). The allowable values are `1901` to `2155`, `0000` in the 4-digit year format, and 1970-2069 if you use the 2-digit format (70-69). MySQL displays `YEAR` values in `YYYY` format, but allows you to assign values to `YEAR` columns using either strings or numbers. (The `YEAR` type is unavailable prior to MySQL Version 3.22.) See Section 6.2.2.4 [`YEAR`], page 467.

`[NATIONAL] CHAR(M) [BINARY | ASCII | UNICODE]`
: A fixed-length string that is always right-padded with spaces to the specified length when stored. The range of `M` is 0 to 255 characters (1 to 255 prior to MySQL Version 3.23). Trailing spaces are removed when the value is retrieved. `CHAR` values are sorted and compared in case-insensitive fashion according to the default character set unless the `BINARY` keyword is given.

  From version 4.1.0, if the `M` value specified is greater than 255, the column type is converted to `TEXT`. This is a compatibility feature.

  `NATIONAL CHAR` (or its equivalent short form, `NCHAR`) is the SQL-99 way to define that a `CHAR` column should use the default CHARACTER set. This is the default in MySQL.

  `CHAR` is a shorthand for `CHARACTER`.

  From version 4.1.0, the `ASCII` attribute can be specified which assigns the `latin1` character set to a `CHAR` column.

  From version 4.1.1, the `UNICODE` attribute can be specified which assigns the `ucs2` character set to a `CHAR` column.

  MySQL allows you to create a column of type `CHAR(0)`. This is mainly useful when you have to be compliant with some old applications that depend on the existence of a column but that do not actually use the value. This is also quite nice when you need a column that only can take 2 values: A `CHAR(0)`, that is not defined as `NOT NULL`, will occupy only one bit and can take only 2 values: `NULL` or `""`. See Section 6.2.3.1 [`CHAR`], page 467.

`CHAR`
: This is a synonym for `CHAR(1)`.

`[NATIONAL] VARCHAR(M) [BINARY]`
: A variable-length string. **Note**: trailing spaces are removed when the value is stored (this differs from the SQL-99 specification). The range of `M` is 0 to 255 characters (1 to 255 prior to MySQL Version 4.0.2). `VARCHAR` values are sorted and compared in case-insensitive fashion unless the `BINARY` keyword is given. See Section 6.5.3.1 [Silent column changes], page 573.

  From version 4.1.0, if the `M` value specified is greater than 255, the column type is converted to `TEXT`. This is a compatibility feature.

  `VARCHAR` is a shorthand for `CHARACTER VARYING`. See Section 6.2.3.1 [CHAR], page 467.

`TINYBLOB`
`TINYTEXT`

A `BLOB` or `TEXT` column with a maximum length of 255 (2^8 - 1) characters. See Section 6.5.3.1 [Silent column changes], page 573. See Section 6.2.3.2 [BLOB], page 468.

`BLOB`
`TEXT`

A `BLOB` or `TEXT` column with a maximum length of 65535 (2^16 - 1) characters. See Section 6.5.3.1 [Silent column changes], page 573. See Section 6.2.3.2 [BLOB], page 468.

`MEDIUMBLOB`
`MEDIUMTEXT`

A `BLOB` or `TEXT` column with a maximum length of 16777215 (2^24 - 1) characters. See Section 6.5.3.1 [Silent column changes], page 573. See Section 6.2.3.2 [BLOB], page 468.

`LONGBLOB`
`LONGTEXT`

A `BLOB` or `TEXT` column with a maximum length of 4294967295 or 4G (2^32 - 1) characters. See Section 6.5.3.1 [Silent column changes], page 573. Up to MySQL version 3.23 the server/client protocol and MyISAM tables had a limit of 16M per communication packet / table row, from version 4.x the maximum allowed length of `LONGTEXT` or `LONGBLOB` columns depends on the configured maximum packet size in the client/server protocol and available memory. See Section 6.2.3.2 [BLOB], page 468.

`ENUM('value1','value2',...)`

An enumeration. A string object that can have only one value, chosen from the list of values `'value1'`, `'value2'`, `...`, `NULL` or the special `""` error value. An `ENUM` can have a maximum of 65535 distinct values. See Section 6.2.3.3 [ENUM], page 469.

`SET('value1','value2',...)`

A set. A string object that can have zero or more values, each of which must be chosen from the list of values `'value1'`, `'value2'`, `...` A `SET` can have a maximum of 64 members. See Section 6.2.3.4 [SET], page 470.

6.2.1 Numeric Types

MySQL supports all of the SQL-92 numeric datatypes. These types include the exact numeric datatypes (`NUMERIC`, `DECIMAL`, `INTEGER`, and `SMALLINT`), as well as the approximate numeric datatypes (`FLOAT`, `REAL`, and `DOUBLE PRECISION`). The keyword `INT` is a synonym for `INTEGER`, and the keyword `DEC` is a synonym for `DECIMAL`.

The `NUMERIC` and `DECIMAL` types are implemented as the same type by MySQL, as permitted by the SQL-92 standard. They are used for values for which it is important to preserve exact precision, for example with monetary data. When declaring a column of one of these types the precision and scale can be (and usually is) specified; for example:

```
salary DECIMAL(5,2)
```

In this example, `5` (`precision`) represents the number of significant decimal digits that will be stored for values, and `2` (`scale`) represents the number of digits that will be stored following the decimal point. In this case, therefore, the range of values that can be stored in the `salary` column is from `-99.99` to `99.99`. (MySQL can actually store numbers up to `999.99` in this column because it doesn't have to store the sign for positive numbers)

In SQL-92, the syntax `DECIMAL(p)` is equivalent to `DECIMAL(p,0)`. Similarly, the syntax `DECIMAL` is equivalent to `DECIMAL(p,0)`, where the implementation is allowed to decide the value of `p`. MySQL does not currently support either of these variant forms of the `DECIMAL`/`NUMERIC` datatypes. This is not generally a serious problem, as the principal benefits of these types derive from the ability to control both precision and scale explicitly.

`DECIMAL` and `NUMERIC` values are stored as strings, rather than as binary floating-point numbers, in order to preserve the decimal precision of those values. One character is used for each digit of the value, the decimal point (if `scale > 0`), and the '`-`' sign (for negative numbers). If `scale` is 0, `DECIMAL` and `NUMERIC` values contain no decimal point or fractional part.

The maximum range of `DECIMAL` and `NUMERIC` values is the same as for `DOUBLE`, but the actual range for a given `DECIMAL` or `NUMERIC` column can be constrained by the `precision` or `scale` for a given column. When such a column is assigned a value with more digits following the decimal point than are allowed by the specified `scale`, the value is rounded to that `scale`. When a `DECIMAL` or `NUMERIC` column is assigned a value whose magnitude exceeds the range implied by the specified (or defaulted) `precision` and `scale`, MySQL stores the value representing the corresponding end point of that range.

As an extension to the SQL-92 standard, MySQL also supports the integer types `TINYINT`, `MEDIUMINT`, and `BIGINT` as listed in the tables above. Another extension is supported by MySQL for optionally specifying the display width of an integer value in parentheses following the base keyword for the type (for example, `INT(4)`). This optional width specification is used to left-pad the display of values whose width is less than the width specified for the column, but does not constrain the range of values that can be stored in the column, nor the number of digits that will be displayed for values whose width exceeds that specified for the column. When used in conjunction with the optional extension attribute `ZEROFILL`, the default padding of spaces is replaced with zeroes. For example, for a column declared as `INT(5) ZEROFILL`, a value of `4` is retrieved as `00004`. Note that if you store larger values than the display width in an integer column, you may experience problems when MySQL generates temporary tables for some complicated joins, as in these cases MySQL trusts that the data did fit into the original column width.

All integer types can have an optional (non-standard) attribute `UNSIGNED`. Unsigned values can be used when you want to allow only positive numbers in a column and you need a little bigger numeric range for the column.

As of MySQL 4.0.2, floating-point types also can be `UNSIGNED`. As with integer types, this attribute prevents negative values from being stored in the column. Unlike the integer types, the upper range of column values remains the same.

The `FLOAT` type is used to represent approximate numeric datatypes. The SQL-92 standard allows an optional specification of the precision (but not the range of the exponent) in bits following the keyword `FLOAT` in parentheses. The MySQL implementation also supports this optional precision specification. When the keyword `FLOAT` is used for a column type without

a precision specification, MySQL uses four bytes to store the values. A variant syntax is also supported, with two numbers given in parentheses following the `FLOAT` keyword. With this option, the first number continues to represent the storage requirements for the value in bytes, and the second number specifies the number of digits to be stored and displayed following the decimal point (as with `DECIMAL` and `NUMERIC`). When MySQL is asked to store a number for such a column with more decimal digits following the decimal point than specified for the column, the value is rounded to eliminate the extra digits when the value is stored.

The `REAL` and `DOUBLE PRECISION` types do not accept precision specifications. As an extension to the SQL-92 standard, MySQL recognises `DOUBLE` as a synonym for the `DOUBLE PRECISION` type. In contrast with the standard's requirement that the precision for `REAL` be smaller than that used for `DOUBLE PRECISION`, MySQL implements both as 8-byte double-precision floating-point values (when not running in "ANSI mode"). For maximum portability, code requiring storage of approximate numeric data values should use `FLOAT` or `DOUBLE PRECISION` with no specification of precision or number of decimal points.

When asked to store a value in a numeric column that is outside the column type's allowable range, MySQL clips the value to the appropriate endpoint of the range and stores the resulting value instead.

For example, the range of an `INT` column is `-2147483648` to `2147483647`. If you try to insert `-9999999999` into an `INT` column, the value is clipped to the lower endpoint of the range, and `-2147483648` is stored instead. Similarly, if you try to insert `9999999999`, `2147483647` is stored instead.

If the `INT` column is `UNSIGNED`, the size of the column's range is the same but its endpoints shift up to `0` and `4294967295`. If you try to store `-9999999999` and `9999999999`, the values stored in the column become `0` and `4294967296`.

Conversions that occur due to clipping are reported as "warnings" for `ALTER TABLE`, `LOAD DATA INFILE`, `UPDATE`, and multi-row `INSERT` statements.

Type	Bytes	From	To
`TINYINT`	1	-128	127
`SMALLINT`	2	-32768	32767
`MEDIUMINT`	3	-8388608	8388607
`INT`	4	-2147483648	2147483647
`BIGINT`	8	-9223372036854775808	9223372036854775807

6.2.2 Date and Time Types

The date and time types are `DATETIME`, `DATE`, `TIMESTAMP`, `TIME`, and `YEAR`. Each of these has a range of legal values, as well as a "zero" value that is used when you specify a really illegal value. Note that MySQL allows you to store certain 'not strictly' legal date values, for example `1999-11-31`. The reason for this is that we think it's the responsibility of the application to handle date checking, not the SQL servers. To make the date checking 'fast', MySQL only checks that the month is in the range of 0-12 and the day is in the range of 0-31. The above ranges are defined this way because MySQL allows you to store, in a `DATE` or `DATETIME` column, dates where the day or month-day is zero. This is extremely useful for applications that need to store a birth-date for which you don't know the exact date.

In this case you simply store the date like `1999-00-00` or `1999-01-00`. (You cannot expect to get a correct value from functions like `DATE_SUB()` or `DATE_ADD` for dates like these.)

Here are some general considerations to keep in mind when working with date and time types:

- MySQL retrieves values for a given date or time type in a standard format, but it attempts to interpret a variety of formats for values that you supply (for example, when you specify a value to be assigned to or compared to a date or time type). Nevertheless, only the formats described in the following sections are supported. It is expected that you will supply legal values, and unpredictable results may occur if you use values in other formats.
- Although MySQL tries to interpret values in several formats, it always expects the year part of date values to be leftmost. Dates must be given in year-month-day order (for example, `'98-09-04'`), rather than in the month-day-year or day-month-year orders commonly used elsewhere (for example, `'09-04-98'`, `'04-09-98'`).
- MySQL automatically converts a date or time type value to a number if the value is used in a numeric context, and vice versa.
- When MySQL encounters a value for a date or time type that is out of range or otherwise illegal for the type (see the start of this section), it converts the value to the "zero" value for that type. (The exception is that out-of-range `TIME` values are clipped to the appropriate endpoint of the `TIME` range.) The following table shows the format of the "zero" value for each type:

Column type	**"Zero" value**
`DATETIME`	`'0000-00-00 00:00:00'`
`DATE`	`'0000-00-00'`
`TIMESTAMP`	`00000000000000` (length depends on display size)
`TIME`	`'00:00:00'`
`YEAR`	`0000`

- The "zero" values are special, but you can store or refer to them explicitly using the values shown in the table. You can also do this using the values `'0'` or `0`, which are easier to write.
- "Zero" date or time values used through `MyODBC` are converted automatically to `NULL` in `MyODBC` Version 2.50.12 and above, because ODBC can't handle such values.

6.2.2.1 Y2K Issues and Date Types

MySQL itself is Y2K-safe (see Section 1.2.5 [Year 2000 compliance], page 10), but input values presented to MySQL may not be. Any input containing 2-digit year values is ambiguous, because the century is unknown. Such values must be interpreted into 4-digit form because MySQL stores years internally using four digits.

For `DATETIME`, `DATE`, `TIMESTAMP`, and `YEAR` types, MySQL interprets dates with ambiguous year values using the following rules:

- Year values in the range `00-69` are converted to `2000-2069`.
- Year values in the range `70-99` are converted to `1970-1999`.

Remember that these rules provide only reasonable guesses as to what your data mean. If the heuristics used by MySQL don't produce the correct values, you should provide unambiguous input containing 4-digit year values.

`ORDER BY` will sort 2-digit `YEAR/DATE/DATETIME` types properly.

Note also that some functions like `MIN()` and `MAX()` will convert a `TIMESTAMP/DATE` to a number. This means that a timestamp with a 2-digit year will not work properly with these functions. The fix in this case is to convert the `TIMESTAMP/DATE` to 4-digit year format or use something like `MIN(DATE_ADD(timestamp,INTERVAL 0 DAYS))`.

6.2.2.2 The `DATETIME`, `DATE`, and `TIMESTAMP` Types

The `DATETIME`, `DATE`, and `TIMESTAMP` types are related. This section describes their characteristics, how they are similar, and how they differ.

The `DATETIME` type is used when you need values that contain both date and time information. MySQL retrieves and displays `DATETIME` values in `'YYYY-MM-DD HH:MM:SS'` format. The supported range is `'1000-01-01 00:00:00'` to `'9999-12-31 23:59:59'`. ("Supported" means that although earlier values might work, there is no guarantee that they will.)

The `DATE` type is used when you need only a date value, without a time part. MySQL retrieves and displays `DATE` values in `'YYYY-MM-DD'` format. The supported range is `'1000-01-01'` to `'9999-12-31'`.

The `TIMESTAMP` column type has varying properties and behaviour, depending on the MySQL version and the SQL mode the server is running in.

`TIMESTAMP` behaviour when running in `MAXDB` mode

When MySQL is running in `MAXDB` mode, `TIMESTAMP` behaves like `DATETIME`. No automatic updating of `TIMESTAMP` columns occurs, as described in the following paragraphs. MySQL can be run in `MAXDB` mode as of version 4.1.1. See Section 4.1.1 [Command-line options], page 195.

`TIMESTAMP` behaviour when not running in `MAXDB` mode

The `TIMESTAMP` column type provides a type that you can use to automatically mark `INSERT` or `UPDATE` operations with the current date and time. If you have multiple `TIMESTAMP` columns, only the first one is updated automatically.

Automatic updating of the first `TIMESTAMP` column occurs under any of the following conditions:

- The column is not specified explicitly in an `INSERT` or `LOAD DATA INFILE` statement.
- The column is not specified explicitly in an `UPDATE` statement and some other column changes value. (Note that an `UPDATE` that sets a column to the value it already has will not cause the `TIMESTAMP` column to be updated, because if you set a column to its current value, MySQL ignores the update for efficiency.)
- You explicitly set the `TIMESTAMP` column to `NULL`.

TIMESTAMP columns other than the first may also be set to the current date and time. Just set the column to NULL or to NOW().

You can set any TIMESTAMP column to a value different from the current date and time by setting it explicitly to the desired value. This is true even for the first TIMESTAMP column. You can use this property if, for example, you want a TIMESTAMP to be set to the current date and time when you create a row, but not to be changed whenever the row is updated later:

- Let MySQL set the column when the row is created. This will initialise it to the current date and time.
- When you perform subsequent updates to other columns in the row, set the TIMESTAMP column explicitly to its current value.

On the other hand, you may find it just as easy to use a DATETIME column that you initialise to NOW() when the row is created and leave alone for subsequent updates.

TIMESTAMP properties when running in MAXDB mode

When MySQL is running in MAXDB mode, TIMESTAMP is identical with DATETIME. It uses the same format to store and display values, and it has the same range. MySQL can be run in MAXDB mode as of version 4.1.1. See Section 4.1.1 [Command-line options], page 195.

TIMESTAMP properties as of MySQL 4.1 when not running in

MAXDB mode

In MySQL 4.1.0, TIMESTAMP columns are stored and displayed in the same format as DATETIME columns. This also means that they cannot be narrowed or widened in the ways described in the following paragraphs. In other words, you cannot use TIMESTAMP(2), TIMESTAMP(4), etc. Other than that, the properties are the same as in previous MySQL versions.

TIMESTAMP properties prior to MySQL 4.1

TIMESTAMP values may range from the beginning of 1970 to sometime in the year 2037, with a resolution of one second. Values are displayed as numbers.

The format in which MySQL retrieves and displays TIMESTAMP values depends on the display size, as illustrated by the following table. The 'full' TIMESTAMP format is 14 digits, but TIMESTAMP columns may be created with shorter display sizes:

Column type	Display format
TIMESTAMP(14)	YYYYMMDDHHMMSS
TIMESTAMP(12)	YYMMDDHHMMSS
TIMESTAMP(10)	YYMMDDHHMM
TIMESTAMP(8)	YYYYMMDD
TIMESTAMP(6)	YYMMDD
TIMESTAMP(4)	YYMM
TIMESTAMP(2)	YY

All TIMESTAMP columns have the same storage size, regardless of display size. The most common display sizes are 6, 8, 12, and 14. You can specify an arbitrary display size at table creation time, but values of 0 or greater than 14 are coerced to 14. Odd-valued sizes in the range from 1 to 13 are coerced to the next higher even number.

Note: From version 4.1, TIMESTAMP is returned as a string with the format 'YYYY-MM-DD HH:MM:SS' and different timestamp lengths are no longer supported.

You can specify DATETIME, DATE, and TIMESTAMP values using any of a common set of formats:

- As a string in either 'YYYY-MM-DD HH:MM:SS' or 'YY-MM-DD HH:MM:SS' format. A "relaxed" syntax is allowed—any punctuation character may be used as the delimiter between date parts or time parts. For example, '98-12-31 11:30:45', '98.12.31 11+30+45', '98/12/31 11*30*45', and '98@12@31 11^30^45' are equivalent.
- As a string in either 'YYYY-MM-DD' or 'YY-MM-DD' format. A "relaxed" syntax is allowed here, too. For example, '98-12-31', '98.12.31', '98/12/31', and '98@12@31' are equivalent.
- As a string with no delimiters in either 'YYYYMMDDHHMMSS' or 'YYMMDDHHMMSS' format, provided that the string makes sense as a date. For example, '19970523091528' and '970523091528' are interpreted as '1997-05-23 09:15:28', but '971122129015' is illegal (it has a nonsensical minute part) and becomes '0000-00-00 00:00:00'.
- As a string with no delimiters in either 'YYYYMMDD' or 'YYMMDD' format, provided that the string makes sense as a date. For example, '19970523' and '970523' are interpreted as '1997-05-23', but '971332' is illegal (it has nonsensical month and day parts) and becomes '0000-00-00'.
- As a number in either YYYYMMDDHHMMSS or YYMMDDHHMMSS format, provided that the number makes sense as a date. For example, 19830905132800 and 830905132800 are interpreted as '1983-09-05 13:28:00'.
- As a number in either YYYYMMDD or YYMMDD format, provided that the number makes sense as a date. For example, 19830905 and 830905 are interpreted as '1983-09-05'.
- As the result of a function that returns a value that is acceptable in a DATETIME, DATE, or TIMESTAMP context, such as NOW() or CURRENT_DATE.

Illegal DATETIME, DATE, or TIMESTAMP values are converted to the "zero" value of the appropriate type ('0000-00-00 00:00:00', '0000-00-00', or 00000000000000).

For values specified as strings that include date part delimiters, it is not necessary to specify two digits for month or day values that are less than 10. '1979-6-9' is the same as '1979-06-09'. Similarly, for values specified as strings that include time part delimiters, it is not necessary to specify two digits for hour, minute, or second values that are less than 10. '1979-10-30 1:2:3' is the same as '1979-10-30 01:02:03'.

Values specified as numbers should be 6, 8, 12, or 14 digits long. If the number is 8 or 14 digits long, it is assumed to be in YYYYMMDD or YYYYMMDDHHMMSS format and that the year is given by the first 4 digits. If the number is 6 or 12 digits long, it is assumed to be in YYMMDD or YYMMDDHHMMSS format and that the year is given by the first 2 digits. Numbers that are not one of these lengths are interpreted as though padded with leading zeros to the closest length.

Values specified as non-delimited strings are interpreted using their length as given. If the string is 8 or 14 characters long, the year is assumed to be given by the first 4 characters. Otherwise, the year is assumed to be given by the first 2 characters. The string is interpreted from left to right to find year, month, day, hour, minute, and second values, for as many parts as are present in the string. This means you should not use strings that have fewer than 6 characters. For example, if you specify `'9903'`, thinking that will represent March, 1999, you will find that MySQL inserts a "zero" date into your table. This is because the year and month values are `99` and `03`, but the day part is completely missing, so the value is not a legal date. However, as of MySQL 3.23, you can explicitly specify a value of zero to represent missing month or day parts. For example, you can use `'990300'` to insert the value `'1999-03-00'`.

`TIMESTAMP` columns store legal values using the full precision with which the value was specified, regardless of the display size. This has several implications:

- Always specify year, month, and day, even if your column types are `TIMESTAMP(4)` or `TIMESTAMP(2)`. Otherwise, the value will not be a legal date and `0` will be stored.
- If you use `ALTER TABLE` to widen a narrow `TIMESTAMP` column, information will be displayed that previously was "hidden".
- Similarly, narrowing a `TIMESTAMP` column does not cause information to be lost, except in the sense that less information is shown when the values are displayed.
- Although `TIMESTAMP` values are stored to full precision, the only function that operates directly on the underlying stored value is `UNIX_TIMESTAMP()`. Other functions operate on the formatted retrieved value. This means you cannot use functions such as `HOUR()` or `SECOND()` unless the relevant part of the `TIMESTAMP` value is included in the formatted value. For example, the `HH` part of a `TIMESTAMP` column is not displayed unless the display size is at least 10, so trying to use `HOUR()` on shorter `TIMESTAMP` values produces a meaningless result.

You can to some extent assign values of one date type to an object of a different date type. However, there may be some alteration of the value or loss of information:

- If you assign a `DATE` value to a `DATETIME` or `TIMESTAMP` object, the time part of the resulting value is set to `'00:00:00'`, because the `DATE` value contains no time information.
- If you assign a `DATETIME` or `TIMESTAMP` value to a `DATE` object, the time part of the resulting value is deleted, because the `DATE` type stores no time information.
- Remember that although `DATETIME`, `DATE`, and `TIMESTAMP` values all can be specified using the same set of formats, the types do not all have the same range of values. For example, `TIMESTAMP` values cannot be earlier than `1970` or later than `2037`. This means that a date such as `'1968-01-01'`, while legal as a `DATETIME` or `DATE` value, is not a valid `TIMESTAMP` value and will be converted to `0` if assigned to such an object.

Be aware of certain pitfalls when specifying date values:

- The relaxed format allowed for values specified as strings can be deceiving. For example, a value such as `'10:11:12'` might look like a time value because of the '`:`' delimiter, but if used in a date context will be interpreted as the year `'2010-11-12'`. The value `'10:45:15'` will be converted to `'0000-00-00'` because `'45'` is not a legal month.

- The MySQL server only performs basic checking on the validity of a date: days `00-31`, months `00-12`, years `1000-9999`. Any date not within this range will revert to `0000-00-00`. Please note that this still allows you to store invalid dates such as `2002-04-31`. It allows web applications to store data from a form without further checking. To ensure a date is valid, perform a check in your application.
- Year values specified as two digits are ambiguous, because the century is unknown. MySQL interprets 2-digit year values using the following rules:
  - Year values in the range `00-69` are converted to `2000-2069`.
  - Year values in the range `70-99` are converted to `1970-1999`.

6.2.2.3 The `TIME` Type

MySQL retrieves and displays `TIME` values in `'HH:MM:SS'` format (or `'HHH:MM:SS'` format for large hours values). `TIME` values may range from `'-838:59:59'` to `'838:59:59'`. The reason the hours part may be so large is that the `TIME` type may be used not only to represent a time of day (which must be less than 24 hours), but also elapsed time or a time interval between two events (which may be much greater than 24 hours, or even negative).

You can specify `TIME` values in a variety of formats:

- As a string in `'D HH:MM:SS.fraction'` format. (Note that MySQL doesn't yet store the fraction for the time column.) One can also use one of the following "relaxed" syntax:

  `HH:MM:SS.fraction`, `HH:MM:SS`, `HH:MM`, `D HH:MM:SS`, `D HH:MM`, `D HH` or `SS`. Here `D` is days between 0-33.
- As a string with no delimiters in `'HHMMSS'` format, provided that it makes sense as a time. For example, `'101112'` is understood as `'10:11:12'`, but `'109712'` is illegal (it has a nonsensical minute part) and becomes `'00:00:00'`.
- As a number in `HHMMSS` format, provided that it makes sense as a time. For example, `101112` is understood as `'10:11:12'`. The following alternative formats are also understood: `SS`, `MMSS`,`HHMMSS`, `HHMMSS.fraction`. Note that MySQL doesn't yet store the fraction part.
- As the result of a function that returns a value that is acceptable in a `TIME` context, such as `CURRENT_TIME`.

For `TIME` values specified as strings that include a time part delimiter, it is not necessary to specify two digits for hours, minutes, or seconds values that are less than `10`. `'8:3:2'` is the same as `'08:03:02'`.

Be careful about assigning "short" `TIME` values to a `TIME` column. Without colons, MySQL interprets values using the assumption that the rightmost digits represent seconds. (MySQL interprets `TIME` values as elapsed time rather than as time of day.) For example, you might think of `'1112'` and `1112` as meaning `'11:12:00'` (12 minutes after 11 o'clock), but MySQL interprets them as `'00:11:12'` (11 minutes, 12 seconds). Similarly, `'12'` and `12` are interpreted as `'00:00:12'`. `TIME` values with colons, by contrast, are always treated as time of the day. That is `'11:12'` will mean `'11:12:00'`, not `'00:11:12'`.

Values that lie outside the `TIME` range but are otherwise legal are clipped to the appropriate endpoint of the range. For example, `'-850:00:00'` and `'850:00:00'` are converted to `'-838:59:59'` and `'838:59:59'`.

Illegal TIME values are converted to '00:00:00'. Note that because '00:00:00' is itself a legal TIME value, there is no way to tell, from a value of '00:00:00' stored in a table, whether the original value was specified as '00:00:00' or whether it was illegal.

6.2.2.4 The YEAR Type

The YEAR type is a 1-byte type used for representing years.

MySQL retrieves and displays YEAR values in YYYY format. The range is 1901 to 2155.

You can specify YEAR values in a variety of formats:

- As a four-digit string in the range '1901' to '2155'.
- As a four-digit number in the range 1901 to 2155.
- As a two-digit string in the range '00' to '99'. Values in the ranges '00' to '69' and '70' to '99' are converted to YEAR values in the ranges 2000 to 2069 and 1970 to 1999.
- As a two-digit number in the range 1 to 99. Values in the ranges 1 to 69 and 70 to 99 are converted to YEAR values in the ranges 2001 to 2069 and 1970 to 1999. Note that the range for two-digit numbers is slightly different from the range for two-digit strings, because you cannot specify zero directly as a number and have it be interpreted as 2000. You **must** specify it as a string '0' or '00' or it will be interpreted as 0000.
- As the result of a function that returns a value that is acceptable in a YEAR context, such as NOW().

Illegal YEAR values are converted to 0000.

6.2.3 String Types

The string types are CHAR, VARCHAR, BLOB, TEXT, ENUM, and SET. This section describes how these types work, their storage requirements, and how to use them in your queries.

Type	Max.size	Bytes
TINYTEXT or TINYBLOB	2^8-1	255
TEXT or BLOB	2^16-1 (64K-1)	65535
MEDIUMTEXT or MEDIUMBLOB	2^24-1 (16M-1)	16777215
LONGBLOB	2^32-1 (4G-1)	4294967295

6.2.3.1 The CHAR and VARCHAR Types

The CHAR and VARCHAR types are similar, but differ in the way they are stored and retrieved.

The length of a CHAR column is fixed to the length that you declare when you create the table. The length can be any value between 1 and 255. (As of MySQL Version 3.23, the length of CHAR may be 0 to 255.) When CHAR values are stored, they are right-padded with spaces to the specified length. When CHAR values are retrieved, trailing spaces are removed.

Values in VARCHAR columns are variable-length strings. You can declare a VARCHAR column to be any length between 1 and 255, just as for CHAR columns. However, in contrast to CHAR, VARCHAR values are stored using only as many characters as are needed, plus one byte to

record the length. Values are not padded; instead, trailing spaces are removed when values are stored. (This space removal differs from the SQL-99 specification.) No case conversion takes place during storage or retrieval.

If you assign a value to a `CHAR` or `VARCHAR` column that exceeds the column's maximum length, the value is truncated to fit.

The following table illustrates the differences between the two types of columns by showing the result of storing various string values into `CHAR(4)` and `VARCHAR(4)` columns:

Value	`CHAR(4)`	**Storage required**	`VARCHAR(4)`	**Storage required**
`''`	`'  '`	4 bytes	`''`	1 byte
`'ab'`	`'ab '`	4 bytes	`'ab'`	3 bytes
`'abcd'`	`'abcd'`	4 bytes	`'abcd'`	5 bytes
`'abcdefgh'`	`'abcd'`	4 bytes	`'abcd'`	5 bytes

The values retrieved from the `CHAR(4)` and `VARCHAR(4)` columns will be the same in each case, because trailing spaces are removed from `CHAR` columns upon retrieval.

Values in `CHAR` and `VARCHAR` columns are sorted and compared in case-insensitive fashion, unless the `BINARY` attribute was specified when the table was created. The `BINARY` attribute means that column values are sorted and compared in case-sensitive fashion according to the ASCII order of the machine where the MySQL server is running. `BINARY` doesn't affect how the column is stored or retrieved.

From version 4.1.0, column type `CHAR BYTE` is an alias for `CHAR BINARY`. This is a compatibility feature.

The `BINARY` attribute is sticky. This means that if a column marked `BINARY` is used in an expression, the whole expression is compared as a `BINARY` value.

MySQL may silently change the type of a `CHAR` or `VARCHAR` column at table creation time. See Section 6.5.3.1 [Silent column changes], page 573.

6.2.3.2 The `BLOB` and `TEXT` Types

A `BLOB` is a binary large object that can hold a variable amount of data. The four `BLOB` types `TINYBLOB`, `BLOB`, `MEDIUMBLOB`, and `LONGBLOB` differ only in the maximum length of the values they can hold. See Section 6.2.6 [Storage requirements], page 472.

The four `TEXT` types `TINYTEXT`, `TEXT`, `MEDIUMTEXT`, and `LONGTEXT` correspond to the four `BLOB` types and have the same maximum lengths and storage requirements. The only difference between `BLOB` and `TEXT` types is that sorting and comparison is performed in case-sensitive fashion for `BLOB` values and case-insensitive fashion for `TEXT` values. In other words, a `TEXT` is a case-insensitive `BLOB`. No case conversion takes place during storage or retrieval.

If you assign a value to a `BLOB` or `TEXT` column that exceeds the column type's maximum length, the value is truncated to fit.

In most respects, you can regard a `TEXT` column as a `VARCHAR` column that can be as big as you like. Similarly, you can regard a `BLOB` column as a `VARCHAR BINARY` column. The differences are:

- You can have indexes on BLOB and TEXT columns with MySQL Version 3.23.2 and newer. Older versions of MySQL did not support this.
- There is no trailing-space removal for BLOB and TEXT columns when values are stored, as there is for VARCHAR columns.
- BLOB and TEXT columns cannot have DEFAULT values.

From version 4.1.0, LONG and LONG VARCHAR map to the MEDIUMTEXT data type. This is a compatibility feature.

MyODBC defines BLOB values as LONGVARBINARY and TEXT values as LONGVARCHAR.

Because BLOB and TEXT values may be extremely long, you may run up against some constraints when using them:

- If you want to use GROUP BY or ORDER BY on a BLOB or TEXT column, you must convert the column value into a fixed-length object. The standard way to do this is with the SUBSTRING function. For example:

```
mysql> SELECT comment FROM tbl_name,SUBSTRING(comment,20) AS substr
    -> ORDER BY substr;
```

  If you don't do this, only the first max_sort_length bytes of the column are used when sorting. The default value of max_sort_length is 1024; this value can be changed using the -O option when starting the mysqld server. You can group on an expression involving BLOB or TEXT values by specifying the column position or by using an alias:

```
mysql> SELECT id,SUBSTRING(blob_col,1,100) FROM tbl_name GROUP BY 2;
mysql> SELECT id,SUBSTRING(blob_col,1,100) AS b FROM tbl_name GROUP BY b;
```

- The maximum size of a BLOB or TEXT object is determined by its type, but the largest value you can actually transmit between the client and server is determined by the amount of available memory and the size of the communications buffers. You can change the message buffer size (max_allowed_packet), but you must do so on both the server and client ends. See Section 5.5.2 [Server parameters], page 427.

Note that each BLOB or TEXT value is represented internally by a separately allocated object. This is in contrast to all other column types, for which storage is allocated once per column when the table is opened.

6.2.3.3 The ENUM Type

An ENUM is a string object whose value normally is chosen from a list of allowed values that are enumerated explicitly in the column specification at table creation time.

The value may also be the empty string ("") or NULL under certain circumstances:

- If you insert an invalid value into an ENUM (that is, a string not present in the list of allowed values), the empty string is inserted instead as a special error value. This string can be distinguished from a 'normal' empty string by the fact that this string has the numerical value 0. More about this later.
- If an ENUM is declared NULL, NULL is also a legal value for the column, and the default value is NULL. If an ENUM is declared NOT NULL, the default value is the first element of the list of allowed values.

Each enumeration value has an index:

- Values from the list of allowable elements in the column specification are numbered beginning with 1.
- The index value of the empty string error value is 0. This means that you can use the following `SELECT` statement to find rows into which invalid `ENUM` values were assigned:

```
mysql> SELECT * FROM tbl_name WHERE enum_col=0;
```

- The index of the `NULL` value is `NULL`.

For example, a column specified as `ENUM("one", "two", "three")` can have any of the values shown here. The index of each value is also shown:

Value	Index
`NULL`	`NULL`
`""`	0
`"one"`	1
`"two"`	2
`"three"`	3

An enumeration can have a maximum of 65535 elements.

Starting from 3.23.51 trailing spaces are automatically deleted from `ENUM` values when the table is created.

Lettercase is irrelevant when you assign values to an `ENUM` column. However, values retrieved from the column later have lettercase matching the values that were used to specify the allowable values at table creation time.

If you retrieve an `ENUM` in a numeric context, the column value's index is returned. For example, you can retrieve numeric values from an `ENUM` column like this:

```
mysql> SELECT enum_col+0 FROM tbl_name;
```

If you store a number into an `ENUM`, the number is treated as an index, and the value stored is the enumeration member with that index. (However, this will not work with `LOAD DATA`, which treats all input as strings.) It's not advisable to store numbers in an `ENUM` string because it will make things confusing.

`ENUM` values are sorted according to the order in which the enumeration members were listed in the column specification. (In other words, `ENUM` values are sorted according to their index numbers.) For example, `"a"` sorts before `"b"` for `ENUM("a", "b")`, but `"b"` sorts before `"a"` for `ENUM("b", "a")`. The empty string sorts before non-empty strings, and `NULL` values sort before all other enumeration values. To prevent unexpected results, specify the `ENUM` list in alphabetical order. You can also use `GROUP BY CONCAT(col)` to make sure the column is sorted alphabetically rather than by index number.

If you want to get all possible values for an `ENUM` column, you should use: `SHOW COLUMNS FROM table_name LIKE enum_column_name` and parse the `ENUM` definition in the second column.

6.2.3.4 The `SET` Type

A `SET` is a string object that can have zero or more values, each of which must be chosen from a list of allowed values specified when the table is created. `SET` column values that consist of multiple set members are specified with members separated by commas (‘`,`’). A consequence of this is that `SET` member values cannot themselves contain commas.

For example, a column specified as `SET("one", "two") NOT NULL` can have any of these values:

```
""
"one"
"two"
"one,two"
```

A `SET` can have a maximum of 64 different members.

Starting from 3.23.51 trailing spaces are automatically deleted from `SET` values when the table is created.

MySQL stores `SET` values numerically, with the low-order bit of the stored value corresponding to the first set member. If you retrieve a `SET` value in a numeric context, the value retrieved has bits set corresponding to the set members that make up the column value. For example, you can retrieve numeric values from a `SET` column like this:

```
mysql> SELECT set_col+0 FROM tbl_name;
```

If a number is stored into a `SET` column, the bits that are set in the binary representation of the number determine the set members in the column value. Suppose a column is specified as `SET("a","b","c","d")`. Then the members have the following bit values:

`SET` member	Decimal value	Binary value
a	1	0001
b	2	0010
c	4	0100
d	8	1000

If you assign a value of `9` to this column, that is `1001` in binary, so the first and fourth `SET` value members `"a"` and `"d"` are selected and the resulting value is `"a,d"`.

For a value containing more than one `SET` element, it does not matter what order the elements are listed in when you insert the value. It also does not matter how many times a given element is listed in the value. When the value is retrieved later, each element in the value will appear once, with elements listed according to the order in which they were specified at table creation time. For example, if a column is specified as `SET("a","b","c","d")`, then `"a,d"`, `"d,a"`, and `"d,a,a,d,d"` will all appear as `"a,d"` when retrieved.

If you set a `SET` column to an unsupported value, the value will be ignored.

`SET` values are sorted numerically. `NULL` values sort before non-`NULL` `SET` values.

Normally, you perform a `SELECT` on a `SET` column using the `LIKE` operator or the `FIND_IN_SET()` function:

```
mysql> SELECT * FROM tbl_name WHERE set_col LIKE '%value%';
mysql> SELECT * FROM tbl_name WHERE FIND_IN_SET('value',set_col)>0;
```

But the following will also work:

```
mysql> SELECT * FROM tbl_name WHERE set_col = 'val1,val2';
mysql> SELECT * FROM tbl_name WHERE set_col & 1;
```

The first of these statements looks for an exact match. The second looks for values containing the first set member.

If you want to get all possible values for a `SET` column, you should use: `SHOW COLUMNS FROM table_name LIKE set_column_name` and parse the `SET` definition in the second column.

6.2.4 Choosing the Right Type for a Column

For the most efficient use of storage, try to use the most precise type in all cases. For example, if an integer column will be used for values in the range between `1` and `99999`, `MEDIUMINT UNSIGNED` is the best type.

Accurate representation of monetary values is a common problem. In MySQL, you should use the `DECIMAL` type. This is stored as a string, so no loss of accuracy should occur. If accuracy is not too important, the `DOUBLE` type may also be good enough.

For high precision, you can always convert to a fixed-point type stored in a `BIGINT`. This allows you to do all calculations with integers and convert results back to floating-point values only when necessary.

6.2.5 Using Column Types from Other Database Engines

To make it easier to use code written for SQL implementations from other vendors, MySQL maps column types as shown in the following table. These mappings make it easier to move table definitions from other database engines to MySQL:

Other vendor type	MySQL type
`BINARY(NUM)`	`CHAR(NUM) BINARY`
`CHAR VARYING(NUM)`	`VARCHAR(NUM)`
`FLOAT4`	`FLOAT`
`FLOAT8`	`DOUBLE`
`INT1`	`TINYINT`
`INT2`	`SMALLINT`
`INT3`	`MEDIUMINT`
`INT4`	`INT`
`INT8`	`BIGINT`
`LONG VARBINARY`	`MEDIUMBLOB`
`LONG VARCHAR`	`MEDIUMTEXT`
`MIDDLEINT`	`MEDIUMINT`
`VARBINARY(NUM)`	`VARCHAR(NUM) BINARY`

Column type mapping occurs at table creation time. If you create a table with types used by other vendors and then issue a `DESCRIBE tbl_name` statement, MySQL reports the table structure using the equivalent MySQL types.

6.2.6 Column Type Storage Requirements

The storage requirements for each of the column types supported by MySQL are listed by category.

Storage Requirements for Numeric Types

Column type	Storage required
`TINYINT`	1 byte
`SMALLINT`	2 bytes

MEDIUMINT	3 bytes
INT	4 bytes
INTEGER	4 bytes
BIGINT	8 bytes
FLOAT(X)	4 if X <= 24 or 8 if 25 <= X <= 53
FLOAT	4 bytes
DOUBLE	8 bytes
DOUBLE PRECISION	8 bytes
REAL	8 bytes
DECIMAL(M,D)	M+2 bytes if D > 0, M+1 bytes if D = 0 (D+2, if M < D)
NUMERIC(M,D)	M+2 bytes if D > 0, M+1 bytes if D = 0 (D+2, if M < D)

Storage Requirements for Date and Time Types

Column type	Storage required
DATE	3 bytes
DATETIME	8 bytes
TIMESTAMP	4 bytes
TIME	3 bytes
YEAR	1 byte

Storage Requirements for String Types

Column type	Storage required
CHAR(M)	M bytes, 1 <= M <= 255
VARCHAR(M)	L+1 bytes, where L <= M and 1 <= M <= 255
TINYBLOB, TINYTEXT	L+1 bytes, where L < 2^8
BLOB, TEXT	L+2 bytes, where L < 2^16
MEDIUMBLOB, MEDIUMTEXT	L+3 bytes, where L < 2^24
LONGBLOB, LONGTEXT	L+4 bytes, where L < 2^32
ENUM('value1','value2',...)	1 or 2 bytes, depending on the number of enumeration values (65535 values maximum)
SET('value1','value2',...)	1, 2, 3, 4 or 8 bytes, depending on the number of set members (64 members maximum)

VARCHAR and the BLOB and TEXT types are variable-length types, for which the storage requirements depend on the actual length of column values (represented by L in the preceding table), rather than on the type's maximum possible size. For example, a VARCHAR(10) column can hold a string with a maximum length of 10 characters. The actual storage required is the length of the string (L), plus 1 byte to record the length of the string. For the string 'abcd', L is 4 and the storage requirement is 5 bytes.

The BLOB and TEXT types require 1, 2, 3, or 4 bytes to record the length of the column value, depending on the maximum possible length of the type. See Section 6.2.3.2 [BLOB], page 468.

If a table includes any variable-length column types, the record format will also be variable-length. Note that when a table is created, MySQL may, under certain conditions, change a

column from a variable-length type to a fixed-length type, or vice-versa. See Section 6.5.3.1 [Silent column changes], page 573.

The size of an `ENUM` object is determined by the number of different enumeration values. One byte is used for enumerations with up to 255 possible values. Two bytes are used for enumerations with up to 65535 values. See Section 6.2.3.3 [ENUM], page 469.

The size of a `SET` object is determined by the number of different set members. If the set size is `N`, the object occupies `(N+7)/8` bytes, rounded up to 1, 2, 3, 4, or 8 bytes. A `SET` can have a maximum of 64 members. See Section 6.2.3.4 [SET], page 470.

The maximum size of a row in a `MyISAM` table is 65534 bytes. Each `BLOB` and `TEXT` column accounts for only 5-9 bytes toward this size.

6.3 Functions for Use in `SELECT` and `WHERE` Clauses

A `select_expression` or `where_definition` in an SQL statement can consist of any expression using the functions described below.

An expression that contains `NULL` always produces a `NULL` value unless otherwise indicated in the documentation for the operators and functions involved in the expression.

Note: there must be no whitespace between a function name and the parentheses following it. This helps the MySQL parser distinguish between function calls and references to tables or columns that happen to have the same name as a function. Spaces around arguments are permitted, though.

You can force MySQL to accept spaces after the function name by starting `mysqld` with `--ansi` or using the `CLIENT_IGNORE_SPACE` to `mysql_connect()`, but in this case all function names will become reserved words. See Section 1.7.2 [ANSI mode], page 33.

For the sake of brevity, examples display the output from the `mysql` program in abbreviated form. So this:

```
mysql> SELECT MOD(29,9);
1 rows in set (0.00 sec)

+-----------+
| mod(29,9) |
+-----------+
|         2 |
+-----------+
```

is displayed like this:

```
mysql> SELECT MOD(29,9);
        -> 2
```

6.3.1 Non-Type-Specific Operators and Functions

6.3.1.1 Parentheses

```
( ... )
```

Use parentheses to force the order of evaluation in an expression. For example:

```
mysql> SELECT 1+2*3;
        -> 7
mysql> SELECT (1+2)*3;
        -> 9
```

6.3.1.2 Comparison Operators

Comparison operations result in a value of `1` (TRUE), `0` (FALSE), or `NULL`. These functions work for both numbers and strings. Strings are automatically converted to numbers and numbers to strings as needed (as in Perl).

MySQL performs comparisons using the following rules:

- If one or both arguments are `NULL`, the result of the comparison is `NULL`, except for the `<=>` operator.
- If both arguments in a comparison operation are strings, they are compared as strings.
- If both arguments are integers, they are compared as integers.
- Hexadecimal values are treated as binary strings if not compared to a number.
- If one of the arguments is a `TIMESTAMP` or `DATETIME` column and the other argument is a constant, the constant is converted to a timestamp before the comparison is performed. This is done to be more ODBC-friendly.
- In all other cases, the arguments are compared as floating-point (real) numbers.

By default, string comparisons are done in case-independent fashion using the current character set (ISO-8859-1 Latin1 by default, which also works excellently for English).

If you are comparing case-insensitive strings with any of the standard operators (`=`, `<>`..., but not `LIKE`) trailing whitespace (spaces, tabs and newlines) will be ignored.

```
mysql> SELECT "a" ="A \n";
        -> 1
```

The following examples illustrate conversion of strings to numbers for comparison operations:

```
mysql> SELECT 1 > '6x';
         -> 0
mysql> SELECT 7 > '6x';
         -> 1
mysql> SELECT 0 > 'x6';
         -> 0
mysql> SELECT 0 = 'x6';
         -> 1
```

Note that when you are comparing a string column with a number, MySQL can't use index to quickly look up the value:

```
SELECT * FROM table_name WHERE string_key=1
```

The reason for this is that there is many different strings that may return the value `1`: `"1"`, `" 1"`, `"1a"` ...

`=` Equal:

```
mysql> SELECT 1 = 0;
        -> 0
mysql> SELECT '0' = 0;
        -> 1
mysql> SELECT '0.0' = 0;
        -> 1
mysql> SELECT '0.01' = 0;
        -> 0
mysql> SELECT '.01' = 0.01;
        -> 1
```

`<>`
`!=` Not equal:

```
mysql> SELECT '.01' <> '0.01';
        -> 1
mysql> SELECT .01 <> '0.01';
        -> 0
mysql> SELECT 'zapp' <> 'zappp';
        -> 1
```

`<=` Less than or equal:

```
mysql> SELECT 0.1 <= 2;
        -> 1
```

`<` Less than:

```
mysql> SELECT 2 < 2;
        -> 0
```

`>=` Greater than or equal:

```
mysql> SELECT 2 >= 2;
        -> 1
```

`>` Greater than:

```
mysql> SELECT 2 > 2;
        -> 0
```

`<=>` `NULL`-safe equal:

```
mysql> SELECT 1 <=> 1, NULL <=> NULL, 1 <=> NULL;
        -> 1 1 0
```

`IS NULL`
`IS NOT NULL`
Test whether a value is or is not `NULL`:

```
mysql> SELECT 1 IS NULL, 0 IS NULL, NULL IS NULL;
        -> 0 0 1
mysql> SELECT 1 IS NOT NULL, 0 IS NOT NULL, NULL IS NOT NULL;
        -> 1 1 0
```

To be able to work well with other programs, MySQL supports the following extra features when using `IS NULL`:

- You can find the last inserted row with:

  ```
  SELECT * FROM tbl_name WHERE auto_col IS NULL
  ```

  This can be disabled by setting `SQL_AUTO_IS_NULL=0`. See Section 5.5.6 [SET OPTION], page 432.

- For `NOT NULL DATE` and `DATETIME` columns you can find the special date `0000-00-00` by using:

  ```
  SELECT * FROM tbl_name WHERE date_column IS NULL
  ```

  This is needed to get some ODBC applications to work (as ODBC doesn't support a `0000-00-00` date)

`expr BETWEEN min AND max`

If `expr` is greater than or equal to `min` and `expr` is less than or equal to `max`, `BETWEEN` returns `1`, otherwise it returns `0`. This is equivalent to the expression `(min <= expr AND expr <= max)` if all the arguments are of the same type. Otherwise type conversion takes place, according to the rules above, but applied to all the three arguments. **Note** that before 4.0.5 arguments were converted to the type of `expr` instead.

```
mysql> SELECT 1 BETWEEN 2 AND 3;
        -> 0
mysql> SELECT 'b' BETWEEN 'a' AND 'c';
        -> 1
mysql> SELECT 2 BETWEEN 2 AND '3';
        -> 1
mysql> SELECT 2 BETWEEN 2 AND 'x-3';
        -> 0
```

`expr NOT BETWEEN min AND max`

Same as `NOT (expr BETWEEN min AND max)`.

`expr IN (value,...)`

Returns `1` if `expr` is any of the values in the `IN` list, else returns `0`. If all values are constants, then all values are evaluated according to the type of `expr` and sorted. The search for the item is then done using a binary search. This means `IN` is very quick if the `IN` value list consists entirely of constants. If `expr` is a case-sensitive string expression, the string comparison is performed in case-sensitive fashion:

```
mysql> SELECT 2 IN (0,3,5,'wefwf');
        -> 0
mysql> SELECT 'wefwf' IN (0,3,5,'wefwf');
        -> 1
```

The number of values in the `IN` list is only limited by the `max_allowed_packet` value.

From 4.1 (to comply with the SQL-99 standard), `IN` returns `NULL` not only if the expression on the left hand side is `NULL`, but also if no match is found in the list and one of the expressions in the list is `NULL`.

From MySQL version 4.1, an IN() clause may also contain a subquery. See Section 6.4.2.3 [ANY IN SOME subqueries], page 539.

`expr NOT IN (value,...)`
Same as `NOT (expr IN (value,...))`.

`ISNULL(expr)`
If `expr` is `NULL`, `ISNULL()` returns `1`, otherwise it returns `0`:

```
mysql> SELECT ISNULL(1+1);
        -> 0
mysql> SELECT ISNULL(1/0);
        -> 1
```

Note that a comparison of `NULL` values using `=` will always be false!

`COALESCE(list)`
Returns first non-`NULL` element in list:

```
mysql> SELECT COALESCE(NULL,1);
        -> 1
mysql> SELECT COALESCE(NULL,NULL,NULL);
        -> NULL
```

`INTERVAL(N,N1,N2,N3,...)`
Returns `0` if `N < N1`, `1` if `N < N2` and so on or `-1` if `N` is `NULL`. All arguments are treated as integers. It is required that `N1 < N2 < N3 < ... < Nn` for this function to work correctly. This is because a binary search is used (very fast):

```
mysql> SELECT INTERVAL(23, 1, 15, 17, 30, 44, 200);
        -> 3
mysql> SELECT INTERVAL(10, 1, 10, 100, 1000);
        -> 2
mysql> SELECT INTERVAL(22, 23, 30, 44, 200);
        -> 0
```

6.3.1.3 Logical Operators

In SQL, all logical operators evaluate to TRUE, FALSE or NULL (UNKNOWN). In MySQL, this is implemented as `1` (TRUE), `0` (FALSE), and `NULL`. Most of this is common between different SQL databases, however some may return any non-zero value for TRUE.

`NOT`
`!` Logical NOT. Evaluates to `1` if the operand is `0`, to `0` if the operand is non-zero, and `NOT NULL` returns `NULL`.

```
mysql> SELECT NOT 10;
        -> 0
```

```
mysql> SELECT NOT 0;
        -> 1
mysql> SELECT NOT NULL;
        -> NULL
mysql> SELECT ! (1+1);
        -> 0
mysql> SELECT ! 1+1;
        -> 1
```

The last example produces `1` because the expression evaluates the same way as `(!1)+1`.

`AND`
`&&` Logical AND. Evaluates to `1` if all operands are non-zero and not `NULL`, to `0` if one or more operands are `0`, otherwise `NULL` is returned.

```
mysql> SELECT 1 && 1;
        -> 1
mysql> SELECT 1 && 0;
        -> 0
mysql> SELECT 1 && NULL;
        -> NULL
mysql> SELECT 0 && NULL;
        -> 0
mysql> SELECT NULL && 0;
        -> 0
```

Please note that MySQL versions prior to 4.0.5 stop evaluation when a `NULL` is encountered, rather than continuing the process to check for possible `0`s. This means that in these versions, `SELECT (NULL AND 0)` returns `NULL` instead of `0`. In 4.0.5 the code has been re-engineered so that the result will always be as prescribed by the SQL standards while still using the optimisation wherever possible.

`OR`
`||` Logical OR. Evaluates to `1` if any operand is non-zero, to `NULL` if any operand is `NULL`, otherwise `0` is returned.

```
mysql> SELECT 1 || 1;
        -> 1
mysql> SELECT 1 || 0;
        -> 1
mysql> SELECT 0 || 0;
        -> 0
mysql> SELECT 0 || NULL;
        -> NULL
mysql> SELECT 1 || NULL;
        -> 1
```

`XOR` Logical XOR. Returns `NULL` if either operand is `NULL`. For non-`NULL` operands, evaluates to `1` if an odd number of operands is non-zero, otherwise `0` is returned.

```
example_for_help_topic XOR
```

```
mysql> SELECT 1 XOR 1;
        -> 0
mysql> SELECT 1 XOR 0;
        -> 1
mysql> SELECT 1 XOR NULL;
        -> NULL
mysql> SELECT 1 XOR 1 XOR 1;
        -> 1
```

`a XOR b` is mathematically equal to `(a AND (NOT b)) OR ((NOT a) and b)`.

`XOR` was added in version 4.0.2.

6.3.1.4 Control Flow Functions

`IFNULL(expr1,expr2)`

If `expr1` is not `NULL`, `IFNULL()` returns `expr1`, else it returns `expr2`. `IFNULL()` returns a numeric or string value, depending on the context in which it is used:

```
mysql> SELECT IFNULL(1,0);
        -> 1
mysql> SELECT IFNULL(NULL,10);
        -> 10
mysql> SELECT IFNULL(1/0,10);
        -> 10
mysql> SELECT IFNULL(1/0,'yes');
        -> 'yes'
```

In 4.0.6 and above the default result value of `IFNULL(expr1,expr2)` is the more 'general' of the two expressions, in the order `STRING`, `REAL` or `INTEGER`. The difference to earlier MySQL versions are mostly notable when you create a table based on expressions or MySQL has to internally store a value from `IFNULL()` in a temporary table.

```
CREATE TABLE foo SELECT IFNULL(1,"test") as test;
```

In MySQL 4.0.6 the type for column 'test' is `CHAR(4)` while in earlier versions you would get `BIGINT`.

`NULLIF(expr1,expr2)`

If `expr1 = expr2` is true, return `NULL` else return `expr1`. This is the same as `CASE WHEN x = y THEN NULL ELSE x END`:

```
mysql> SELECT NULLIF(1,1);
        -> NULL
mysql> SELECT NULLIF(1,2);
        -> 1
```

Note that `expr1` is evaluated twice in MySQL if the arguments are not equal.

`IF(expr1,expr2,expr3)`

If `expr1` is TRUE (`expr1 <> 0` and `expr1 <> NULL`) then `IF()` returns `expr2`, else it returns `expr3`. `IF()` returns a numeric or string value, depending on the context in which it is used:

```
mysql> SELECT IF(1>2,2,3);
        -> 3
mysql> SELECT IF(1<2,'yes','no');
        -> 'yes'
mysql> SELECT IF(STRCMP('test','test1'),'no','yes');
        -> 'no'
```

If `expr2` or `expr3` is explicitely `NULL` then the result type of the `IF()` function is the type of the not `NULL` column. (This behaviour is new in MySQL 4.0.3).

`expr1` is evaluated as an integer value, which means that if you are testing floating-point or string values, you should do so using a comparison operation:

```
mysql> SELECT IF(0.1,1,0);
        -> 0
mysql> SELECT IF(0.1<>0,1,0);
        -> 1
```

In the first case above, `IF(0.1)` returns `0` because `0.1` is converted to an integer value, resulting in a test of `IF(0)`. This may not be what you expect. In the second case, the comparison tests the original floating-point value to see whether it is non-zero. The result of the comparison is used as an integer.

The default return type of `IF()` (which may matter when it is stored into a temporary table) is calculated in MySQL Version 3.23 as follows:

Expression	**Return value**
expr2 or expr3 returns string	string
expr2 or expr3 returns a floating-point value	floating-point
expr2 or expr3 returns an integer	integer

If expr2 and expr3 are strings, then the result is case-insensitive if both strings are case-insensitive. (Starting from 3.23.51)

```
CASE value WHEN [compare-value] THEN result [WHEN [compare-value] THEN result
...] [ELSE result] END
CASE WHEN [condition] THEN result [WHEN [condition] THEN result ...] [ELSE
result] END
```

The first version returns the `result` where `value=compare-value`. The second version returns the result for the first condition, which is true. If there was no matching result value, then the result after `ELSE` is returned. If there is no `ELSE` part then `NULL` is returned:

```
mysql> SELECT CASE 1 WHEN 1 THEN "one"
           WHEN 2 THEN "two" ELSE "more" END;
       -> "one"
mysql> SELECT CASE WHEN 1>0 THEN "true" ELSE "false" END;
       -> "true"
mysql> SELECT CASE BINARY "B" WHEN "a" THEN 1 WHEN "b" THEN 2 END;
       -> NULL
```

The type of the return value (`INTEGER`, `DOUBLE` or `STRING`) is the same as the type of the first returned value (the expression after the first `THEN`).

6.3.2 String Functions

String-valued functions return NULL if the length of the result would be greater than the max_allowed_packet server parameter. See Section 5.5.2 [Server parameters], page 427.

For functions that operate on string positions, the first position is numbered 1.

ASCII(str)
: Returns the ASCII code value of the leftmost character of the string str. Returns 0 if str is the empty string. Returns NULL if str is NULL:

```
mysql> SELECT ASCII('2');
        -> 50
mysql> SELECT ASCII(2);
        -> 50
mysql> SELECT ASCII('dx');
        -> 100
```

See also the ORD() function.

ORD(str)
: If the leftmost character of the string str is a multi-byte character, returns the code for that character, calculated from the ASCII code values of its constituent characters using this formula: ((first byte ASCII code)*256+(second byte ASCII code))[*256+third byte ASCII code...]. If the leftmost character is not a multi-byte character, returns the same value that the ASCII() function does:

```
mysql> SELECT ORD('2');
        -> 50
```

CONV(N,from_base,to_base)
: Converts numbers between different number bases. Returns a string representation of the number N, converted from base from_base to base to_base. Returns NULL if any argument is NULL. The argument N is interpreted as an integer, but may be specified as an integer or a string. The minimum base is 2 and the maximum base is 36. If to_base is a negative number, N is regarded as a signed number. Otherwise, N is treated as unsigned. CONV works with 64-bit precision:

```
mysql> SELECT CONV("a",16,2);
        -> '1010'
mysql> SELECT CONV("6E",18,8);
        -> '172'
mysql> SELECT CONV(-17,10,-18);
        -> '-H'
mysql> SELECT CONV(10+"10"+'10'+0xa,10,10);
        -> '40'
```

BIN(N)
: Returns a string representation of the binary value of N, where N is a longlong (BIGINT) number. This is equivalent to CONV(N,10,2). Returns NULL if N is NULL:

```
mysql> SELECT BIN(12);
        -> '1100'
```

`OCT(N)` Returns a string representation of the octal value of `N`, where `N` is a longlong number. This is equivalent to `CONV(N,10,8)`. Returns `NULL` if `N` is `NULL`:

```
mysql> SELECT OCT(12);
        -> '14'
```

`HEX(N_or_S)`

If N_OR_S is a number, returns a string representation of the hexadecimal value of `N`, where `N` is a longlong (`BIGINT`) number. This is equivalent to `CONV(N,10,16)`.

If N_OR_S is a string, returns a hexadecimal string of N_OR_S where each character in N_OR_S is converted to 2 hexadecimal digits. This is the inverse of the `0xff` strings.

```
mysql> SELECT HEX(255);
        -> 'FF'
mysql> SELECT HEX("abc");
        -> 616263
mysql> SELECT 0x616263;
        -> "abc"
```

`CHAR(N,...)`

`CHAR()` interprets the arguments as integers and returns a string consisting of the characters given by the ASCII code values of those integers. `NULL` values are skipped:

```
mysql> SELECT CHAR(77,121,83,81,'76');
        -> 'MySQL'
mysql> SELECT CHAR(77,77.3,'77.3');
        -> 'MMM'
```

`CONCAT(str1,str2,...)`

Returns the string that results from concatenating the arguments. Returns `NULL` if any argument is `NULL`. May have more than 2 arguments. A numeric argument is converted to its equivalent string form:

```
mysql> SELECT CONCAT('My', 'S', 'QL');
        -> 'MySQL'
mysql> SELECT CONCAT('My', NULL, 'QL');
        -> NULL
mysql> SELECT CONCAT(14.3);
        -> '14.3'
```

`CONCAT_WS(separator, str1, str2,...)`

`CONCAT_WS()` stands for CONCAT With Separator and is a special form of `CONCAT()`. The first argument is the separator for the rest of the arguments. The separator is added between the strings to be concatenated: The separator can be a string as can the rest of the arguments. If the separator is `NULL`, the result is `NULL`. The function skips any `NULL` values after the separator argument.

```
mysql> SELECT CONCAT_WS(",","First name","Second name","Last Name");
       -> 'First name,Second name,Last Name'
mysql> SELECT CONCAT_WS(",","First name",NULL,"Last Name");
```

```
                -> 'First name,Last Name'
```

Before MySQL 4.1.1, `CONCAT_WS()` skips empty strings as well as `NULL` values.

`LENGTH(str)`
`OCTET_LENGTH(str)`
`CHAR_LENGTH(str)`
`CHARACTER_LENGTH(str)`

Returns the length of the string `str`:

```
mysql> SELECT LENGTH('text');
        -> 4
mysql> SELECT OCTET_LENGTH('text');
        -> 4
```

`LENGTH()` and `OCTET_LENGTH()` are synonyms, and measure string length in bytes (octets). A multi-byte character counts as multiple bytes. `CHAR_LENGTH()` and `CHARACTER_LENGTH()` are synonyms, and measure string length in characters. A multiple-byte character counts as a single character. This means that for a string containing five two-byte characters, `LENGTH()` returns `10`, whereas `CHAR_LENGTH()` returns `5`.

`BIT_LENGTH(str)`

Returns the length of the string `str` in bits:

```
mysql> SELECT BIT_LENGTH('text');
        -> 32
```

`LOCATE(substr,str)`
`POSITION(substr IN str)`

Returns the position of the first occurrence of substring `substr` in string `str`. Returns `0` if `substr` is not in `str`:

```
mysql> SELECT LOCATE('bar', 'foobarbar');
        -> 4
mysql> SELECT LOCATE('xbar', 'foobar');
        -> 0
```

This function is multi-byte safe. In MySQL 3.23 this function is case sensitive, while in 4.0 it's only case-sensitive if either argument is a binary string.

`LOCATE(substr,str,pos)`

Returns the position of the first occurrence of substring `substr` in string `str`, starting at position `pos`. Returns `0` if `substr` is not in `str`:

```
mysql> SELECT LOCATE('bar', 'foobarbar',5);
        -> 7
```

This function is multi-byte safe. In MySQL 3.23 this function is case sensitive, while in 4.0 it's only case-sensitive if either argument is a binary string.

`INSTR(str,substr)`

Returns the position of the first occurrence of substring `substr` in string `str`. This is the same as the two-argument form of `LOCATE()`, except that the arguments are swapped:

```
mysql> SELECT INSTR('foobarbar', 'bar');
        -> 4
mysql> SELECT INSTR('xbar', 'foobar');
        -> 0
```

This function is multi-byte safe. In MySQL 3.23 this function is case sensitive, while in 4.0 it's only case-sensitive if either argument is a binary string.

`LPAD(str,len,padstr)`

Returns the string `str`, left-padded with the string `padstr` to a length of `len` characters. If `str` is longer than `len`, the return value is shortened to `len` characters.

```
mysql> SELECT LPAD('hi',4,'??');
        -> '??hi'
```

`RPAD(str,len,padstr)`

Returns the string `str`, right-padded with the string `padstr` to a length of `len` characters. If `str` is longer than `len`, the return value is shortened to `len` characters.

```
mysql> SELECT RPAD('hi',5,'?');
        -> 'hi???'
```

`LEFT(str,len)`

Returns the leftmost `len` characters from the string `str`:

```
mysql> SELECT LEFT('foobarbar', 5);
        -> 'fooba'
```

This function is multi-byte safe.

`RIGHT(str,len)`

Returns the rightmost `len` characters from the string `str`:

```
mysql> SELECT RIGHT('foobarbar', 4);
        -> 'rbar'
```

This function is multi-byte safe.

`SUBSTRING(str,pos,len)`
`SUBSTRING(str FROM pos FOR len)`
`MID(str,pos,len)`

Returns a substring `len` characters long from string `str`, starting at position `pos`. The variant form that uses `FROM` is SQL-92 syntax:

```
mysql> SELECT SUBSTRING('Quadratically',5,6);
        -> 'ratica'
```

This function is multi-byte safe.

`SUBSTRING(str,pos)`
`SUBSTRING(str FROM pos)`

Returns a substring from string `str` starting at position `pos`:

```
mysql> SELECT SUBSTRING('Quadratically',5);
        -> 'ratically'
mysql> SELECT SUBSTRING('foobarbar' FROM 4);
```

```
        -> 'barbar'
```

This function is multi-byte safe.

`SUBSTRING_INDEX(str,delim,count)`

Returns the substring from string `str` before `count` occurrences of the delimiter `delim`. If `count` is positive, everything to the left of the final delimiter (counting from the left) is returned. If `count` is negative, everything to the right of the final delimiter (counting from the right) is returned:

```
mysql> SELECT SUBSTRING_INDEX('www.mysql.com', '.', 2);
        -> 'www.mysql'
mysql> SELECT SUBSTRING_INDEX('www.mysql.com', '.', -2);
        -> 'mysql.com'
```

This function is multi-byte safe.

`LTRIM(str)`

Returns the string `str` with leading space characters removed:

```
mysql> SELECT LTRIM('  barbar');
        -> 'barbar'
```

`RTRIM(str)`

Returns the string `str` with trailing space characters removed:

```
mysql> SELECT RTRIM('barbar   ');
        -> 'barbar'
```

This function is multi-byte safe.

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

Returns the string `str` with all `remstr` prefixes and/or suffixes removed. If none of the specifiers `BOTH`, `LEADING` or `TRAILING` are given, `BOTH` is assumed. If `remstr` is not specified, spaces are removed:

```
mysql> SELECT TRIM('  bar   ');
        -> 'bar'
mysql> SELECT TRIM(LEADING 'x' FROM 'xxxbarxxx');
        -> 'barxxx'
mysql> SELECT TRIM(BOTH 'x' FROM 'xxxbarxxx');
        -> 'bar'
mysql> SELECT TRIM(TRAILING 'xyz' FROM 'barxxyz');
        -> 'barx'
```

This function is multi-byte safe.

`SOUNDEX(str)`

Returns a soundex string from `str`. Two strings that sound almost the same should have identical soundex strings. A standard soundex string is 4 characters long, but the `SOUNDEX()` function returns an arbitrarily long string. You can use `SUBSTRING()` on the result to get a standard soundex string. All non-alphanumeric characters are ignored in the given string. All international alpha characters outside the A-Z range are treated as vowels:

```
mysql> SELECT SOUNDEX('Hello');
        -> 'H400'
```

```
mysql> SELECT SOUNDEX('Quadratically');
        -> 'Q36324'
```

`SPACE(N)` Returns a string consisting of `N` space characters:

```
mysql> SELECT SPACE(6);
        -> '      '
```

`REPLACE(str,from_str,to_str)`

Returns the string `str` with all occurrences of the string `from_str` replaced by the string `to_str`:

```
mysql> SELECT REPLACE('www.mysql.com', 'w', 'Ww');
        -> 'WwWwWw.mysql.com'
```

This function is multi-byte safe.

`REPEAT(str,count)`

Returns a string consisting of the string `str` repeated `count` times. If `count <= 0`, returns an empty string. Returns `NULL` if `str` or `count` are `NULL`:

```
mysql> SELECT REPEAT('MySQL', 3);
        -> 'MySQLMySQLMySQL'
```

`REVERSE(str)`

Returns the string `str` with the order of the characters reversed:

```
mysql> SELECT REVERSE('abc');
        -> 'cba'
```

This function is multi-byte safe.

`INSERT(str,pos,len,newstr)`

Returns the string `str`, with the substring beginning at position `pos` and `len` characters long replaced by the string `newstr`:

```
mysql> SELECT INSERT('Quadratic', 3, 4, 'What');
        -> 'QuWhattic'
```

This function is multi-byte safe.

`ELT(N,str1,str2,str3,...)`

Returns `str1` if `N = 1`, `str2` if `N = 2`, and so on. Returns `NULL` if `N` is less than `1` or greater than the number of arguments. `ELT()` is the complement of `FIELD()`:

```
mysql> SELECT ELT(1, 'ej', 'Heja', 'hej', 'foo');
        -> 'ej'
mysql> SELECT ELT(4, 'ej', 'Heja', 'hej', 'foo');
        -> 'foo'
```

`FIELD(str,str1,str2,str3,...)`

Returns the index of `str` in the `str1`, `str2`, `str3`, `...` list. Returns `0` if `str` is not found. `FIELD()` is the complement of `ELT()`:

```
mysql> SELECT FIELD('ej', 'Hej', 'ej', 'Heja', 'hej', 'foo');
        -> 2
mysql> SELECT FIELD('fo', 'Hej', 'ej', 'Heja', 'hej', 'foo');
        -> 0
```

`FIND_IN_SET(str,strlist)`

Returns a value `1` to `N` if the string `str` is in the list `strlist` consisting of `N` substrings. A string list is a string composed of substrings separated by '`,`' characters. If the first argument is a constant string and the second is a column of type `SET`, the `FIND_IN_SET()` function is optimised to use bit arithmetic! Returns `0` if `str` is not in `strlist` or if `strlist` is the empty string. Returns `NULL` if either argument is `NULL`. This function will not work properly if the first argument contains a comma '`,`':

```
mysql> SELECT FIND_IN_SET('b','a,b,c,d');
        -> 2
```

`MAKE_SET(bits,str1,str2,...)`

Returns a set (a string containing substrings separated by '`,`' characters) consisting of the strings that have the corresponding bit in `bits` set. `str1` corresponds to bit 0, `str2` to bit 1, etc. `NULL` strings in `str1`, `str2`, `...` are not appended to the result:

```
mysql> SELECT MAKE_SET(1,'a','b','c');
        -> 'a'
mysql> SELECT MAKE_SET(1 | 4,'hello','nice','world');
        -> 'hello,world'
mysql> SELECT MAKE_SET(0,'a','b','c');
        -> ''
```

`EXPORT_SET(bits,on,off,[separator,[number_of_bits]])`

Returns a string where for every bit set in 'bit', you get an 'on' string and for every reset bit you get an 'off' string. Each string is separated with 'separator' (default ',') and only 'number_of_bits' (default 64) of 'bits' is used:

```
mysql> SELECT EXPORT_SET(5,'Y','N',',',4)
        -> Y,N,Y,N
```

`LCASE(str)`
`LOWER(str)`

Returns the string `str` with all characters changed to lowercase according to the current character set mapping (the default is ISO-8859-1 Latin1):

```
mysql> SELECT LCASE('QUADRATICALLY');
        -> 'quadratically'
```

This function is multi-byte safe.

`UCASE(str)`
`UPPER(str)`

Returns the string `str` with all characters changed to uppercase according to the current character set mapping (the default is ISO-8859-1 Latin1):

```
mysql> SELECT UCASE('Hej');
        -> 'HEJ'
```

This function is multi-byte safe.

`LOAD_FILE(file_name)`

Reads the file and returns the file contents as a string. The file must be on the server, you must specify the full pathname to the file, and you must have

the FILE privilege. The file must be readable by all and be smaller than max_allowed_packet.

If the file doesn't exist or can't be read due to one of the above reasons, the function returns NULL:

```
mysql> UPDATE tbl_name
           SET blob_column=LOAD_FILE("/tmp/picture")
           WHERE id=1;
```

If you are not using MySQL Version 3.23, you have to do the reading of the file inside your application and create an INSERT statement to update the database with the file information. One way to do this, if you are using the MySQL++ library, can be found at http://www.mysql.com/documentation/mysql++/mysql++-examples.html.

QUOTE(str)

Quotes a string to produce a result that can be used as a properly escaped data value in an SQL statement. The string is returned surrounded by single quotes and with each instance of single quote (''), backslash ('\'), ASCII NUL, and Control-Z preceded by a backslash. If the argument is NULL, the return value is the word "NULL" without surrounding single quotes. The QUOTE() function was added in MySQL version 4.0.3.

```
mysql> SELECT QUOTE("Don't");
        -> 'Don\'t!'
mysql> SELECT QUOTE(NULL);
        -> NULL
```

6.3.2.1 String Comparison Functions

MySQL automatically converts numbers to strings as necessary, and vice-versa:

```
mysql> SELECT 1+"1";
        -> 2
mysql> SELECT CONCAT(2,' test');
        -> '2 test'
```

If you want to convert a number to a string explicitly, pass it as the argument to CONCAT().

If a string function is given a binary string as an argument, the resulting string is also a binary string. A number converted to a string is treated as a binary string. This only affects comparisons.

Normally, if any expression in a string comparison is case-sensitive, the comparison is performed in case-sensitive fashion.

expr LIKE pat [ESCAPE 'escape-char']

Pattern matching using SQL simple regular expression comparison. Returns 1 (TRUE) or 0 (FALSE). With LIKE you can use the following two wildcard characters in the pattern:

Char	Description
%	Matches any number of characters, even zero characters

_	Matches exactly one character

```
mysql> SELECT 'David!' LIKE 'David_';
        -> 1
mysql> SELECT 'David!' LIKE '%D%v%';
        -> 1
```

To test for literal instances of a wildcard character, precede the character with the escape character. If you don't specify the `ESCAPE` character, '\' is assumed:

String	Description
\%	Matches one % character
_	Matches one _ character

```
mysql> SELECT 'David!' LIKE 'David\_';
        -> 0
mysql> SELECT 'David_' LIKE 'David\_';
        -> 1
```

To specify a different escape character, use the `ESCAPE` clause:

```
mysql> SELECT 'David_' LIKE 'David|_' ESCAPE '|';
        -> 1
```

The following two statements illustrate that string comparisons are case-insensitive unless one of the operands is a binary string:

```
mysql> SELECT 'abc' LIKE 'ABC';
        -> 1
mysql> SELECT 'abc' LIKE BINARY 'ABC';
        -> 0
```

`LIKE` is allowed on numeric expressions! (This is a MySQL extension to the SQL-99 `LIKE`.)

```
mysql> SELECT 10 LIKE '1%';
        -> 1
```

Note: Because MySQL uses the C escape syntax in strings (for example, '`\n`'), you must double any '\' that you use in your `LIKE` strings. For example, to search for '`\n`', specify it as '`\\n`'. To search for '\', specify it as '`\\\\`' (the backslashes are stripped once by the parser and another time when the pattern match is done, leaving a single backslash to be matched).

Note: Currently `LIKE` is not `multi-byte character` safe. Comparison is done character by character.

`expr NOT LIKE pat [ESCAPE 'escape-char']`
: Same as `NOT (expr LIKE pat [ESCAPE 'escape-char'])`.

`expr SOUNDS LIKE expr`
: Same as `SOUNDEX(expr)=SOUNDEX(expr)` (available only in version 4.1 or later).

`expr REGEXP pat`
`expr RLIKE pat`
: Performs a pattern match of a string expression `expr` against a pattern `pat`. The pattern can be an extended regular expression. See Appendix G [Regexp], page 1020. Returns `1` if `expr` matches `pat`, otherwise returns `0`. `RLIKE` is a

synonym for REGEXP, provided for mSQL compatibility. Note: Because MySQL uses the C escape syntax in strings (for example, '\n'), you must double any '\' that you use in your REGEXP strings. As of MySQL Version 3.23.4, REGEXP is case-insensitive for normal (not binary) strings:

```
mysql> SELECT 'Monty!' REGEXP 'm%y%%';
        -> 0
mysql> SELECT 'Monty!' REGEXP '.*';
        -> 1
mysql> SELECT 'new*\n*line' REGEXP 'new\\*.\\*line';
        -> 1
mysql> SELECT "a" REGEXP "A", "a" REGEXP BINARY "A";
        -> 1  0
mysql> SELECT "a" REGEXP "^[a-d]";
        -> 1
```

REGEXP and RLIKE use the current character set (ISO-8859-1 Latin1 by default) when deciding the type of a character.

`expr NOT REGEXP pat`
`expr NOT RLIKE pat`
: Same as `NOT (expr REGEXP pat)`.

`STRCMP(expr1,expr2)`
: STRCMP() returns 0 if the strings are the same, -1 if the first argument is smaller than the second according to the current sort order, and 1 otherwise:

```
mysql> SELECT STRCMP('text', 'text2');
        -> -1
mysql> SELECT STRCMP('text2', 'text');
        -> 1
mysql> SELECT STRCMP('text', 'text');
        -> 0
```

`MATCH (col1,col2,...) AGAINST (expr)`
`MATCH (col1,col2,...) AGAINST (expr IN BOOLEAN MODE)`
: MATCH ... AGAINST() is used for full-text search and returns relevance - similarity measure between the text in columns (col1,col2,...) and the query expr. Relevance is a positive floating-point number. Zero relevance means no similarity. MATCH ... AGAINST() is available in MySQL version 3.23.23 or later. IN BOOLEAN MODE extension was added in version 4.0.1. For details and usage examples, see Section 6.8 [Fulltext Search], page 584.

6.3.2.2 Case-Sensitivity

BINARY
: The BINARY operator casts the string following it to a binary string. This is an easy way to force a column comparison to be case-sensitive even if the column isn't defined as BINARY or BLOB:

```
mysql> SELECT "a" = "A";
        -> 1
```

```
mysql> SELECT BINARY "a" = "A";
        -> 0
```

`BINARY string` is a shorthand for `CAST(string AS BINARY)`. See Section 6.3.5 [Cast Functions], page 513. `BINARY` was introduced in MySQL Version 3.23.0.

Note that in some context MySQL will not be able to use the index efficiently when you cast an indexed column to `BINARY`.

If you want to compare a blob case-insensitively you can always convert the blob to upper case before doing the comparison:

```
SELECT 'A' LIKE UPPER(blob_col) FROM table_name;
```

We plan to soon introduce casting between different character sets to make string comparison even more flexible.

6.3.3 Numeric Functions

6.3.3.1 Arithmetic Operations

The usual arithmetic operators are available. Note that in the case of '`-`', '`+`', and '`*`', the result is calculated with `BIGINT` (64-bit) precision if both arguments are integers! If one of the argument is an unsigned integer, and the other argument is also an integer, the result will be an unsigned integer. See Section 6.3.5 [Cast Functions], page 513.

`+` Addition:

```
mysql> SELECT 3+5;
        -> 8
```

`-` Subtraction:

```
mysql> SELECT 3-5;
        -> -2
```

`*` Multiplication:

```
mysql> SELECT 3*5;
        -> 15
mysql> SELECT 18014398509481984*18014398509481984.0;
        -> 324518553658426726783156020576256.0
mysql> SELECT 18014398509481984*18014398509481984;
        -> 0
```

The result of the last expression is incorrect because the result of the integer multiplication exceeds the 64-bit range of `BIGINT` calculations.

`/` Division:

```
mysql> SELECT 3/5;
        -> 0.60
```

Division by zero produces a `NULL` result:

```
mysql> SELECT 102/(1-1);
        -> NULL
```

A division will be calculated with `BIGINT` arithmetic only if performed in a context where its result is converted to an integer!

6.3.3.2 Mathematical Functions

All mathematical functions return `NULL` in case of an error.

`-` Unary minus. Changes the sign of the argument:

```
mysql> SELECT - 2;
        -> -2
```

Note that if this operator is used with a `BIGINT`, the return value is a `BIGINT`! This means that you should avoid using `-` on integers that may have the value of `-2^63`!

`ABS(X)` Returns the absolute value of `X`:

```
mysql> SELECT ABS(2);
        -> 2
mysql> SELECT ABS(-32);
        -> 32
```

This function is safe to use with `BIGINT` values.

`SIGN(X)` Returns the sign of the argument as `-1`, `0`, or `1`, depending on whether `X` is negative, zero, or positive:

```
mysql> SELECT SIGN(-32);
        -> -1
mysql> SELECT SIGN(0);
        -> 0
mysql> SELECT SIGN(234);
        -> 1
```

`MOD(N,M)`
`%` Modulo (like the `%` operator in C). Returns the remainder of `N` divided by `M`:

```
mysql> SELECT MOD(234, 10);
        -> 4
mysql> SELECT 253 % 7;
        -> 1
mysql> SELECT MOD(29,9);
        -> 2
mysql> SELECT 29 MOD 9;
        -> 2
```

This function is safe to use with `BIGINT` values. The last example only works in MySQL 4.1

`FLOOR(X)` Returns the largest integer value not greater than `X`:

```
mysql> SELECT FLOOR(1.23);
        -> 1
mysql> SELECT FLOOR(-1.23);
        -> -2
```

Note that the return value is converted to a `BIGINT`!

`CEILING(X)`
`CEIL(X)` Returns the smallest integer value not less than `X`:

```
mysql> SELECT CEILING(1.23);
        -> 2
mysql> SELECT CEIL(-1.23);
        -> -1
```

The `CEIL()` alias was added in version 4.0.6.

Note that the return value is converted to a `BIGINT`!

`ROUND(X)`
`ROUND(X,D)`

Returns the argument `X`, rounded to the nearest integer. With two arguments rounded to a number to `D` decimals.

```
mysql> SELECT ROUND(-1.23);
        -> -1
mysql> SELECT ROUND(-1.58);
        -> -2
mysql> SELECT ROUND(1.58);
        -> 2
mysql> SELECT ROUND(1.298, 1);
        -> 1.3
mysql> SELECT ROUND(1.298, 0);
        -> 1
mysql> SELECT ROUND(23.298, -1);
        -> 20
```

Note that the behaviour of `ROUND()` when the argument is half way between two integers depends on the C library implementation. Some round to the nearest even number, always up, always down, or always toward zero. If you need one kind of rounding, you should use a well-defined function like `TRUNCATE()` or `FLOOR()` instead.

`DIV` Integer division. Similar to `FLOOR()` but safe with `BIGINT` values.

```
mysql> SELECT 5 DIV 2
        -> 2
```

`DIV` is new in MySQL 4.1.0.

`EXP(X)` Returns the value of `e` (the base of natural logarithms) raised to the power of `X`:

```
mysql> SELECT EXP(2);
        -> 7.389056
mysql> SELECT EXP(-2);
        -> 0.135335
```

`LN(X)` Returns the natural logarithm of `X`:

```
mysql> SELECT LN(2);
        -> 0.693147
mysql> SELECT LN(-2);
        -> NULL
```

This function was added in MySQL version 4.0.3. It is synonymous with `LOG(X)` in MySQL.

`LOG(X)`
`LOG(B,X)` If called with one parameter, this function returns the natural logarithm of `X`:

```
mysql> SELECT LOG(2);
        -> 0.693147
mysql> SELECT LOG(-2);
        -> NULL
```

If called with two parameters, this function returns the logarithm of `X` for an arbitary base `B`:

```
mysql> SELECT LOG(2,65536);
        -> 16.000000
mysql> SELECT LOG(1,100);
        -> NULL
```

The arbitrary base option was added in MySQL version 4.0.3. `LOG(B,X)` is equivalent to `LOG(X)/LOG(B)`.

`LOG2(X)` Returns the base-2 logarithm of `X`:

```
mysql> SELECT LOG2(65536);
        -> 16.000000
mysql> SELECT LOG2(-100);
        -> NULL
```

`LOG2()` is useful for finding out how many bits a number would require for storage. This function was added in MySQL version 4.0.3. In earlier versions, you can use `LOG(X)/LOG(2)` instead.

`LOG10(X)` Returns the base-10 logarithm of `X`:

```
mysql> SELECT LOG10(2);
        -> 0.301030
mysql> SELECT LOG10(100);
        -> 2.000000
mysql> SELECT LOG10(-100);
        -> NULL
```

`POW(X,Y)`
`POWER(X,Y)`
Returns the value of `X` raised to the power of `Y`:

```
mysql> SELECT POW(2,2);
        -> 4.000000
mysql> SELECT POW(2,-2);
        -> 0.250000
```

`SQRT(X)` Returns the non-negative square root of `X`:

```
mysql> SELECT SQRT(4);
        -> 2.000000
mysql> SELECT SQRT(20);
        -> 4.472136
```

`PI()` Returns the value of PI. The default shown number of decimals is 5, but MySQL internally uses the full double precession for PI.

```
mysql> SELECT PI();
        -> 3.141593
mysql> SELECT PI()+0.000000000000000000;
        -> 3.141592653589793116
```

`COS(X)` Returns the cosine of `X`, where `X` is given in radians:

```
mysql> SELECT COS(PI());
        -> -1.000000
```

`SIN(X)` Returns the sine of `X`, where `X` is given in radians:

```
mysql> SELECT SIN(PI());
        -> 0.000000
```

`TAN(X)` Returns the tangent of `X`, where `X` is given in radians:

```
mysql> SELECT TAN(PI()+1);
        -> 1.557408
```

`ACOS(X)` Returns the arc cosine of `X`, that is, the value whose cosine is `X`. Returns `NULL` if `X` is not in the range `-1` to `1`:

```
mysql> SELECT ACOS(1);
        -> 0.000000
mysql> SELECT ACOS(1.0001);
        -> NULL
mysql> SELECT ACOS(0);
        -> 1.570796
```

`ASIN(X)` Returns the arc sine of `X`, that is, the value whose sine is `X`. Returns `NULL` if `X` is not in the range `-1` to `1`:

```
mysql> SELECT ASIN(0.2);
        -> 0.201358
mysql> SELECT ASIN('foo');
        -> 0.000000
```

`ATAN(X)` Returns the arc tangent of `X`, that is, the value whose tangent is `X`:

```
mysql> SELECT ATAN(2);
        -> 1.107149
mysql> SELECT ATAN(-2);
        -> -1.107149
```

`ATAN(Y,X)`
`ATAN2(Y,X)`

Returns the arc tangent of the two variables `X` and `Y`. It is similar to calculating the arc tangent of `Y / X`, except that the signs of both arguments are used to determine the quadrant of the result:

```
mysql> SELECT ATAN(-2,2);
        -> -0.785398
mysql> SELECT ATAN2(PI(),0);
        -> 1.570796
```

`COT(X)` Returns the cotangent of `X`:

```
mysql> SELECT COT(12);
        -> -1.57267341
mysql> SELECT COT(0);
        -> NULL
```

`CRC32(expr)`

Computes a cyclic redundancy check value and returns a 32-bit unsigned value. The result is `NULL` if the argument is `NULL`. The argument is expected be a string and will be treated as one if it is not.

```
mysql> SELECT CRC32('MySQL');
        -> 3259397556
```

`CRC32()` is available as of MySQL 4.1.0.

`RAND()`
`RAND(N)` Returns a random floating-point value in the range `0` to `1.0`. If an integer argument `N` is specified, it is used as the seed value (producing a repeatable sequence):

```
mysql> SELECT RAND();
        -> 0.9233482386203
mysql> SELECT RAND(20);
        -> 0.15888261251047
mysql> SELECT RAND(20);
        -> 0.15888261251047
mysql> SELECT RAND();
        -> 0.63553050033332
mysql> SELECT RAND();
        -> 0.70100469486881
```

You can't use a column with `RAND()` values in an `ORDER BY` clause, because `ORDER BY` would evaluate the column multiple times. From version 3.23 you can do: `SELECT * FROM table_name ORDER BY RAND()`

This is useful to get a random sample of a set `SELECT * FROM table1,table2 WHERE a=b AND c<d ORDER BY RAND() LIMIT 1000`.

Note that a `RAND()` in a `WHERE` clause will be re-evaluated every time the `WHERE` is executed.

`RAND()` is not meant to be a perfect random generator, but instead a fast way to generate ad hoc random numbers that will be portable between platforms for the same MySQL version.

`LEAST(X,Y,...)`

With two or more arguments, returns the smallest (minimum-valued) argument. The arguments are compared using the following rules:

- If the return value is used in an `INTEGER` context, or all arguments are integer-valued, they are compared as integers.
- If the return value is used in a `REAL` context, or all arguments are real-valued, they are compared as reals.
- If any argument is a case-sensitive string, the arguments are compared as case-sensitive strings.
- In other cases, the arguments are compared as case-insensitive strings:

```
mysql> SELECT LEAST(2,0);
        -> 0
mysql> SELECT LEAST(34.0,3.0,5.0,767.0);
        -> 3.0
mysql> SELECT LEAST("B","A","C");
        -> "A"
```

In MySQL versions prior to Version 3.22.5, you can use `MIN()` instead of `LEAST`.

`GREATEST(X,Y,...)`

Returns the largest (maximum-valued) argument. The arguments are compared using the same rules as for `LEAST`:

```
mysql> SELECT GREATEST(2,0);
        -> 2
mysql> SELECT GREATEST(34.0,3.0,5.0,767.0);
        -> 767.0
mysql> SELECT GREATEST("B","A","C");
        -> "C"
```

In MySQL versions prior to Version 3.22.5, you can use `MAX()` instead of `GREATEST`.

`DEGREES(X)`

Returns the argument `X`, converted from radians to degrees:

```
mysql> SELECT DEGREES(PI());
        -> 180.000000
```

`RADIANS(X)`

Returns the argument `X`, converted from degrees to radians:

```
mysql> SELECT RADIANS(90);
        -> 1.570796
```

`TRUNCATE(X,D)`

Returns the number `X`, truncated to `D` decimals. If `D` is `0`, the result will have no decimal point or fractional part:

```
mysql> SELECT TRUNCATE(1.223,1);
        -> 1.2
mysql> SELECT TRUNCATE(1.999,1);
        -> 1.9
mysql> SELECT TRUNCATE(1.999,0);
        -> 1
mysql> SELECT TRUNCATE(-1.999,1);
        -> -1.9
```

Starting from MySQL 3.23.51, all numbers are rounded toward zero.

If `D` is negative, then the whole part of the number is zeroed out:

```
mysql> SELECT TRUNCATE(122,-2);
       -> 100
```

Note that as decimal numbers are normally not stored as exact numbers in computers, but as double-precision values, you may be fooled by the following result:

```
mysql> SELECT TRUNCATE(10.28*100,0);
       -> 1027
```

The above happens because 10.28 is actually stored as something like 10.2799999999999999.

6.3.4 Date and Time Functions

This section describes the functions that can be used to manipulate temporal values. See Section 6.2.2 [Date and time types], page 460 for a description of the range of values each date and time type has and the valid formats in which values may be specified.

Here is an example that uses date functions. The following query selects all records with a `date_col` value from within the last 30 days:

```
mysql> SELECT something FROM tbl_name
           WHERE TO_DAYS(NOW()) - TO_DAYS(date_col) <= 30;
```

(Note that the query will also select records with dates that lie in the future.)

Functions that expect date values usually will accept datetime values and ignore the time part. Functions that expect time values usually will accept datetime values and ignore the date part.

Functions that return the current date or time each are evaluated only once per query at the start of query execution. This means that multiple references to a function such as `NOW()` within a single query will always produce the same result. This principle also applies to `CURDATE()`, `CURTIME()`, `UTC_DATE()`, `UTC_TIME()`, `UTC_TIMESTAMP()`, and any of their synonyms.

The return value ranges in the following function descriptions apply for complete dates. If a date is a "zero" value or an incomplete date such as `'2001-11-00'`, functions that extract a part of a date may return `0`. For example, `DAYOFMONTH('2001-11-00')` returns `0`.

`DATE(expr)`
: Extracts the date part of the date or datetime expression `expr`.

```
mysql> SELECT DATE('2003-12-31 01:02:03');
        -> '2003-12-31'
```

`DATE()` is available as of MySQL 4.1.1.

`TIME(expr)`

Extracts the time part of the time or datetime expression `expr`.

```
mysql> SELECT TIME('2003-12-31 01:02:03');
        -> '01:02:03'
mysql> SELECT TIME('2003-12-31 01:02:03.000123');
        -> '01:02:03.000123'
```

`TIME()` is available as of MySQL 4.1.1.

`TIMESTAMP(expr)`
`TIMESTAMP(expr,expr2)`

With one argument, returns the date or datetime expression `expr` as a datetime value. With two arguments, adds the time expression `expr2` to the date or datetime expression `expr` and returns a datetime value.

```
mysql> SELECT TIMESTAMP('2003-12-31');
        -> '2003-12-31 00:00:00'
mysql> SELECT TIMESTAMP('2003-12-31 12:00:00','12:00:00');
        -> '2004-01-01 00:00:00'
```

`TIMESTAMP()` is available as of MySQL 4.1.1.

`DAYOFWEEK(date)`

Returns the weekday index for `date` (`1` = Sunday, `2` = Monday, ... `7` = Saturday). These index values correspond to the ODBC standard.

```
mysql> SELECT DAYOFWEEK('1998-02-03');
        -> 3
```

`WEEKDAY(date)`

Returns the weekday index for `date` (`0` = Monday, `1` = Tuesday, ... `6` = Sunday):

```
mysql> SELECT WEEKDAY('1998-02-03 22:23:00');
        -> 1
mysql> SELECT WEEKDAY('1997-11-05');
        -> 2
```

`DAYOFMONTH(date)`

Returns the day of the month for `date`, in the range `1` to `31`:

```
mysql> SELECT DAYOFMONTH('1998-02-03');
        -> 3
```

`DAY(date)`

`DAY()` is a synonym for `DAYOFMONTH()`. It is available as of MySQL 4.1.1.

`DAYOFYEAR(date)`

Returns the day of the year for `date`, in the range `1` to `366`:

```
mysql> SELECT DAYOFYEAR('1998-02-03');
        -> 34
```

`MONTH(date)`

Returns the month for `date`, in the range `1` to `12`:

```
mysql> SELECT MONTH('1998-02-03');
        -> 2
```

`DAYNAME(date)`

Returns the name of the weekday for `date`:

```
mysql> SELECT DAYNAME('1998-02-05');
        -> 'Thursday'
```

`MONTHNAME(date)`

Returns the name of the month for `date`:

```
mysql> SELECT MONTHNAME('1998-02-05');
        -> 'February'
```

`QUARTER(date)`

Returns the quarter of the year for `date`, in the range `1` to `4`:

```
mysql> SELECT QUARTER('98-04-01');
        -> 2
```

`WEEK(date)`
`WEEK(date,start)`

With a single argument, returns the week for `date`, in the range `0` to `53` (yes, there may be the beginnings of a week 53), for locations where Sunday is the first day of the week. The two-argument form of `WEEK()` allows you to specify whether the week starts on Sunday or Monday and whether the return value should be in the range `0-53` or `1-52`.

The following table demonstrates how the `start` argument works:

Value	Meaning
`0`	Week starts on Sunday; return value range is `0` to `53`
`1`	Week starts on Monday; return value range is `0` to `53`
`2`	Week starts on Sunday; return value range is `1` to `53`
`3`	Week starts on Monday; return value range is `1` to `53` (ISO 8601)

The `start` value of `3` can be used as of MySQL 4.0.5.

```
mysql> SELECT WEEK('1998-02-20');
        -> 7
mysql> SELECT WEEK('1998-02-20',0);
        -> 7
mysql> SELECT WEEK('1998-02-20',1);
        -> 8
mysql> SELECT WEEK('1998-12-31',1);
        -> 53
```

For MySQL 3.23 and 4.0, the default value for the `start` argument is 0. In MySQL 4.1, you can control the default value of the `start` argument by using the `default_week_format` variable. The syntax for setting `default_week_format` is:

```
SET [SESSION | GLOBAL] default_week_format = {0|1|2|3};
```

Note: In Version 4.0, `WEEK(date,0)` was changed to match the calendar in the USA. Before that, `WEEK()` was calculated incorrectly for dates in USA. (In effect, `WEEK(date)` and `WEEK(date,0)` was incorrect for all cases.)

Note that if a date falls in the last week of the previous year, MySQL will return `0` if you don't use `2` or `3` as the optional `start` argument:

```
mysql> SELECT YEAR('2000-01-01'), WEEK('2000-01-01',0);
        -> 2000, 0
```

One might argue that MySQL should return `52` for the `WEEK()` function, because the given date actually occurs in the 52nd week of 1999. We decided to return `0` instead as we want the function to return "the week number in the given year." This makes the usage of the `WEEK()` function reliable when combined with other functions that extract a date part from a date.

If you would prefer the result to be evaluated with respect to the year that contains the first day of the week for the given date, you should use `2` or `3` as the optional `start` argument.

```
mysql> SELECT WEEK('2000-01-01',2);
        -> 52
```

Alternatively, use the `YEARWEEK()` function:

```
mysql> SELECT YEARWEEK('2000-01-01');
        -> 199952
mysql> SELECT MID(YEARWEEK('2000-01-01'),5,2);
        -> '52'
```

`WEEKOFYEAR(date)`

Returns the calendar week of the date as a number in the range from `1` to `53`.

```
mysql> SELECT WEEKOFYEAR('1998-02-20');
        -> 8
```

`WEEKOFYEAR()` is available as of MySQL 4.1.1.

`YEAR(date)`

Returns the year for `date`, in the range `1000` to `9999`:

```
mysql> SELECT YEAR('98-02-03');
        -> 1998
```

`YEARWEEK(date)`
`YEARWEEK(date,start)`

Returns year and week for a date. The `start` argument works exactly like the `start` argument to `WEEK()`. Note that the year in the result may be different from the year in the date argument for the first and the last week of the year:

```
mysql> SELECT YEARWEEK('1987-01-01');
        -> 198653
```

Note that the week number is different from what the `WEEK()` function would return (`0`) for optional arguments `0` or `1`, as `WEEK()` then returns the week in the context of the given year.

`HOUR(time)`

Returns the hour for `time`. The range of the return value will be `0` to `23` for time-of-day values:

```
mysql> SELECT HOUR('10:05:03');
        -> 10
```

However, the range of `TIME` values actually is much larger, so `HOUR` can return values greater than `23`:

```
mysql> SELECT HOUR('272:59:59');
        -> 272
```

`MINUTE(time)`

Returns the minute for `time`, in the range `0` to `59`:

```
mysql> SELECT MINUTE('98-02-03 10:05:03');
        -> 5
```

`SECOND(time)`

Returns the second for `time`, in the range `0` to `59`:

```
mysql> SELECT SECOND('10:05:03');
        -> 3
```

`MICROSECOND(expr)`

Returns the microseconds from the time or datetime expression `expr` as a number in the range from `0` to `999999`.

```
mysql> SELECT MICROSECOND('12:00:00.123456');
        -> 123456
mysql> SELECT MICROSECOND('1997-12-31 23:59:59.000010');
        -> 10
```

`MICROSECOND()` is available as of MySQL 4.1.1.

`PERIOD_ADD(P,N)`

Adds `N` months to period `P` (in the format `YYMM` or `YYYYMM`). Returns a value in the format `YYYYMM`.

Note that the period argument `P` is **not** a date value:

```
mysql> SELECT PERIOD_ADD(9801,2);
        -> 199803
```

`PERIOD_DIFF(P1,P2)`

Returns the number of months between periods `P1` and `P2`. `P1` and `P2` should be in the format `YYMM` or `YYYYMM`.

Note that the period arguments `P1` and `P2` are **not** date values:

```
mysql> SELECT PERIOD_DIFF(9802,199703);
        -> 11
```

`DATE_ADD(date,INTERVAL expr type)`
`DATE_SUB(date,INTERVAL expr type)`

These functions perform date arithmetic.

As of MySQL Version 3.23, `INTERVAL expr type` is allowed on either side of the `+` operator if the expression on the other side is a date or datetime value. For the `-` operator, `INTERVAL expr type` is allowed only on the right side, because it makes no sense to subtract a date or datetime value from an interval. (See examples below.)

`date` is a `DATETIME` or `DATE` value specifying the starting date. `expr` is an expression specifying the interval value to be added or subtracted from the starting date. `expr` is a string; it may start with a '`-`' for negative intervals. `type` is a keyword indicating how the expression should be interpreted.

The following table shows how the `type` and `expr` arguments are related:

`type` **Value**	**Expected** `expr` **Format**
SECOND	SECONDS
MINUTE	MINUTES
HOUR	HOURS
DAY	DAYS
MONTH	MONTHS
YEAR	YEARS
MINUTE_SECOND	'MINUTES:SECONDS'
HOUR_MINUTE	'HOURS:MINUTES'
DAY_HOUR	'DAYS HOURS'
YEAR_MONTH	'YEARS-MONTHS'
HOUR_SECOND	'HOURS:MINUTES:SECONDS'
DAY_MINUTE	'DAYS HOURS:MINUTES'
DAY_SECOND	'DAYS HOURS:MINUTES:SECONDS'
DAY_MICROSECOND	'DAYS.MICROSECONDS'
HOUR_MICROSECOND	'HOURS.MICROSECONDS'
MINUTE_MICROSECOND	'MINUTES.MICROSECONDS'
SECOND_MICROSECOND	'SECONDS.MICROSECONDS'
MICROSECOND	'MICROSECONDS'

The `type` values `DAY_MICROSECOND`, `HOUR_MICROSECOND`, `MINUTE_MICROSECOND`, `SECOND_MICROSECOND`, and `MICROSECOND` are allowed as of MySQL 4.1.1.

MySQL allows any punctuation delimiter in the `expr` format. Those shown in the table are the suggested delimiters. If the `date` argument is a `DATE` value and your calculations involve only `YEAR`, `MONTH`, and `DAY` parts (that is, no time parts), the result is a `DATE` value. Otherwise, the result is a `DATETIME` value:

```
mysql> SELECT '1997-12-31 23:59:59' + INTERVAL 1 SECOND;
        -> '1998-01-01 00:00:00'
mysql> SELECT INTERVAL 1 DAY + '1997-12-31';
        -> '1998-01-01'
mysql> SELECT '1998-01-01' - INTERVAL 1 SECOND;
        -> '1997-12-31 23:59:59'
mysql> SELECT DATE_ADD('1997-12-31 23:59:59',
    ->                 INTERVAL 1 SECOND);
        -> '1998-01-01 00:00:00'
mysql> SELECT DATE_ADD('1997-12-31 23:59:59',
    ->                 INTERVAL 1 DAY);
```

```
        -> '1998-01-01 23:59:59'
mysql> SELECT DATE_ADD('1997-12-31 23:59:59',
    ->                 INTERVAL '1:1' MINUTE_SECOND);
        -> '1998-01-01 00:01:00'
mysql> SELECT DATE_SUB('1998-01-01 00:00:00',
    ->                 INTERVAL '1 1:1:1' DAY_SECOND);
        -> '1997-12-30 22:58:59'
mysql> SELECT DATE_ADD('1998-01-01 00:00:00',
    ->                 INTERVAL '-1 10' DAY_HOUR);
        -> '1997-12-30 14:00:00'
mysql> SELECT DATE_SUB('1998-01-02', INTERVAL 31 DAY);
        -> '1997-12-02'
mysql> SELECT DATE_ADD('1992-12-31 23:59:59.000002',
    ->                 INTERVAL '1.999999' SECOND_MICROSECOND);
        -> '1993-01-01 00:00:01.000001'
```

If you specify an interval value that is too short (does not include all the interval parts that would be expected from the `type` keyword), MySQL assumes you have left out the leftmost parts of the interval value. For example, if you specify a `type` of `DAY_SECOND`, the value of `expr` is expected to have days, hours, minutes, and seconds parts. If you specify a value like `'1:10'`, MySQL assumes that the days and hours parts are missing and the value represents minutes and seconds. In other words, `'1:10' DAY_SECOND` is interpreted in such a way that it is equivalent to `'1:10' MINUTE_SECOND`. This is analogous to the way that MySQL interprets `TIME` values as representing elapsed time rather than as time of day.

Note that if you add to or subtract from a date value something that contains a time part, the result is automatically converted to a datetime value:

```
mysql> SELECT DATE_ADD('1999-01-01', INTERVAL 1 DAY);
        -> '1999-01-02'
mysql> SELECT DATE_ADD('1999-01-01', INTERVAL 1 HOUR);
        -> '1999-01-01 01:00:00'
```

If you use really malformed dates, the result is `NULL`. If you add `MONTH`, `YEAR_MONTH`, or `YEAR` and the resulting date has a day that is larger than the maximum day for the new month, the day is adjusted to the maximum days in the new month:

```
mysql> SELECT DATE_ADD('1998-01-30', interval 1 month);
        -> '1998-02-28'
```

Note from the preceding example that the keyword `INTERVAL` and the `type` specifier are not case-sensitive.

`ADDDATE(date,INTERVAL expr type)`
`SUBDATE(date,INTERVAL expr type)`
`ADDDATE(expr,days)`
`SUBDATE(expr,days)`

When invoked with the `INTERVAL` form of the second argument, `ADDDATE()` and `SUBDATE()` are synonyms for `DATE_ADD()` and `DATE_SUB()`.

```
mysql> SELECT DATE_ADD('1998-01-02', INTERVAL 31 DAY);
        -> '1998-02-02'
mysql> SELECT ADDDATE('1998-01-02', INTERVAL 31 DAY);
        -> '1998-02-02'
mysql> SELECT DATE_SUB('1998-01-02', INTERVAL 31 DAY);
        -> '1997-12-02'
mysql> SELECT SUBDATE('1998-01-02', INTERVAL 31 DAY);
        -> '1997-12-02'
```

As of MySQL 4.1.1, the second syntax is allowed, where `expr` is a date or datetime expression and `days` is the number of days to be added to or subtracted from `expr`.

```
mysql> SELECT ADDDATE('1998-01-02', 31);
        -> '1998-02-02'
mysql> SELECT SUBDATE('1998-01-02 12:00:00', 31);
        -> '1997-12-02 12:00:00'
```

`ADDTIME(expr,expr2)`
`SUBTIME(expr,expr2)`

`expr` is a date or datetime expression, and `expr2` is a time expression.

`ADDTIME()` adds `expr2` to `expr` and returns the result. `SUBTIME()` subtracts `expr2` from `expr` and returns the result.

```
mysql> SELECT ADDTIME("1997-12-31 23:59:59.999999", "1 1:1:1.000002");
        -> '1998-01-02 01:01:01.000001'
mysql> SELECT SUBTIME("1997-12-31 23:59:59.999999", "1 1:1:1.000002");
        -> '1997-12-30 22:58:58.999997'
mysql> SELECT ADDTIME("01:00:00.999999", "02:00:00.999998");
        -> '03:00:01.999997'
mysql> SELECT SUBTIME("01:00:00.999999", "02:00:00.999998");
        -> '-00:59:59.999999'
```

`ADDTIME()` and `SUBTIME()` were added in MySQL 4.1.1.

`EXTRACT(type FROM date)`

The `EXTRACT()` function uses the same kinds of interval type specifiers as `DATE_ADD()` or `DATE_SUB()`, but extracts parts from the date rather than performing date arithmetic.

```
mysql> SELECT EXTRACT(YEAR FROM "1999-07-02");
       -> 1999
mysql> SELECT EXTRACT(YEAR_MONTH FROM "1999-07-02 01:02:03");
       -> 199907
mysql> SELECT EXTRACT(DAY_MINUTE FROM "1999-07-02 01:02:03");
       -> 20102
mysql> SELECT EXTRACT(MICROSECOND FROM "2003-01-02 10:30:00.00123");
        -> 123
```

`DATEDIFF(expr,expr2)`
`TIMEDIFF(expr,expr2)`

`DATEDIFF()` returns the number of days between the start date `expr` and the end date `expr2`. `expr` and `expr2` are date or date-and-time expressions. Only the date parts of the values are used in the calculation.

`TIMEDIFF()` returns the time between the start time `expr` and the end time `expr2`. `expr` and `expr2` are time or date-and-time expressions, but both must be of the same type.

```
mysql> SELECT DATEDIFF('1997-12-31 23:59:59','1997-12-30');
        -> 1
mysql> SELECT DATEDIFF('1997-11-31 23:59:59','1997-12-31');
        -> -30
mysql> SELECT TIMEDIFF('2000:01:01 00:00:00', '2000:01:01 00:00:00.000001');
        -> '-00:00:00.000001'
mysql> SELECT TIMEDIFF('1997-12-31 23:59:59.000001','1997-12-30 01:01:01.000
        -> '46:58:57.999999'
```

`DATEDIFF()` and `TIMEDIFF()` were added in MySQL 4.1.1.

`TO_DAYS(date)`

Given a date `date`, returns a daynumber (the number of days since year 0):

```
mysql> SELECT TO_DAYS(950501);
        -> 728779
mysql> SELECT TO_DAYS('1997-10-07');
        -> 729669
```

`TO_DAYS()` is not intended for use with values that precede the advent of the Gregorian calendar (1582), because it doesn't take into account the days that were lost when the calendar was changed.

`FROM_DAYS(N)`

Given a daynumber `N`, returns a `DATE` value:

```
mysql> SELECT FROM_DAYS(729669);
        -> '1997-10-07'
```

`FROM_DAYS()` is not intended for use with values that precede the advent of the Gregorian calendar (1582), because it doesn't take into account the days that were lost when the calendar was changed.

`DATE_FORMAT(date,format)`

Formats the `date` value according to the `format` string. The following specifiers may be used in the `format` string:

Specifier	Description
`%M`	Month name (`January`..`December`)
`%W`	Weekday name (`Sunday`..`Saturday`)
`%D`	Day of the month with English suffix (`0th`, `1st`, `2nd`, `3rd`, etc.)
`%Y`	Year, numeric, 4 digits
`%y`	Year, numeric, 2 digits
`%X`	Year for the week where Sunday is the first day of the week, numeric, 4 digits; used with `%V`

%x	Year for the week, where Monday is the first day of the week, numeric, 4 digits; used with %v
%a	Abbreviated weekday name (Sun..Sat)
%d	Day of the month, numeric (00..31)
%e	Day of the month, numeric (0..31)
%m	Month, numeric (00..12)
%c	Month, numeric (0..12)
%b	Abbreviated month name (Jan..Dec)
%j	Day of year (001..366)
%H	Hour (00..23)
%k	Hour (0..23)
%h	Hour (01..12)
%I	Hour (01..12)
%l	Hour (1..12)
%i	Minutes, numeric (00..59)
%r	Time, 12-hour (hh:mm:ss followed by AM or PM)
%T	Time, 24-hour (hh:mm:ss)
%S	Seconds (00..59)
%s	Seconds (00..59)
%f	Microseconds (000000..999999)
%p	AM or PM
%w	Day of the week (0=Sunday..6=Saturday)
%U	Week (00..53), where Sunday is the first day of the week
%u	Week (00..53), where Monday is the first day of the week
%V	Week (01..53), where Sunday is the first day of the week; used with %X
%v	Week (01..53), where Monday is the first day of the week; used with %x
%%	A literal '%'.

All other characters are just copied to the result without interpretation.

The %f format specifier is available as of MySQL 4.1.1.

As of MySQL Version 3.23, the '%' character is required before format specifier characters. In earlier versions of MySQL, '%' was optional.

The reason the ranges for the month and day specifiers begin with zero is that MySQL allows incomplete dates such as '2004-00-00' to be stored as of MySQL 3.23.

```
mysql> SELECT DATE_FORMAT('1997-10-04 22:23:00', '%W %M %Y');
        -> 'Saturday October 1997'
mysql> SELECT DATE_FORMAT('1997-10-04 22:23:00', '%H:%i:%s');
        -> '22:23:00'
mysql> SELECT DATE_FORMAT('1997-10-04 22:23:00',
                          '%D %y %a %d %m %b %j');
        -> '4th 97 Sat 04 10 Oct 277'
mysql> SELECT DATE_FORMAT('1997-10-04 22:23:00',
                          '%H %k %I %r %T %S %w');
        -> '22 22 10 10:23:00 PM 22:23:00 00 6'
```

```
mysql> SELECT DATE_FORMAT('1999-01-01', '%X %V');
        -> '1998 52'
```

`STR_TO_DATE(str,format)`

This is the reverse function of the `DATE_FORMAT()` function. It takes a string `str`, and a format string `format`, and returns a DATETIME value. The date, time, or datetime values contained in `str` should be given in the format indicated by `format`. For the specifiers that can be used in `format`, see the table in the `DATE_FORMAT()` function description. All other characters are just taken verbatim, thus not being interpreted. If `str` contains an illegal date, time, or datetime value, `STR_TO_DATE()` returns `NULL`.

```
mysql> SELECT STR_TO_DATE('2003-10-03')
        -> 2003-10-03 00:00:00
mysql> SELECT STR_TO_DATE('03.10.2003 09.20', '%d.%m.%Y %H.%i')
        -> 2003-10-03 09:20:00
mysql> SELECT STR_TO_DATE('10rap', '%crap')
        -> 0000-10-00 00:00:00
mysql> SELECT STR_TO_DATE('2003-15-10 00:00:00', '%Y-%m-%d %H:%i:%s')
        -> NULL
```

`STR_TO_DATE()` is available as of MySQL 4.1.1.

`GET_FORMAT(DATE | TIME | TIMESTAMP, 'EUR' | 'USA' | 'JIS' | 'ISO' | 'INTERNAL')`

Returns a format string. This function is useful in combination with the `DATE_FORMAT()` and the `STR_TO_DATE()` functions, and when setting the server variables `DATE_FORMAT`, `TIME_FORMAT`, and `DATETIME_FORMAT`. The three possible values for the first argument and the five possible values for the second argument result in 15 possible format strings (for the specifiers used, see the table in the `DATE_FORMAT()` function description):

Function call	**Result**
`GET_FORMAT(DATE,'USA')`	`'%m.%d.%Y'`
`GET_FORMAT(DATE,'JIS')`	`'%Y-%m-%d'`
`GET_FORMAT(DATE,'ISO')`	`'%Y-%m-%d'`
`GET_FORMAT(DATE,'EUR')`	`'%d.%m.%Y'`
`GET_FORMAT(DATE,'INTERNAL')`	`'%Y%m%d'`
`GET_FORMAT(TIMESTAMP,'USA')`	`'%Y-%m-%d-%H.%i.%s'`
`GET_FORMAT(TIMESTAMP,'JIS')`	`'%Y-%m-%d %H:%i:%s'`
`GET_FORMAT(TIMESTAMP,'ISO')`	`'%Y-%m-%d %H:%i:%s'`
`GET_FORMAT(TIMESTAMP,'EUR')`	`'%Y-%m-%d-%H.%i.%s'`
`GET_FORMAT(TIMESTAMP,'INTERNAL')`	`'%Y%m%d%H%i%s'`
`GET_FORMAT(TIME,'USA')`	`'%h:%i:%s %p'`
`GET_FORMAT(TIME,'JIS')`	`'%H:%i:%s'`
`GET_FORMAT(TIME,'ISO')`	`'%H:%i:%s'`
`GET_FORMAT(TIME,'EUR')`	`'%H.%i.%S'`
`GET_FORMAT(TIME,'INTERNAL')`	`'%H%i%s'`

ISO format is ISO 9075, not ISO 8601.

```
mysql> SELECT DATE_FORMAT('2003-10-03', GET_FORMAT(DATE, 'EUR')
        -> '03.10.2003'
```

```
mysql> SELECT STR_TO_DATE('10.31.2003', GET_FORMAT(DATE, 'USA'))
    -> 2003-10-31
mysql> SET DATE_FORMAT=GET_FORMAT(DATE, 'USA'); SELECT '2003-10-31';
    -> 10-31-2003
```

`GET_FORMAT()` is available as of MySQL 4.1.1. See See Section 5.5.6 [SET OPTION], page 432.

`TIME_FORMAT(time,format)`

This is used like the `DATE_FORMAT()` function above, but the `format` string may contain only those format specifiers that handle hours, minutes, and seconds. Other specifiers produce a `NULL` value or `0`.

If the `time` value contains an hour part that is greater than `23`, the `%H` and `%k` hour format specifiers produce a value larger than the usual range of `0..23`. The other hour format specifiers produce the hour value modulo 12:

```
mysql> SELECT TIME_FORMAT('100:00:00', '%H %k %h %I %l');
    -> '100 100 04 04 4'
```

`MAKEDATE(year,dayofyear)`

Returns a date, given year and day-of-year values. `dayofyear` must be greater than 0 or the result will `NULL`.

```
mysql> SELECT MAKEDATE(2001,31), MAKEDATE(2001,32);
    -> '2001-01-31', '2001-02-01'
mysql> SELECT MAKEDATE(2001,365), MAKEDATE(2004,365);
    -> '2001-12-31', '2004-12-30'
mysql> SELECT MAKEDATE(2001,0);
    -> NULL
```

`MAKEDATE()` is available as of MySQL 4.1.1.

`MAKETIME(hour,minute,second)`

Returns a time value calculated from the `hour`, `minute`, and `second` arguments.

```
mysql> SELECT MAKETIME(12,15,30);
    -> '12:15:30'
```

`MAKETIME()` is available as of MySQL 4.1.1.

`CURDATE()`
`CURRENT_DATE`
`CURRENT_DATE()`

Returns the current date as a value in `'YYYY-MM-DD'` or `YYYYMMDD` format, depending on whether the function is used in a string or numeric context:

```
mysql> SELECT CURDATE();
    -> '1997-12-15'
mysql> SELECT CURDATE() + 0;
    -> 19971215
```

`CURTIME()`
`CURRENT_TIME`
`CURRENT_TIME()`

Returns the current time as a value in `'HH:MM:SS'` or `HHMMSS` format, depending on whether the function is used in a string or numeric context:

```
mysql> SELECT CURTIME();
        -> '23:50:26'
mysql> SELECT CURTIME() + 0;
        -> 235026
```

NOW()
SYSDATE()
CURRENT_TIMESTAMP
CURRENT_TIMESTAMP()
LOCALTIME
LOCALTIME()
LOCALTIMESTAMP
LOCALTIMESTAMP()

Returns the current date and time as a value in 'YYYY-MM-DD HH:MM:SS' or YYYYMMDDHHMMSS format, depending on whether the function is used in a string or numeric context:

```
mysql> SELECT NOW();
        -> '1997-12-15 23:50:26'
mysql> SELECT NOW() + 0;
        -> 19971215235026
```

UNIX_TIMESTAMP()
UNIX_TIMESTAMP(date)

If called with no argument, returns a Unix timestamp (seconds since '1970-01-01 00:00:00' GMT) as an unsigned integer. If UNIX_TIMESTAMP() is called with a date argument, it returns the value of the argument as seconds since '1970-01-01 00:00:00' GMT. date may be a DATE string, a DATETIME string, a TIMESTAMP, or a number in the format YYMMDD or YYYYMMDD in local time:

```
mysql> SELECT UNIX_TIMESTAMP();
        -> 882226357
mysql> SELECT UNIX_TIMESTAMP('1997-10-04 22:23:00');
        -> 875996580
```

When UNIX_TIMESTAMP is used on a TIMESTAMP column, the function returns the internal timestamp value directly, with no implicit "string-to-Unix-timestamp" conversion. If you pass an out-of-range date to UNIX_TIMESTAMP() it returns 0, but please note that only basic checking is performed (year 1970-2037, month 01-12, day 01-31).

If you want to subtract UNIX_TIMESTAMP() columns, you may want to cast the result to signed integers. See Section 6.3.5 [Cast Functions], page 513.

FROM_UNIXTIME(unix_timestamp)
FROM_UNIXTIME(unix_timestamp,format)

Returns a representation of the unix_timestamp argument as a value in 'YYYY-MM-DD HH:MM:SS' or YYYYMMDDHHMMSS format, depending on whether the function is used in a string or numeric context:

```
mysql> SELECT FROM_UNIXTIME(875996580);
        -> '1997-10-04 22:23:00'
mysql> SELECT FROM_UNIXTIME(875996580) + 0;
```

```
            -> 19971004222300
```

If `format` is given, the result is formatted according to the `format` string. `format` may contain the same specifiers as those listed in the entry for the `DATE_FORMAT()` function:

```
mysql> SELECT FROM_UNIXTIME(UNIX_TIMESTAMP(),
    ->                      '%Y %D %M %h:%i:%s %x');
        -> '2003 6th August 06:22:58 2003'
```

`SEC_TO_TIME(seconds)`

Returns the `seconds` argument, converted to hours, minutes, and seconds, as a value in `'HH:MM:SS'` or `HHMMSS` format, depending on whether the function is used in a string or numeric context:

```
mysql> SELECT SEC_TO_TIME(2378);
        -> '00:39:38'
mysql> SELECT SEC_TO_TIME(2378) + 0;
        -> 3938
```

`TIME_TO_SEC(time)`

Returns the `time` argument, converted to seconds:

```
mysql> SELECT TIME_TO_SEC('22:23:00');
        -> 80580
mysql> SELECT TIME_TO_SEC('00:39:38');
        -> 2378
```

`UTC_DATE`
`UTC_DATE()`

Returns the current UTC date as a value in `'YYYY-MM-DD'` or `YYYYMMDD` format, depending on whether the function is used in a string or numeric context:

```
mysql> SELECT UTC_DATE(), UTC_DATE() + 0;
        -> '2003-08-14', 20030814
```

`UTC_DATE()` is available as of MySQL 4.1.1.

`UTC_TIME`
`UTC_TIME()`

Returns the current UTC time as a value in `'HH:MM:SS'` or `HHMMSS` format, depending on whether the function is used in a string or numeric context:

```
mysql> SELECT UTC_TIME(), UTC_TIME() + 0;
        -> '18:07:53', 180753
```

`UTC_TIME()` is available as of MySQL 4.1.1.

`UTC_TIMESTAMP`
`UTC_TIMESTAMP()`

Returns the current UTC date and time as a value in `'YYYY-MM-DD HH:MM:SS'` or `YYYYMMDDHHMMSS` format, depending on whether the function is used in a string or numeric context:

```
mysql> SELECT UTC_TIMESTAMP(), UTC_TIMESTAMP() + 0;
        -> '2003-08-14 18:08:04', 20030814180804
```

`UTC_TIMESTAMP()` is available as of MySQL 4.1.1.

6.3.5 Cast Functions

The `CAST()` and `CONVERT()` functions may be used to take a value of one type and produce a value of another type. Their syntax is:

```
CAST(expression AS type)
CONVERT(expression,type)
CONVERT(expr USING transcoding_name)
```

The `type` value can be one of the following:

- `BINARY`
- `CHAR`
- `DATE`
- `DATETIME`
- `SIGNED {INTEGER}`
- `TIME`
- `UNSIGNED {INTEGER}`

`CAST()` and `CONVERT()` are available as of MySQL 4.0.2. The `CHAR` conversion type is available as of 4.0.6. The `USING` form of `CONVERT()` is available as of 4.1.0.

`CAST()` and `CONVERT(... USING ...)` are SQL-99 syntax. The non-`USING` form of `CONVERT()` is ODBC syntax.

The cast functions are useful when you want to create a column with a specific type in a `CREATE ... SELECT` statement:

```
CREATE TABLE new_table SELECT CAST('2000-01-01' AS DATE);
```

The functions also can be useful for sorting `ENUM` columns in lexical order. Normally sorting of `ENUM` columns occurs using the internal numeric values. Casting the values to `CHAR` results in a lexical sort:

```
SELECT enum_col FROM tbl_name ORDER BY CAST(enum_col AS CHAR);
```

`CAST(string AS BINARY)` is the same thing as `BINARY string`. `CAST(expr AS CHAR)` treats the expression as a string with the default character set.

NOTE: In MysQL 4.0 the `CAST()` to `DATE`, `DATETIME`, or `TIME` only marks the column to be a specific type but doesn't change the value of the column.

In MySQL 4.1.0 the value is converted to the correct column type when it's sent to the user (this is a feature of how the new protocol in 4.1 sends date information to the client):

```
mysql> SELECT CAST(NOW() AS DATE);
       -> 2003-05-26
```

In later MySQL versions (probably 4.1.2 or 5.0) we will fix that `CAST` also changes the result if you use it as part of a more complex expression, like `CONCAT("Date: ",CAST(NOW() AS DATE))`.

You should not use `CAST()` to extract data in different formats but instead use string functions like `LEFT` or `EXTRACT()`. See Section 6.3.4 [Date and time functions], page 499.

To cast a string to a numeric value, you don't normally have to do anything; just use the string value as it would be a number:

```
mysql> SELECT 1+'1';
       -> 2
```

If you use a number in string context, the number will automatically be converted to a `BINARY` string.

```
mysql> SELECT CONCAT("hello you ",2);
       ->  "hello you 2"
```

MySQL supports arithmetic with both signed and unsigned 64-bit values. If you are using numerical operations (like `+`) and one of the operands is `unsigned integer`, the result will be unsigned. You can override this by using the `SIGNED` and `UNSIGNED` cast operators to cast the operation to a signed or unsigned 64-bit integer, respectively.

```
mysql> SELECT CAST(1-2 AS UNSIGNED)
        -> 18446744073709551615
mysql> SELECT CAST(CAST(1-2 AS UNSIGNED) AS SIGNED);
        -> -1
```

Note that if either operand is a floating-point value, the result is a floating-point value and is not affected by the above rule. (In this context, `DECIMAL` values are regarded as floating-point values.)

```
mysql> SELECT CAST(1 AS UNSIGNED) - 2.0;
        -> -1.0
```

If you are using a string in an arithmetic operation, this is converted to a floating-point number.

The handing of unsigned values was changed in MySQL 4.0 to be able to support `BIGINT` values properly. If you have some code that you want to run in both MySQL 4.0 and 3.23 (in which case you probably can't use the `CAST()` function), you can use the following technique to get a signed result when subtracting two unsigned integer columns:

```
SELECT (unsigned_column_1+0.0)-(unsigned_column_2+0.0);
```

The idea is that the columns are converted to floating-point values before the subtraction occurs.

If you get a problem with `UNSIGNED` columns in your old MySQL application when porting to MySQL 4.0, you can use the `--sql-mode=NO_UNSIGNED_SUBTRACTION` option when starting `mysqld`. Note however that as long as you use this, you will not be able to make efficient use of the `BIGINT UNSIGNED` column type.

`CONVERT()` with `USING` is used to convert data between different character sets. In MySQL, transcoding names are the same as the corresponding character set names. For example, this statement converts the string `'abc'` in the server's default character set to the corresponding string in the `utf8` character set:

```
SELECT CONVERT('abc' USING utf8);
```

6.3.6 Other Functions

6.3.6.1 Bit Functions

MySQL uses `BIGINT` (64-bit) arithmetic for bit operations, so these operators have a maximum range of 64 bits.

`|` Bitwise OR

```
mysql> SELECT 29 | 15;
        -> 31
```

The result is an unsigned 64-bit integer.

`&` Bitwise AND

```
mysql> SELECT 29 & 15;
        -> 13
```

The result is an unsigned 64-bit integer.

`^` Bitwise XOR

```
mysql> SELECT 1 ^ 1;
        -> 0
mysql> SELECT 1 ^ 0;
        -> 1
mysql> SELECT 11 ^ 3;
        -> 8
```

The result is an unsigned 64-bit integer.

`XOR` was added in version 4.0.2.

`<<` Shifts a longlong (`BIGINT`) number to the left:

```
mysql> SELECT 1 << 2;
        -> 4
```

The result is an unsigned 64-bit integer.

`>>` Shifts a longlong (`BIGINT`) number to the right:

```
mysql> SELECT 4 >> 2;
        -> 1
```

The result is an unsigned 64-bit integer.

`~` Invert all bits:

```
mysql> SELECT 5 & ~1;
        -> 4
```

The result is an unsigned 64-bit integer.

`BIT_COUNT(N)`

Returns the number of bits that are set in the argument `N`:

```
mysql> SELECT BIT_COUNT(29);
        -> 4
```

6.3.6.2 Miscellaneous Functions

`DATABASE()`

Returns the current database name:

```
mysql> SELECT DATABASE();
        -> 'test'
```

If there is no current database, `DATABASE()` returns `NULL` as of MySQL 4.1.1, and the empty string before that.

`USER()`
`SYSTEM_USER()`
`SESSION_USER()`

Returns the current MySQL username and hostname:

```
mysql> SELECT USER();
        -> 'davida@localhost'
```

The value indicates the username you specified when connecting to the server, and the client host from which you connected. (Prior to MySQL Version 3.22.11, the function value does not include the client hostname.)

You can extract just the username part, regardless of whether the value includes a hostname part, like this:

```
mysql> SELECT SUBSTRING_INDEX(USER(),"@",1);
        -> 'davida'
```

`CURRENT_USER()`

Returns the username and hostname that the current session was authenticated as. This value corresponds to the account that is used for assessing your access privileges. It may be different than the value of `USER()`.

```
mysql> SELECT USER();
        -> 'davida@localhost'
mysql> SELECT * FROM mysql.user;
        -> ERROR 1044: Access denied for user: '@localhost' to database 'mys
mysql> SELECT CURRENT_USER();
        -> '@localhost'
```

The example illustrates that although the client specified a username of `davida` (as indicated by the value of the `USER()` function), the server authenticated the client using an anonymous user account (as seen by the empty username part of the `CURRENT_USER()` value). One way this might occur is that there is no account listed in the grant tables for `davida`.

`PASSWORD(str)`
`OLD_PASSWORD(str)`

Calculates a password string from the plaintext password `str`. This is the function that is used for encrypting MySQL passwords for storage in the `Password` column of the `user` grant table:

```
mysql> SELECT PASSWORD('badpwd');
        -> '7f84554057dd964b'
```

`PASSWORD()` encryption is non-reversible.

`PASSWORD()` does not perform password encryption in the same way that Unix passwords are encrypted. See `ENCRYPT()`.

Note: The `PASSWORD()` function is used by the authentication system in MySQL Server, you should **NOT** use it in your own applications. For that purpose, use `MD5()` or `SHA1()` instead. Also see `RFC-2195` for more information about handling passwords and authentication securely in your application.

`ENCRYPT(str[,salt])`

Encrypt `str` using the Unix `crypt()` system call. The `salt` argument should be a string with two characters. (As of MySQL Version 3.22.16, `salt` may be longer than two characters.)

```
mysql> SELECT ENCRYPT("hello");
        -> 'VxuFAJXVARROc'
```

`ENCRYPT()` ignores all but the first 8 characters of `str`, at least on some systems. This behaviour is determined by the implementation of the underlying `crypt()` system call.

If `crypt()` is not available on your system, `ENCRYPT()` always returns `NULL`. Because of this we recommend that you use `MD5()` or `SHA1()` instead; these two functions exist on all platforms.

`ENCODE(str,pass_str)`

Encrypt `str` using `pass_str` as the password. To decrypt the result, use `DECODE()`.

The results is a binary string of the same length as `string`. If you want to save it in a column, use a `BLOB` column type.

`DECODE(crypt_str,pass_str)`

Descrypts the encrypted string `crypt_str` using `pass_str` as the password. `crypt_str` should be a string returned from `ENCODE()`.

`MD5(string)`

Calculates an MD5 128-bit checksum for the string. The value is returned as a 32-digit hex number that may, for example, be used as a hash key:

```
mysql> SELECT MD5("testing");
        -> 'ae2b1fca515949e5d54fb22b8ed95575'
```

This is the "RSA Data Security, Inc. MD5 Message-Digest Algorithm".

`SHA1(string)`
`SHA(string)`

Calculates an SHA1 160-bit checksum for the string, as described in RFC 3174 (Secure Hash Algorithm). The value is returned as a 40-digit hex number, or `NULL` in case the input argument was `NULL`. One of the possible uses for this function is as a hash key. You can also use it as cryptographically safe function for storing passwords.

```
mysql> SELECT SHA1("abc");
        -> 'a9993e364706816aba3e25717850c26c9cd0d89d'
```

`SHA1()` was added in version 4.0.2, and can be considered a cryptographically more secure equivalent of `MD5()`. `SHA()` is synonym for `SHA1()`.

`AES_ENCRYPT(string,key_string)`
`AES_DECRYPT(string,key_string)`

These functions allow encryption/decryption of data using the official AES (Advanced Encryption Standard) algorithm, previously known as Rijndael. Encoding with a 128-bit key length is used, but you can extend it up to 256 bits by

modifying the source. We chose 128 bits because it is much faster and it is usually secure enough.

The input arguments may be any length. If either argument is `NULL`, the result of this function is also `NULL`.

As AES is a block-level algorithm, padding is used to encode uneven length strings and so the result string length may be calculated as 16*(trunc(string_length/16)+1).

If `AES_DECRYPT()` detects invalid data or incorrect padding, it returns `NULL`. However, it is possible for `AES_DECRYPT()` to return a non-`NULL` value (possibly garbage) if the input data or the key are invalid.

You can use the AES functions to store data in an encrypted form by modifying your queries:

```
INSERT INTO t VALUES (1,AES_ENCRYPT('text','password'));
```

You can get even more security by not transferring the key over the connection for each query, which can be accomplished by storing it in a server side variable at connection time:

```
SELECT @password:='my password';
INSERT INTO t VALUES (1,AES_ENCRYPT('text',@password));
```

`AES_ENCRYPT()` and `AES_DECRYPT()` were added in version 4.0.2, and can be considered the most cryptographically secure encryption functions currently available in MySQL.

`DES_ENCRYPT(string_to_encrypt [, (key_number | key_string) ] )`

Encrypts the string with the given key using the Triple-DES algorithm.

Note that this function only works if MySQL has been configured with SSL support. See Section 4.4.10 [Secure connections], page 252.

The encryption key to use is chosen the following way:

Argument	**Description**
Only one argument	The first key from `des-key-file` is used.
key number	The given key (0-9) from the `des-key-file` is used.
string	The given `key_string` will be used to crypt `string_to_encrypt`.

The return string will be a binary string where the first character will be `CHAR(128 | key_number)`.

The 128 is added to make it easier to recognise an encrypted key. If you use a string key, `key_number` will be 127.

On error, this function returns `NULL`.

The string length for the result will be `new_length= org_length + (8-(org_length % 8))+1`.

The `des-key-file` has the following format:

```
key_number des_key_string
key_number des_key_string
```

Each `key_number` must be a number in the range from 0 to 9. Lines in the file may be in any order. `des_key_string` is the string that will be used to

encrypt the message. Between the number and the key there should be at least one space. The first key is the default key that will be used if you don't specify any key argument to `DES_ENCRYPT()`

You can tell MySQL to read new key values from the key file with the `FLUSH DES_KEY_FILE` command. This requires the `Reload_priv` privilege.

One benefit of having a set of default keys is that it gives applications a way to check for the existence of encrypted column values, without giving the end user the right to decrypt those values.

```
mysql> SELECT customer_address FROM customer_table WHERE
       crypted_credit_card = DES_ENCRYPT("credit_card_number");
```

`DES_DECRYPT(string_to_decrypt [, key_string])`

Decrypts a string encrypted with `DES_ENCRYPT()`.

Note that this function only works if MySQL has been configured with SSL support. See Section 4.4.10 [Secure connections], page 252.

If no `key_string` argument is given, `DES_DECRYPT()` examines the first byte of the encrypted string to determine the DES key number that was used to encrypt the original string, then reads the key from the `des-key-file` to decrypt the message. For this to work the user must have the `SUPER` privilege.

If you pass this function a `key_string` argument, that string is used as the key for decrypting the message.

If the `string_to_decrypt` doesn't look like an encrypted string, MySQL will return the given `string_to_decrypt`.

On error, this function returns `NULL`.

`COMPRESS(string_to_compress)`

Compresses a string.

```
mysql> SELECT LENGTH(COMPRESS(REPEAT("a",1000)));
        -> 21
mysql> SELECT LENGTH(COMPRESS(""));
        -> 0
mysql> SELECT LENGTH(COMPRESS("a"));
        -> 13
mysql> SELECT LENGTH(COMPRESS(REPEAT("a",16)));
        -> 15
```

`COMPRESS()` was added in MySQL version 4.1.1. If requires MySQL to have been compiled with a compression library such as `zlib`. Otherwise, the return value is always `NULL`.

The compressed string consists is stored the following way:

- Empty strings are stored as empty strings
- Non empty strings are stored as a 4 byte length (low-byte-first) of the uncompressed string followed by the string compressed with gzip. If the string ends with space we add an extra '.' to avoid problems with end space trims if someone would store the result in a CHAR field (this is not recommended).

`UNCOMPRESS(string_to_uncompress)`

Uncompresses a string compressed by the `COMPRESS()` function.

```
mysql> SELECT UNCOMPRESS(COMPRESS("any string"));
        -> 'any string'
```

`UNCOMPRESS()` was added in MySQL version 4.1.1. If requires MySQL to have been compiled with a compression library such as `zlib`. Otherwise, the return value is always `NULL`.

`UNCOMPRESSED_LENGTH(compressed_string)`

Returns the length of a compressed string before compressing.

```
mysql> SELECT UNCOMPRESSED_LENGTH(COMPRESS(REPEAT("a",30)));
        -> 30
```

`UNCOMPRESSED_LENGTH()` was added in MySQL version 4.1.1.

`LAST_INSERT_ID([expr])`

Returns the last automatically generated value that was inserted into an `AUTO_INCREMENT` column.

```
mysql> SELECT LAST_INSERT_ID();
        -> 195
```

The last ID that was generated is maintained in the server on a per-connection basis. This means the value the function returns to a given client is the most recent `AUTO_INCREMENT` value generated by that client. The value cannot be affected by other clients, even if they generate `AUTO_INCREMENT` values of their own. This behaviour ensures that you can retrieve your own ID without concern for the activity of other clients, and without the need for locks or transactions.

The value of `LAST_INSERT_ID()` is not changed if you update the `AUTO_INCREMENT` column of a row with a non-magic value (that is, a value that is not `NULL` and not `0`).

If you insert many rows at the same time with an insert statement, `LAST_INSERT_ID()` returns the value for the first inserted row. The reason for this is to make it possible to easily reproduce the same `INSERT` statement against some other server.

If `expr` is given as an argument to `LAST_INSERT_ID()`, then the value of the argument is returned by the function, and is set as the next value to be returned by `LAST_INSERT_ID()`. This can be used to simulate sequences:

First create the table:

```
mysql> CREATE TABLE sequence (id INT NOT NULL);
mysql> INSERT INTO sequence VALUES (0);
```

Then the table can be used to generate sequence numbers like this:

```
mysql> UPDATE sequence SET id=LAST_INSERT_ID(id+1);
```

You can generate sequences without calling `LAST_INSERT_ID()`, but the utility of using the function this way is that the ID value is maintained in the server as the last automatically generated value (multi-user safe). You can retrieve the new ID as you would read any normal `AUTO_INCREMENT` value in MySQL.

For example, `LAST_INSERT_ID()` (without an argument) will return the new ID. The C API function `mysql_insert_id()` can also be used to get the value.

Note that as `mysql_insert_id()` is only updated after `INSERT` and `UPDATE` statements, so you can't use the C API function to retrieve the value for `LAST_INSERT_ID(expr)` after executing other SQL statements like `SELECT` or `SET`. See Section 11.1.3.31 [`mysql_insert_id()`], page 743.

`FORMAT(X,D)`

Formats the number `X` to a format like `'#,###,###.##'`, rounded to `D` decimals, and returns the result as a string. If `D` is `0`, the result will have no decimal point or fractional part:

```
mysql> SELECT FORMAT(12332.123456, 4);
        -> '12,332.1235'
mysql> SELECT FORMAT(12332.1,4);
        -> '12,332.1000'
mysql> SELECT FORMAT(12332.2,0);
        -> '12,332'
```

`VERSION()`

Returns a string indicating the MySQL server version:

```
mysql> SELECT VERSION();
        -> '3.23.13-log'
```

Note that if your version ends with `-log` this means that logging is enabled.

`CONNECTION_ID()`

Returns the connection ID (thread ID) for the connection. Every connection has its own unique ID:

```
mysql> SELECT CONNECTION_ID();
        -> 23786
```

`GET_LOCK(str,timeout)`

Tries to obtain a lock with a name given by the string `str`, with a timeout of `timeout` seconds. Returns `1` if the lock was obtained successfully, `0` if the attempt timed out (for example, because another client has already locked the name), or `NULL` if an error occurred (such as running out of memory or the thread was killed with `mysqladmin kill`). A lock is released when you execute `RELEASE_LOCK()`, execute a new `GET_LOCK()`, or the thread terminates (either normally or abnormally).

This function can be used to implement application locks or to simulate record locks. Names are locked on a server-wide basis. If a name has been locked by one client, `GET_LOCK()` blocks any request by another client for a lock with the same name. This allows clients that agree on a given lock name to use the name to perform cooperative advisory locking:

```
mysql> SELECT GET_LOCK("lock1",10);
        -> 1
mysql> SELECT IS_FREE_LOCK("lock2");
        -> 1
mysql> SELECT GET_LOCK("lock2",10);
```

```
        -> 1
mysql> SELECT RELEASE_LOCK("lock2");
        -> 1
mysql> SELECT RELEASE_LOCK("lock1");
        -> NULL
```

Note that the second `RELEASE_LOCK()` call returns `NULL` because the lock `"lock1"` was automatically released by the second `GET_LOCK()` call.

`RELEASE_LOCK(str)`

Releases the lock named by the string `str` that was obtained with `GET_LOCK()`. Returns `1` if the lock was released, `0` if the lock wasn't locked by this thread (in which case the lock is not released), and `NULL` if the named lock didn't exist. (The lock will not exist if it was never obtained by a call to `GET_LOCK()` or if it already has been released.)

The `DO` statement is convinient to use with `RELEASE_LOCK()`. See Section 6.4.10 [DO], page 563.

`IS_FREE_LOCK(str)`

Checks if the lock named `str` is free to use (that is, not locked). Returns `1` if the lock is free (no one is using the lock), `0` if the lock is in use, and `NULL` on errors (such as incorrect arguments).

`BENCHMARK(count,expr)`

The `BENCHMARK()` function executes the expression `expr` repeatedly `count` times. It may be used to time how fast MySQL processes the expression. The result value is always `0`. The intended use is in the `mysql` client, which reports query execution times:

```
mysql> SELECT BENCHMARK(1000000,ENCODE("hello","goodbye"));
+----------------------------------------------+
| BENCHMARK(1000000,ENCODE("hello","goodbye")) |
+----------------------------------------------+
|                                            0 |
+----------------------------------------------+
1 row in set (4.74 sec)
```

The time reported is elapsed time on the client end, not CPU time on the server end. It may be advisable to execute `BENCHMARK()` several times, and interpret the result with regard to how heavily loaded the server machine is.

`INET_NTOA(expr)`

Given a numeric network address (4 or 8 byte), returns the dotted-quad representation of the address as a string:

```
mysql> SELECT INET_NTOA(3520061480);
       ->  "209.207.224.40"
```

`INET_ATON(expr)`

Given the dotted-quad representation of a network address as a string, returns an integer that represents the numeric value of the address. Addresses may be 4 or 8 byte addresses:

```
mysql> SELECT INET_ATON("209.207.224.40");
       ->  3520061480
```

The generated number is always in network byte order; for example the above number is calculated as `209*256^3 + 207*256^2 + 224*256 +40`.

`MASTER_POS_WAIT(log_name, log_pos [, timeout])`

Blocks until the slave reaches (that is, has read and applied all updates up to) the specified position in the master log. If master information is not initialised, or if the arguments are incorrect, returns `NULL`. If the slave is not running, will block and wait until it is started and goes to or past the specified position. If the slave is already past the specified position, returns immediately.

If `timeout` (new in 4.0.10) is specified, will give up waiting when `timeout` seconds have elapsed. `timeout` must be greater than 0; a zero or negative `timeout` means no timeout. The return value is the number of log events it had to wait to get to the specified position, or `NULL` in case of error, or `-1` if the timeout has been exceeded.

This command is useful for control of master/slave synchronisation.

`FOUND_ROWS()`

A `SELECT` statement may include a `LIMIT` clause to restrict the number of rows the server returns to the client. In some cases, it is desirable to know how many rows the statement would have returned without the `LIMIT`, but without running the statement again. To get this row count, include a `SQL_CALC_FOUND_ROWS` option in the `SELECT` statement, then invoke `FOUND_ROWS()` afterward:

```
mysql> SELECT SQL_CALC_FOUND_ROWS * FROM tbl_name
       WHERE id > 100 LIMIT 10;
mysql> SELECT FOUND_ROWS();
```

The second `SELECT` will return a number indicating how many rows the first `SELECT` would have returned had it been written without the `LIMIT` clause. (If the preceding `SELECT` statement does not include the `SQL_CALC_FOUND_ROWS` option, then `FOUND_ROWS()` may return a different result when `LIMIT` is used than when it is not.)

Note that if you are using `SELECT SQL_CALC_FOUND_ROWS ...` MySQL has to calculate how many rows are in the full result set. However, this is faster than running the query again without `LIMIT`, because the result set need not be sent to the client.

`SQL_CALC_FOUND_ROWS` and `FOUND_ROWS()` can be useful in situations when you want to restrict the number of rows that a query returns, but also determine the number of rows in the full result set without running the query again. An example is a web script that presents a paged display containing links to the pages that show other sections of a search result. Using `FOUND_ROWS()` allows you to determine how many other pages are needed for the rest of the result.

The use of `SQL_CALC_FOUND_ROWS` and `FOUND_ROWS()` is more complex for `UNION` queries than for simple `SELECT` statements, because `LIMIT` may occur at multiple places in a `UNION`. It may be applied to individual `SELECT` statements in the `UNION`, or global to the `UNION` result as a whole.

The intent of SQL_CALC_FOUND_ROWS for UNION is that it should return the row count that would be returned without a global LIMIT. The conditions for use of SQL_CALC_FOUND_ROWS with UNION are:

- The SQL_CALC_FOUND_ROWS keyword must appear in the first SELECT of the UNION.
- The value of FOUND_ROWS() is exact only if UNION ALL is used. If UNION without ALL is used, duplicate removal occurs and the value of FOUND_ROWS() is only approximate.
- If no LIMIT is present in the UNION, SQL_CALC_FOUND_ROWS is ignored and returns the number of rows in the temporary table that is created to process the UNION.

SQL_CALC_FOUND_ROWS and FOUND_ROWS() are available starting at MySQL version 4.0.0.

6.3.7 Functions and Modifiers for Use with GROUP BY Clauses

6.3.7.1 GROUP BY Functions

If you use a group function in a statement containing no GROUP BY clause, it is equivalent to grouping on all rows.

COUNT(expr)

Returns a count of the number of non-NULL values in the rows retrieved by a SELECT statement:

```
mysql> SELECT student.student_name,COUNT(*)
    ->        FROM student,course
    ->        WHERE student.student_id=course.student_id
    ->        GROUP BY student_name;
```

COUNT(*) is somewhat different in that it returns a count of the number of rows retrieved, whether or not they contain NULL values.

COUNT(*) is optimised to return very quickly if the SELECT retrieves from one table, no other columns are retrieved, and there is no WHERE clause. For example:

```
mysql> SELECT COUNT(*) FROM student;
```

This optimisation applies only to MyISAM and ISAM tables only, because an exact record count is stored for these table types and can be accessed very quickly. For transactional storage engines (InnodB, BDB), storing an exact row count is more problematic because multiple transactions may be occurring, each of which may affect the count.

COUNT(DISTINCT expr,[expr...])

Returns a count of the number of different non-NULL values:

```
mysql> SELECT COUNT(DISTINCT results) FROM student;
```

In MySQL you can get the number of distinct expression combinations that don't contain NULL by giving a list of expressions. In SQL-99 you would have to do a concatenation of all expressions inside `COUNT(DISTINCT ...)`.

`AVG(expr)`

Returns the average value of `expr`:

```
mysql> SELECT student_name, AVG(test_score)
    ->        FROM student
    ->        GROUP BY student_name;
```

`MIN(expr)`
`MAX(expr)`

Returns the minimum or maximum value of `expr`. `MIN()` and `MAX()` may take a string argument; in such cases they return the minimum or maximum string value. See Section 5.4.3 [MySQL indexes], page 421.

```
mysql> SELECT student_name, MIN(test_score), MAX(test_score)
    ->        FROM student
    ->        GROUP BY student_name;
```

In `MIN()`, `MAX()` and other aggregate functions, MySQL currently compares `ENUM` and `SET` columns by their string value rather than by the string's relative position in the set. This will be rectified.

`SUM(expr)`

Returns the sum of `expr`. Note that if the return set has no rows, it returns NULL!

`GROUP_CONCAT(expr)`

Full syntax:

```
GROUP_CONCAT([DISTINCT] expr [,expr ...]
             [ORDER BY {unsigned_integer | col_name | formula} [ASC | DESC]
             [SEPARATOR str_val])
```

This function was added in MySQL version 4.1. It returns a string result with the concatenated values from a group:

```
mysql> SELECT student_name,
    ->        GROUP_CONCAT(test_score)
    ->        FROM student
    ->        GROUP BY student_name;
or
mysql> SELECT student_name,
    ->        GROUP_CONCAT(DISTINCT test_score
    ->                     ORDER BY test_score DESC SEPARATOR " ")
    ->        FROM student
    ->        GROUP BY student_name;
```

In MySQL you can get the concatenated values of expression combinations. You can eliminate duplicate values by using `DISTINCT`. If you want to sort values in the result you should use `ORDER BY` clause. To sort in reverse order, add the `DESC` (descending) keyword to the name of the column you are sorting by in the `ORDER BY` clause. The default is ascending order; this may be specified

explicitly using the `ASC` keyword. `SEPARATOR` is the string value which should be inserted between values of result. The default is a comma (‘`","`’). You can remove the separator altogether by specifying `SEPARATOR ""`.

You can set a maximum allowed length with the variable `group_concat_max_len` in your configuration. The syntax to do this at runtime is:

```
SET [SESSION | GLOBAL] group_concat_max_len = unsigned_integer;
```

If a maximum length has been set, the result is truncated to this maximum length.

The `GROUP_CONCAT()` function is an enhanced implementation of the basic `LIST()` function supported by Sybase SQL Anywhere. `GROUP_CONCAT()` is backward compatible with the extremely limited functionality of `LIST()`, if only one column and no other options are specified. `LIST()` does have a default sorting order.

`VARIANCE(expr)`

Returns the standard variance of `expr` (considering rows as the whole population, not as a sample; so it has the number of rows as denominator). This is an extension to SQL-99 (available only in version 4.1 or later).

`STD(expr)`
`STDDEV(expr)`

Returns the standard deviation of `expr` (the square root of `VARIANCE()`. This is an extension to SQL-99. The `STDDEV()` form of this function is provided for Oracle compatibility.

`BIT_OR(expr)`

Returns the bitwise `OR` of all bits in `expr`. The calculation is performed with 64-bit (`BIGINT`) precision.

Function returns 0 if there was no matching rows.

`BIT_XOR(expr)`

Returns the bitwise `XOR` of all bits in `expr`. The calculation is performed with 64-bit (`BIGINT`) precision.

Function returns 0 if there was no matching rows.

This function is available as of MySQL 4.1.1.

`BIT_AND(expr)`

Returns the bitwise `AND` of all bits in `expr`. The calculation is performed with 64-bit (`BIGINT`) precision.

Function returns -1 if there was no matching rows.

6.3.7.2 `GROUP BY` Modifiers

As of MySQL 4.1.1, the `GROUP BY` clause allows a `WITH ROLLUP` modifier that causes extra rows to be added to the summary output. These rows represent higher-level (or super-aggregate) summary operations. `ROLLUP` thus allows you to answer questions at multiple levels of analysis with a single query. It can be used, for example, to provide support for OLAP (Online Analytical Processing) operations.

As an illustration, suppose that a table named `sales` has `year`, `country`, `product`, and `profit` columns for recording sales profitability:

```
CREATE TABLE sales
(
    year    INT NOT NULL,
    country VARCHAR(20) NOT NULL,
    product VARCHAR(32) NOT NULL,
    profit  INT
);
```

The table's contents can be summarized per year with a simple `GROUP BY` like this:

```
mysql> SELECT year, SUM(profit) FROM sales GROUP BY year;
+------+-------------+
| year | SUM(profit) |
+------+-------------+
| 2000 |        4525 |
| 2001 |        3010 |
+------+-------------+
```

This output shows the total profit for each year, but if you also want to determine the total profit summed over all years, you must add up the individual values yourself or run an additional query.

Or you can use `ROLLUP`, which provides both levels of analysis with a single query. Adding a `WITH ROLLUP` modifier to the `GROUP BY` clause causes the query to produce another row that shows the grand total over all year values:

```
mysql> SELECT year, SUM(profit) FROM sales GROUP BY year WITH ROLLUP;
+------+-------------+
| year | SUM(profit) |
+------+-------------+
| 2000 |        4525 |
| 2001 |        3010 |
| NULL |        7535 |
+------+-------------+
```

The grand total super-aggregate line is identified by the value `NULL` in the `year` column.

`ROLLUP` has a more complex effect when there are multiple `GROUP BY` columns. In this case, each time there is a "break" (change in value) in any but the last grouping column, the query produces an extra super-aggregate summary row.

For example, without `ROLLUP`, a summary on the `sales` table based on `year`, `country`, and `product` might look like this:

```
mysql> SELECT year, country, product, SUM(profit)
    -> FROM sales
    -> GROUP BY year, country, product;
+------+---------+------------+-------------+
| year | country | product    | SUM(profit) |
+------+---------+------------+-------------+
| 2000 | Finland | Computer   |        1500 |
| 2000 | Finland | Phone      |         100 |
```

```
| 2000 | India   | Calculator |         150 |
| 2000 | India   | Computer   |        1200 |
| 2000 | USA     | Calculator |          75 |
| 2000 | USA     | Computer   |        1500 |
| 2001 | Finland | Phone      |          10 |
| 2001 | USA     | Calculator |          50 |
| 2001 | USA     | Computer   |        2700 |
| 2001 | USA     | TV         |         250 |
+------+---------+------------+-------------+
```

The output indicates summary values only at the year/country/product level of analysis. When `ROLLUP` is added, the query produces several extra rows:

```
mysql> SELECT year, country, product, SUM(profit)
    -> FROM sales
    -> GROUP BY year, country, product WITH ROLLUP;
+------+---------+------------+-------------+
| year | country | product    | SUM(profit) |
+------+---------+------------+-------------+
| 2000 | Finland | Computer   |        1500 |
| 2000 | Finland | Phone      |         100 |
| 2000 | Finland | NULL       |        1600 |
| 2000 | India   | Calculator |         150 |
| 2000 | India   | Computer   |        1200 |
| 2000 | India   | NULL       |        1350 |
| 2000 | USA     | Calculator |          75 |
| 2000 | USA     | Computer   |        1500 |
| 2000 | USA     | NULL       |        1575 |
| 2000 | NULL    | NULL       |        4525 |
| 2001 | Finland | Phone      |          10 |
| 2001 | Finland | NULL       |          10 |
| 2001 | USA     | Calculator |          50 |
| 2001 | USA     | Computer   |        2700 |
| 2001 | USA     | TV         |         250 |
| 2001 | USA     | NULL       |        3000 |
| 2001 | NULL    | NULL       |        3010 |
| NULL | NULL    | NULL       |        7535 |
+------+---------+------------+-------------+
```

For this query, adding `ROLLUP` causes the output to include summary information at four levels of analysis, not just one. Here's how to interpret the `ROLLUP` output:

- Following each set of product rows for a given year and country, an extra summary row is produced showing the total for all products. These rows have the `product` column set to `NULL`.
- Following each set of rows for a given year, an extra summary row is produced showing the total for all countries and products. These rows have the `country` and `products` columns set to `NULL`.
- Finally, following all other rows, an extra summary row is produced showing the grand

total for all years, countries, and products. This row has the `year`, `country`, and `products` columns set to `NULL`.

Other Considerations When using `ROLLUP`

The following items list some behaviours specific to the MySQL implementation of `ROLLUP`:

When you use `ROLLUP`, you cannot also use an `ORDER BY` clause to sort the results. (In other words, `ROLLUP` and `ORDER BY` are mutually exclusive.) However, you still have some control over sort order. `GROUP BY` in MySQL sorts results, and you can use explicit `ASC` and `DESC` keywords with columns named in the `GROUP BY` list to specify sort order for individual columns. (The higher-level summary rows added by `ROLLUP` still appear after the rows from which they are calculated, regardless of the sort order.)

`LIMIT` can be used to restrict the number of rows returned to the client. `LIMIT` is applied after `ROLLUP`, so the limit applies against the extra rows added by `ROLLUP`. For example:

```
mysql> SELECT year, country, product, SUM(profit)
    -> FROM sales
    -> GROUP BY year, country, product WITH ROLLUP
    -> LIMIT 5;
+------+---------+------------+-------------+
| year | country | product    | SUM(profit) |
+------+---------+------------+-------------+
| 2000 | Finland | Computer   |        1500 |
| 2000 | Finland | Phone      |         100 |
| 2000 | Finland | NULL       |        1600 |
| 2000 | India   | Calculator |         150 |
| 2000 | India   | Computer   |        1200 |
+------+---------+------------+-------------+
```

Note that using `LIMIT` with `ROLLUP` may produce results that are more difficult to interpret, because you have less context for understanding the super-aggregate rows.

The `NULL` indicators in each super-aggregate row are produced when the row is sent to the client. The server looks at the columns named in the `GROUP BY` clause following the leftmost one that has changed value. For any column in the result set with a name that is a lexical match to any of those names, its value is set to `NULL`. (If you specify grouping columns by column number, the server identifies which columns to set to `NULL` by number.)

Because the `NULL` values in the super-aggregate rows are placed into the result set at such a late stage in query processing, you cannot test them as `NULL` values within the query itself. For example, you cannot add `HAVING product IS NULL` to the query to eliminate from the output all but the super-aggregate rows.

On the other hand, the `NULL` values do appear as `NULL` on the client side and can be tested as such using any MySQL client programming interface.

6.3.7.3 `GROUP BY` with Hidden Fields

MySQL has extended the use of `GROUP BY`. You can use columns or calculations in the `SELECT` expressions that don't appear in the `GROUP BY` part. This stands for *any possible value for this group*. You can use this to get better performance by avoiding sorting and

grouping on unnecessary items. For example, you don't need to group on `customer.name` in the following query:

```
mysql> SELECT order.custid,customer.name,MAX(payments)
    ->        FROM order,customer
    ->        WHERE order.custid = customer.custid
    ->        GROUP BY order.custid;
```

In standard SQL, you would have to add `customer.name` to the `GROUP BY` clause. In MySQL, the name is redundant if you don't run in ANSI mode.

Don't use this feature if the columns you omit from the `GROUP BY` part aren't unique in the group! You will get unpredictable results.

In some cases, you can use `MIN()` and `MAX()` to obtain a specific column value even if it isn't unique. The following gives the value of `column` from the row containing the smallest value in the `sort` column:

```
SUBSTR(MIN(CONCAT(RPAD(sort,6,' '),column)),7)
```

See Section 3.6.4 [example-Maximum-column-group-row], page 185.

Note that if you are using MySQL Version 3.22 (or earlier) or if you are trying to follow SQL-99, you can't use expressions in `GROUP BY` or `ORDER BY` clauses. You can work around this limitation by using an alias for the expression:

```
mysql> SELECT id,FLOOR(value/100) AS val FROM tbl_name
    ->        GROUP BY id,val ORDER BY val;
```

In MySQL Version 3.23 you can do:

```
mysql> SELECT id,FLOOR(value/100) FROM tbl_name ORDER BY RAND();
```

6.4 Data Manipulation: SELECT, INSERT, UPDATE, DELETE

6.4.1 SELECT Syntax

```
SELECT [STRAIGHT_JOIN]
       [SQL_SMALL_RESULT] [SQL_BIG_RESULT] [SQL_BUFFER_RESULT]
       [SQL_CACHE | SQL_NO_CACHE] [SQL_CALC_FOUND_ROWS] [HIGH_PRIORITY]
       [DISTINCT | DISTINCTROW | ALL]
    select_expression,...
    [INTO {OUTFILE | DUMPFILE} 'file_name' export_options]
    [FROM table_references
      [WHERE where_definition]
      [GROUP BY {unsigned_integer | col_name | formula} [ASC | DESC], ...
        [WITH ROLLUP]]
      [HAVING where_definition]
      [ORDER BY {unsigned_integer | col_name | formula} [ASC | DESC] ,...]
      [LIMIT [offset,] row_count | row_count OFFSET offset]
      [PROCEDURE procedure_name(argument_list)]
      [FOR UPDATE | LOCK IN SHARE MODE]]
```

SELECT is used to retrieve rows selected from one or more tables. Each select_expression indicates a column you want to retrieve. SELECT may also be used to retrieve rows computed without reference to any table. For example:

```
mysql> SELECT 1 + 1;
        -> 2
```

All clauses used must be given in exactly the order shown in the syntax description. For example, a HAVING clause must come after any GROUP BY clause and before any ORDER BY clause.

- A SELECT expression may be given an alias using AS alias_name. The alias is used as the expression's column name and can be used with ORDER BY or HAVING clauses. For example:

  ```
  mysql> SELECT CONCAT(last_name,', ',first_name) AS full_name
      FROM mytable ORDER BY full_name;
  ```

  The AS keyword is optional when aliasing a SELECT expression. The preceding example could have been written like this:

  ```
  mysql> SELECT CONCAT(last_name,', ',first_name) full_name
      FROM mytable ORDER BY full_name;
  ```

  Because the AS is optional, a subtle problem can occur if you forget the comma between two SELECT expressions: MySQL will interpret the second as an alias name. For example, in the following statement, columnb is treated as an alias name:

  ```
  mysql> SELECT columna columnb FROM mytable;
  ```

- It is not allowed to use a column alias in a WHERE clause, because the column value may not yet be determined when the WHERE clause is executed. See Section A.5.4 [Problems with alias], page 867.

- The FROM table_references clause indicates the tables from which to retrieve rows. If you name more than one table, you are performing a join. For information on join syntax, see Section 6.4.1.1 [JOIN], page 535. For each table specified, you may optionally specify an alias.

  ```
  table_name [[AS] alias] [[USE INDEX (key_list)] | [IGNORE INDEX (key_list)] | FORCE
  ```

  As of MySQL Version 3.23.12, you can give hints about which index MySQL should use when retrieving information from a table. This is useful if EXPLAIN shows that MySQL is using the wrong index from the list of possible indexes. By specifying USE INDEX (key_list), you can tell MySQL to use only one of the possible indexes to find rows in the table. The alternative syntax IGNORE INDEX (key_list) can be used to tell MySQL to not use some particular index.

  In MySQL 4.0.9 you can also use FORCE INDEX. This acts likes USE INDEX (key_list) but with the addition that a table scan is assumed to be VERY expensive. In other words a table scan will only be used if there is no way to use one of the given index to find rows in the table.

  USE/IGNORE/FORCE KEY are synonyms for USE/IGNORE/FORCE INDEX.

  Note: USE/IGNORE/FORCE INDEX only affects which indexes are used when MySQL decides how to find rows in the table and how to do the join. It doesn't affect whether an index will be used when resolving an ORDER BY or GROUP BY.

In MySQL 4.0.14 you can use `SET MAX_SEEKS_FOR_KEY=#` as an alternative way to force MySQL to prefer key scans instead of table scans.

- You can refer to a table as `tbl_name` (within the current database), or as `dbname.tbl_name` to explicitly specify a database. You can refer to a column as `col_name`, `tbl_name.col_name`, or `db_name.tbl_name.col_name`. You need not specify a `tbl_name` or `db_name.tbl_name` prefix for a column reference in a `SELECT` statement unless the reference would be ambiguous. See Section 6.1.2 [Legal names], page 444, for examples of ambiguity that require the more explicit column reference forms.
- From version 4.1.0, you are allowed to specify `DUAL` as a dummy table name, in situations where no tables are referenced. This is purely compatibility feature, some other servers require this syntax.

```
mysql> SELECT 1 + 1 FROM DUAL;
         -> 2
```

- A table reference may be aliased using `tbl_name [AS] alias_name`:

```
mysql> SELECT t1.name, t2.salary FROM employee AS t1, info AS t2
    ->        WHERE t1.name = t2.name;
mysql> SELECT t1.name, t2.salary FROM employee t1, info t2
    ->        WHERE t1.name = t2.name;
```

- Columns selected for output may be referred to in `ORDER BY` and `GROUP BY` clauses using column names, column aliases, or column positions. Column positions begin with 1:

```
mysql> SELECT college, region, seed FROM tournament
    ->        ORDER BY region, seed;
mysql> SELECT college, region AS r, seed AS s FROM tournament
    ->        ORDER BY r, s;
mysql> SELECT college, region, seed FROM tournament
    ->        ORDER BY 2, 3;
```

  To sort in reverse order, add the `DESC` (descending) keyword to the name of the column in the `ORDER BY` clause that you are sorting by. The default is ascending order; this may be specified explicitly using the `ASC` keyword.
- In the `WHERE` clause, you can use any of the functions that MySQL supports, except for aggregate (summary) functions. See Section 6.3 [Functions], page 474.
- The `HAVING` clause can refer to any column or alias named in the `select_expression`. It is applied nearly last, just before items are sent to the client, with no optimisation. (`LIMIT` is applied after `HAVING`.) Don't use `HAVING` for items that should be in the `WHERE` clause. For example, do not write this:

```
mysql> SELECT col_name FROM tbl_name HAVING col_name > 0;
```

  Write this instead:

```
mysql> SELECT col_name FROM tbl_name WHERE col_name > 0;
```

  In MySQL Version 3.22.5 or later, you can also write queries like this:

```
mysql> SELECT user,MAX(salary) FROM users
    ->        GROUP BY user HAVING MAX(salary)>10;
```

  In older MySQL versions, you can write this instead:

```
mysql> SELECT user,MAX(salary) AS sum FROM users
    ->        group by user HAVING sum>10;
```

- The options DISTINCT, DISTINCTROW and ALL specify whether duplicate rows should be returned. The default is (ALL), all matching rows are returned. DISTINCT and DISTINCTROW are synonyms and specify that duplicate rows in the result set should be removed.
- STRAIGHT_JOIN, HIGH_PRIORITY, and options beginning with SQL_ are MySQL extensions to SQL-99.
  - STRAIGHT_JOIN forces the optimiser to join the tables in the order in which they are listed in the FROM clause. You can use this to speed up a query if the optimiser joins the tables in non-optimal order. See Section 5.2.1 [EXPLAIN], page 399.
  - HIGH_PRIORITY will give the SELECT higher priority than a statement that updates a table. You should only use this for queries that are very fast and must be done at once. A SELECT HIGH_PRIORITY query will run if the table is locked for read even if there is an update statement that is waiting for the table to be free.
  - SQL_BIG_RESULT can be used with GROUP BY or DISTINCT to tell the optimiser that the result set will have many rows. In this case, MySQL will directly use disk-based temporary tables if needed. MySQL will also, in this case, prefer sorting to doing a temporary table with a key on the GROUP BY elements.
  - SQL_BUFFER_RESULT forces the result to be put into a temporary table. This helps MySQL free the table locks early and helps in cases where it takes a long time to send the result set to the client.
  - SQL_SMALL_RESULT, a MySQL-specific option, can be used with GROUP BY or DISTINCT to tell the optimiser that the result set will be small. In this case, MySQL uses fast temporary tables to store the resulting table instead of using sorting. In MySQL Version 3.23 this shouldn't normally be needed.
  - SQL_CALC_FOUND_ROWS (version 4.0.0 and up) tells MySQL to calculate how many rows there would be in the result set, disregarding any LIMIT clause. The number of rows can then be retrieved with SELECT FOUND_ROWS(). See Section 6.3.6.2 [Miscellaneous functions], page 515.

    Please note that in versions prior to 4.1.0 this does not work with LIMIT 0, which is optimised to return instantly (resulting in a row count of 0). See Section 5.2.9 [LIMIT optimisation], page 412.
  - SQL_CACHE tells MySQL to store the query result in the query cache if you are using QUERY_CACHE_TYPE=2 (DEMAND). See Section 6.9 [Query Cache], page 589. In case of query with UNIONs and/or subqueries this option will take effect to be used in any SELECT of the query.
  - SQL_NO_CACHE tells MySQL not to store the query result in the query cache. See Section 6.9 [Query Cache], page 589. In case of query with UNIONs and/or subqueries this option will take effect to be used in any SELECT of the query.
- If you use GROUP BY, the output rows will be sorted according to the GROUP BY as if you had an ORDER BY over all the fields in the GROUP BY. MySQL has extended the GROUP BY clause so that you can also specify ASC and DESC after columns named in the clause:

```
SELECT a,COUNT(b) FROM test_table GROUP BY a DESC
```

- MySQL has extended the use of GROUP BY to allow you to select fields that are not mentioned in the GROUP BY clause. If you are not getting the results you expect from

your query, please read the GROUP BY description. See Section 6.3.7 [Group by functions and modifiers], page 524.

- As of MySQL 4.1.1, GROUP BY allows a WITH ROLLUP modifier. See Section 6.3.7.2 [GROUP BY Modifiers], page 526.
- The LIMIT clause can be used to constrain the number of rows returned by the SELECT statement. LIMIT takes one or two numeric arguments, which must be integer constants.

  With one argument, the value specifies the number of rows to return from the beginning of the result set. With two arguments, the first specifies the offset of the first row to return, the second specifies the maximum number of rows to return. The offset of the initial row is 0 (not 1):

  To be compatible with PostgreSQL MySQL also supports the syntax: LIMIT row_count OFFSET offset.

  ```
  mysql> SELECT * FROM table LIMIT 5,10;  # Retrieve rows 6-15
  ```

  To retrieve all rows from a certain offset up to the end of the result set, you can use -1 for the second parameter:

  ```
  mysql> SELECT * FROM table LIMIT 95,-1; # Retrieve rows 96-last.
  ```

  If one argument is given, it indicates the maximum number of rows to return:

  ```
  mysql> SELECT * FROM table LIMIT 5;     # Retrieve first 5 rows
  ```

  In other words, LIMIT n is equivalent to LIMIT 0,n.
- The SELECT ... INTO OUTFILE 'file_name' form of SELECT writes the selected rows to a file. The file is created on the server host and cannot already exist (among other things, this prevents database tables and files such as '/etc/passwd' from being destroyed). You must have the FILE privilege on the server host to use this form of SELECT.

  The SELECT ... INTO OUTFILE statement is intended primarily to let you very quickly dump a table on the server machine. If you want to create the resulting file on some other host than the server host, you can't use SELECT ... INTO OUTFILE. In this case you should instead use some client program like mysqldump --tab or mysql -e "SELECT ..." > outfile to generate the file.

  SELECT ... INTO OUTFILE is the complement of LOAD DATA INFILE; the syntax for the export_options part of the statement consists of the same FIELDS and LINES clauses that are used with the LOAD DATA INFILE statement. See Section 6.4.8 [LOAD DATA], page 555.

  In the resulting text file, only the following characters are escaped by the ESCAPED BY character:

  - The ESCAPED BY character
  - The first character in FIELDS TERMINATED BY
  - The first character in LINES TERMINATED BY

  Additionally, ASCII 0 is converted to ESCAPED BY followed by 0 (ASCII 48).

  The reason for the above is that you **must** escape any FIELDS TERMINATED BY, ESCAPED BY, or LINES TERMINATED BY characters to reliably be able to read the file back. ASCII 0 is escaped to make it easier to view with some pagers.

As the resulting file doesn't have to conform to the SQL syntax, nothing else need be escaped.

Here follows an example of getting a file in the format used by many old programs.

```
SELECT a,b,a+b INTO OUTFILE "/tmp/result.text"
FIELDS TERMINATED BY ',' OPTIONALLY ENCLOSED BY '"'
LINES TERMINATED BY "\n"
FROM test_table;
```

- If you use `INTO DUMPFILE` instead of `INTO OUTFILE`, MySQL will only write one row into the file, without any column or line terminations and without performing any escape processing. This is useful if you want to store a `BLOB` value in a file.
- Note that any file created by `INTO OUTFILE` and `INTO DUMPFILE` will be writeable by all users on the server host! The reason is that the MySQL server can't create a file that is owned by anyone else than the user it's running as (you should never run `mysqld` as `root`). The file thus must be world-writeable so that you can manipulate its contents.
- A `PROCEDURE` clause names a procedure that should process the data in the result set. For an example, see Section 13.3.1 [procedure analyse], page 845.
- If you use `FOR UPDATE` on a storage engine with page or row locks, the examined rows are write locked until the end of the current transaction.

6.4.1.1 `JOIN` Syntax

MySQL supports the following `JOIN` syntaxes for use in `SELECT` statements:

```
table_reference, table_reference
table_reference [INNER | CROSS] JOIN table_reference [join_condition]
table_reference STRAIGHT_JOIN table_reference
table_reference LEFT [OUTER] JOIN table_reference [join_condition]
table_reference NATURAL [LEFT [OUTER]] JOIN table_reference
{ OJ table_reference LEFT OUTER JOIN table_reference ON conditional_expr }
table_reference RIGHT [OUTER] JOIN table_reference [join_condition]
table_reference NATURAL [RIGHT [OUTER]] JOIN table_reference
```

Where `table_reference` is defined as:

```
table_name [[AS] alias] [[USE INDEX (key_list)] | [IGNORE INDEX (key_list)] | [FORCE I
```

and `join_condition` is defined as:

```
ON conditional_expr |
USING (column_list)
```

You should generally not have any conditions in the `ON` part that are used to restrict which rows you want in the result set, but rather specify these conditions in the `WHERE` clause. There are exceptions to this rule.

Note that in versions before Version 3.23.17, the `INNER JOIN` didn't take a `join_condition`!

The last `LEFT OUTER JOIN` syntax shown in the preceding list exists only for compatibility with ODBC:

- A table reference may be aliased using `tbl_name AS alias_name` or `tbl_name alias_name`:

```
mysql> SELECT t1.name, t2.salary FROM employee AS t1, info AS t2
    ->        WHERE t1.name = t2.name;
```

- The `ON` conditional is any conditional of the form that may be used in a `WHERE` clause.
- If there is no matching record for the right table in the `ON` or `USING` part in a `LEFT JOIN`, a row with all columns set to `NULL` is used for the right table. You can use this fact to find records in a table that have no counterpart in another table:

  ```
  mysql> SELECT table1.* FROM table1
      ->        LEFT JOIN table2 ON table1.id=table2.id
      ->        WHERE table2.id IS NULL;
  ```

  This example finds all rows in `table1` with an `id` value that is not present in `table2` (that is, all rows in `table1` with no corresponding row in `table2`). This assumes that `table2.id` is declared `NOT NULL`, of course. See Section 5.2.7 [LEFT JOIN optimisation], page 410.
- The `USING (column_list)` clause names a list of columns that must exist in both tables. The following two clauses are semantically identical:

  ```
  a LEFT JOIN b USING (c1,c2,c3)
  a LEFT JOIN b ON a.c1=b.c1 AND a.c2=b.c2 AND a.c3=b.c3
  ```
- The `NATURAL [LEFT] JOIN` of two tables is defined to be semantically equivalent to an `INNER JOIN` or a `LEFT JOIN` with a `USING` clause that names all columns that exist in both tables.
- `INNER JOIN` and `,` (comma) are semantically equivalent in the absence of a join condition: both will produce a Cartesian product between the specified tables (that is, each and every row in the first table will be joined onto all rows in the second table).
- `RIGHT JOIN` works analogously to `LEFT JOIN`. To keep code portable across databases, it's recommended to use `LEFT JOIN` instead of `RIGHT JOIN`.
- `STRAIGHT_JOIN` is identical to `JOIN`, except that the left table is always read before the right table. This can be used for those (few) cases where the join optimiser puts the tables in the wrong order.
- As of MySQL Version 3.23.12, you can give hints about which index MySQL should use when retrieving information from a table. This is useful if `EXPLAIN` shows that MySQL is using the wrong index from the list of possible indexes. By specifying `USE INDEX (key_list)`, you can tell MySQL to use only one of the possible indexes to find rows in the table. The alternative syntax `IGNORE INDEX (key_list)` can be used to tell MySQL to not use some particular index.

  In MySQL 4.0.9 you can also use `FORCE INDEX`. This acts likes `USE INDEX (key_list)` but with the addition that a table scan is assumed to be VERY expensive. In other words a table scan will only be used if there is no way to use one of the given index to find rows in the table.

  `USE/IGNORE KEY` are synonyms for `USE/IGNORE INDEX`.

Note: `USE/IGNORE/FORCE INDEX` only affects which indexes are used when MySQL decides how to find rows in the table and how to do the join. It doesn't affect whether an index will be used when resolving an `ORDER BY` or `GROUP BY`.

Some examples:

```
mysql> SELECT * FROM table1,table2 WHERE table1.id=table2.id;
mysql> SELECT * FROM table1 LEFT JOIN table2 ON table1.id=table2.id;
mysql> SELECT * FROM table1 LEFT JOIN table2 USING (id);
mysql> SELECT * FROM table1 LEFT JOIN table2 ON table1.id=table2.id
    ->          LEFT JOIN table3 ON table2.id=table3.id;
mysql> SELECT * FROM table1 USE INDEX (key1,key2)
    ->          WHERE key1=1 AND key2=2 AND key3=3;
mysql> SELECT * FROM table1 IGNORE INDEX (key3)
    ->          WHERE key1=1 AND key2=2 AND key3=3;
```

See Section 5.2.7 [LEFT JOIN optimisation], page 410.

6.4.1.2 UNION Syntax

```
SELECT ...
UNION [ALL]
SELECT ...
  [UNION
   SELECT ...]
```

UNION is implemented in MySQL 4.0.0.

UNION is used to combine the result from many SELECT statements into one result set.

The columns listed in the select_expression portion of the SELECT should have the same type. The column names used in the first SELECT query will be used as the column names for the results returned.

The SELECT commands are normal select commands, but with the following restrictions:

- Only the last SELECT command can have INTO OUTFILE.

If you don't use the keyword ALL for the UNION, all returned rows will be unique, as if you had done a DISTINCT for the total result set. If you specify ALL, then you will get all matching rows from all the used SELECT statements.

If you want to use an ORDER BY for the total UNION result, you should use parentheses:

```
(SELECT a FROM table_name WHERE a=10 AND B=1 ORDER BY a LIMIT 10)
UNION
(SELECT a FROM table_name WHERE a=11 AND B=2 ORDER BY a LIMIT 10)
ORDER BY a;
```

6.4.2 Subquery Syntax

A subquery is a SELECT statement inside another statement. For example:

```
SELECT * FROM t1 WHERE column1 = (SELECT column1 FROM t2);
```

In the above example, SELECT * FROM t1 ... is the *outer query* (or *outer statement*), and (SELECT column1 FROM t2) is the *subquery*. We say that the subquery is *nested* in the outer query, and in fact it's possible to nest subqueries within other subqueries, to a great depth. A subquery must always be inside parentheses.

Starting with version 4.1, MySQL supports all subquery forms and operations which the SQL standard requires, as well as a few features which are MySQL-specific. The main advantages of subqueries are:

- they allow queries which are *structured* so that it's possible to isolate each part of a statement,
- they provide alternative ways to perform operations which would otherwise require complex joins and unions,
- they are, in many people's opinion, readable. Indeed, it was the innovation of subqueries which gave people the original idea of calling the early `SQL` "Structured Query Language".

With earlier MySQL versions it was necessary to work around or avoid subqueries, but people starting to write code now will find that subqueries are a very useful part of the toolkit.

Here is an example statement which shows the major points about subquery syntax as specified by the SQL standard and supported in MySQL.

```
DELETE FROM t1
WHERE s11 > ANY
 (SELECT COUNT(*) /* no hint */ FROM t2
 WHERE NOT EXISTS
  (SELECT * FROM t3
   WHERE ROW(5*t2.s1,77)=
    (SELECT 50,11*s1 FROM t4 UNION SELECT 50,77 FROM
     (SELECT * FROM t5) AS t5)));
```

For MySQL versions prior to 4.1, most subqueries can be successfully rewritten using joins and and other methods. See Section 6.4.2.11 [Rewriting subqueries], page 545.

6.4.2.1 The Subquery as Scalar Operand

In its simplest form (the *scalar* subquery as opposed to the *row* or *table* subqueries which will be discussed later), a subquery is a simple operand. Thus you can use it wherever a column value or literal is legal, and you can expect it to have those characteristics that all operands have: a data type, a length, an indication whether it can be `NULL`, and so on. For example:

```
CREATE TABLE t1 (s1 INT, s2 CHAR(5) NOT NULL);
SELECT (SELECT s2 FROM t1);
```

The subquery in the above `SELECT` has a data type of `CHAR`, a length of 5, a character set and collation equal to the defaults in effect at `CREATE TABLE` time, and an indication that the value in the column can be `NULL`. In fact almost all subqueries can be `NULL`, because if the table is empty – as in the example – then the value of the subquery will be `NULL`. There are few restrictions.

- A subquery's outer statement can be any one of: `SELECT`, `INSERT`, `UPDATE`, `DELETE`, `SET`, or `DO`.
- A subquery can contain any of the keywords or clauses that an ordinary `SELECT` can contain: `DISTINCT`, `GROUP BY`, `ORDER BY`, `LIMIT`, joins, hints, `UNION`s, comments, functions, and so on.

So, when you see examples in the following sections that contain the rather Spartan construct `(SELECT column1 FROM t1)`, imagine that your own code will contain much more diverse and complex constructions.

For example, suppose we make two tables:

```
CREATE TABLE t1 (s1 INT);
INSERT INTO t1 VALUES (1);
CREATE TABLE t2 (s1 INT);
INSERT INTO t2 VALUES (2);
```

Then perform a SELECT:

```
SELECT (SELECT s1 FROM t2) FROM t1;
```

The result will be 2 because there is a row in t2, with a column s1, with a value of 2.

The subquery may be part of an expression. If it is an operand for a function, don't forget the parentheses. For example:

```
SELECT UPPER((SELECT s1 FROM t1)) FROM t2;
```

6.4.2.2 Comparisons Using Subqueries

The most common use of a subquery is in the form:

```
<non-subquery operand> <comparison operator> (<subquery>)
```

Where <comparison operator> is one of:

```
= > < >= <= <>
```

For example:

```
... 'a' = (SELECT column1 FROM t1)
```

At one time the only legal place for a subquery was on the right side of a comparison, and you might still find some old DBMSs which insist on that.

Here is an example of a common-form subquery comparison which you can't do with a join: find all the values in table t1 which are equal to a maximum value in table t2.

```
SELECT column1 FROM t1
       WHERE column1 = (SELECT MAX(column2) FROM t2);
```

Here is another example, which again is impossible with a join because it involves aggregating for one of the tables: find all rows in table t1 which contain a value which occurs twice.

```
SELECT * FROM t1
       WHERE 2 = (SELECT COUNT(column1) FROM t1);
```

6.4.2.3 Subqueries with ANY, IN, and SOME

Syntax:

```
<operand> <comparison operator> ANY (<subquery>)
<operand> IN (<subquery>)
<operand> <comparison operator> SOME (<subquery>)
```

The word ANY, which must follow a comparison operator, means "return TRUE if the comparison is TRUE for ANY of the rows that the subquery returns." For example,

```
SELECT s1 FROM t1 WHERE s1 > ANY (SELECT s1 FROM t2);
```

Suppose that there is a row in table `t1` containing {10}. The expression is `TRUE` if table `t2` contains {21,14,7} because there is a value in `t2` – 7 – which is less than 10. The expression is `FALSE` if table `t2` contains {20,10}, or if table `t2` is empty. The expression is `UNKNOWN` if table `t2` contains {NULL,NULL,NULL}.

The word `IN` is an alias for `= ANY`. Thus these two statements are the same:

```
SELECT s1 FROM t1 WHERE s1 = ANY (SELECT s1 FROM t2);
SELECT s1 FROM t1 WHERE s1 IN    (SELECT s1 FROM t2);
```

The word `SOME` is an alias for `ANY`. Thus these two statements are the same:

```
SELECT s1 FROM t1 WHERE s1 <> ANY  (SELECT s1 FROM t2);
SELECT s1 FROM t1 WHERE s1 <> SOME (SELECT s1 FROM t2);
```

Use of the word `SOME` is rare, but the above example shows why it might be useful. The English phrase "a is not equal to any b" means, to most people's ears, "there is no b which is equal to a" – which isn't what is meant by the SQL syntax. By using `<> SOME` instead, you ensure that everyone understands the true meaning of the query.

6.4.2.4 Subqueries with ALL

Syntax:

```
<operand> <comparison operator> ALL (<subquery>)
```

The word `ALL`, which must follow a comparison operator, means "return `TRUE` if the comparison is `TRUE` for `ALL` of the rows that the subquery returns". For example,

```
SELECT s1 FROM t1 WHERE s1 > ALL (SELECT s1 FROM t2);
```

Suppose that there is a row in table `t1` containing {10}. The expression is `TRUE` if table `t2` contains {-5,0,+5} because all three values in `t2` are less than 10. The expression is `FALSE` if table `t2` contains {12,6,NULL,-100} because there is a single value in table `t2` – 12 – which is greater than 10. The expression is `UNKNOWN` if table `t2` contains {0,NULL,1}.

Finally, if table `t2` is empty, the result is `TRUE`. You might think the result should be `UNKNOWN`, but sorry, it's `TRUE`. So, rather oddly,

```
SELECT * FROM t1 WHERE 1 > ALL (SELECT s1 FROM t2);
```

is `TRUE` when table `t2` is empty, but

```
SELECT * FROM t1 WHERE 1 > (SELECT s1 FROM t2);
```

is `UNKNOWN` when table `t2` is empty. In addition,

```
SELECT * FROM t1 WHERE 1 > ALL (SELECT MAX(s1) FROM t2);
```

is `UNKNOWN` when table `t2` is empty. In general, *tables with NULLs* and *empty tables* are *edge cases* – when writing subquery code, always consider whether you have taken those two possibilities into account.

6.4.2.5 Correlated Subqueries

A *correlated subquery* is a subquery which contains a reference to a column which is also in the outer query. For example:

```
SELECT * FROM t1 WHERE column1 = ANY
       (SELECT column1 FROM t2 WHERE t2.column2 = t1.column2);
```

Notice, in the example, that the subquery contains a reference to a column of `t1`, even though the subquery's `FROM` clause doesn't mention a table `t1`. So MySQL looks outside the subquery, and finds t1 in the outer query.

Suppose that table `t1` contains a row where `column1 = 5` and `column2 = 6`; meanwhile table `t2` contains a row where `column1 = 5` and `column2 = 7`. The simple expression `... WHERE column1 = ANY (SELECT column1 FROM t2)` would be `TRUE`, but in this example the `WHERE` clause within the subquery is `FALSE` (because 7 <> 5), so the subquery as a whole is `FALSE`.

Scoping rule: MySQL evaluates from inside to outside. For example:

```
SELECT column1 FROM t1 AS x
  WHERE x.column1 = (SELECT column1 FROM t2 AS x
    WHERE x.column1 = (SELECT column1 FROM t3 WHERE x.column2 = t3.column1));
```

In the above, `x.column2` must be a column in table `t2` because `SELECT column1 FROM t2 AS x ...` renames `t2`. It is not a column in table `t1` because `SELECT column1 FROM t1 ...` is an outer query which is *further out*.

For subqueries in `HAVING` or `ORDER BY` clauses, MySQL also looks for column names in the outer select list.

MySQL's unofficial recommendation is: avoid correlation because it makes your queries look more complex, and run more slowly.

6.4.2.6 EXISTS and NOT EXISTS

If a subquery returns any values at all, then `EXISTS <subquery>` is `TRUE`, and `NOT EXISTS <subquery>` is `FALSE`. For example:

```
SELECT column1 FROM t1 WHERE EXISTS (SELECT * FROM t2);
```

Traditionally an `EXISTS` subquery starts with `SELECT *` but it could begin with `SELECT 5` or `SELECT column1` or anything at all – MySQL ignores the `SELECT` list in such a subquery, so it doesn't matter.

For the above example, if `t2` contains any rows, even rows with nothing but `NULL` values, then the `EXISTS` condition is `TRUE`. This is actually an unlikely example, since almost always a `[NOT] EXISTS` subquery will contain correlations. Here are some more realistic examples.

Example: What kind of store is present in one or more cities?

```
SELECT DISTINCT store_type FROM Stores
  WHERE EXISTS (SELECT * FROM Cities_Stores
                WHERE Cities_Stores.store_type = Stores.store_type);
```

Example: What kind of store is present in no cities?

```
SELECT DISTINCT store_type FROM Stores
  WHERE NOT EXISTS (SELECT * FROM Cities_Stores
                    WHERE Cities_Stores.store_type = Stores.store_type);
```

Example: What kind of store is present in all cities?

```
SELECT DISTINCT store_type FROM Stores S1
  WHERE NOT EXISTS (
```

```
SELECT * FROM Cities WHERE NOT EXISTS (
  SELECT * FROM Cities_Stores
   WHERE Cities_Stores.city = Cities.city
   AND Cities_Stores.store_type = Stores.store_type));
```

The last example is a double-nested `NOT EXISTS` query – it has a `NOT EXISTS` clause within a `NOT EXISTS` clause. Formally, it answers the question "does a city exist with a store which is not in Stores?". But it's easier to say that a nested `NOT EXISTS` answers the question "is x TRUE for all y?".

6.4.2.7 Row Subqueries

The discussion to this point has been of *column (or scalar) subqueries* – subqueries which return a single column value. A *row subquery* is a subquery variant that returns a single row value – and may thus return more than one column value. Here are two examples:

```
SELECT * FROM t1 WHERE (1,2) = (SELECT column1, column2 FROM t2);
SELECT * FROM t1 WHERE ROW(1,2) = (SELECT column1, column2 FROM t2);
```

The queries above are both `TRUE` if table `t2` has a row where `column1 = 1` and `column2 = 2`.

The expression `(1,2)` is sometimes called a *row constructor* and is legal in other contexts too. For example

```
SELECT * FROM t1 WHERE (column1,column2) = (1,1);
```

is equivalent to

```
SELECT * FROM t1 WHERE column1 = 1 AND column2 = 1;
```

The normal use of row constructors, though, is for comparisons with subqueries that return two or more columns. For example, this query answers the request: "find all rows in table t1 which are duplicated in table t2":

```
SELECT column1,column2,column3
       FROM t1
       WHERE (column1,column2,column3) IN
             (SELECT column1,column2,column3 FROM t2);
```

6.4.2.8 Subqueries in the `FROM` clause

Subqueries are legal in a `SELECT` statement's `FROM` clause. The syntax that you'll actually see is:

```
SELECT ... FROM (<subquery>) AS <name> ...
```

The `AS <name>` clause is mandatory, because any table in a `FROM` clause must have a name. Any columns in the `<subquery>` select list must have unique names. You may find this syntax described elsewhere in this manual, where the term used is "derived tables".

For illustration, assume you have this table:

```
CREATE TABLE t1 (s1 INT, s2 CHAR(5), s3 FLOAT);
```

Here's how to use the *Subqueries in the FROM clause* feature, using the example table:

```
INSERT INTO t1 VALUES (1,'1',1.0);
INSERT INTO t1 VALUES (2,'2',2.0);
SELECT sb1,sb2,sb3
       FROM (SELECT s1 AS sb1, s2 AS sb2, s3*2 AS sb3 FROM t1) AS sb
       WHERE sb1 > 1;
```

Result: 2, '2', 4.0.

Here's another example: Suppose you want to know the average of the sum for a grouped table. This won't work:

```
SELECT AVG(SUM(column1)) FROM t1 GROUP BY column1;
```

But this query will provide the desired information:

```
SELECT AVG(sum_column1)
       FROM (SELECT SUM(column1) AS sum_column1
             FROM t1 GROUP BY column1) AS t1;
```

Notice that the column name used within the subquery (`sum_column1`) is recognized in the outer query.

At the moment, subqueries in the `FROM` clause cannot be correlated subqueries.

6.4.2.9 Subquery Errors

There are some new error returns which apply only to subqueries. This section groups them together because reviewing them will help remind you of some points.

- ```
  ERROR 1235 (ER_NOT_SUPPORTED_YET)
  SQLSTATE = 42000
  Message = "This version of MySQL doesn't yet support
  'LIMIT & IN/ALL/ANY/SOME subquery'"
  ```

  This means that

  ```
  SELECT * FROM t1 WHERE s1 IN (SELECT s2 FROM t2 ORDER BY s1 LIMIT 1)
  ```

  will not work, but only in some early versions, such as MySQL 4.1.1.

- ```
  ERROR 1240 (ER_CARDINALITY_COL)
  SQLSTATE = 21000
  Message = "Operand should contain 1 column(s)"
  ```

  This error will occur in cases like this:

  ```
  SELECT (SELECT column1, column2 FROM t2) FROM t1;
  ```

  It's okay to use a subquery that returns multiple columns, if the purpose is comparison. See Section 6.4.2.7 [Row subqueries], page 542. But in other contexts the subquery must be a scalar operand.

- ```
  ERROR 1241 (ER_SUBSELECT_NO_1_ROW)
  SQLSTATE = 21000
  Message = "Subquery returns more than 1 row"
  ```

  This error will occur in cases like this:
  ```

```
SELECT * FROM t1 WHERE column1 = (SELECT column1 FROM t2);
```

but only when there is more than one row in `t2`. That means this error might occur in code that has been working for years, because somebody happened to make a change which affected the number of rows that the subquery can return. Remember that if the object is to find any number of rows, not just one, then the correct statement would look like this:

```
SELECT * FROM t1 WHERE column1 = ANY (SELECT column1 FROM t2);
```

- ```
  Error 1093 (ER_UPDATE_TABLE_USED)
  SQLSTATE = HY000
  Message = "You can't specify target table 'x' for update in FROM clause"
  ```

  This error will occur in cases like this:

  ```
  UPDATE t1 SET column2 = (SELECT MAX(column1) FROM t1);
  ```

It's okay to use a subquery for assignment within an `UPDATE` statement, since subqueries are legal in `UPDATE` and in `DELETE` statements as well as in `SELECT` statements. However, you cannot use the same table, in this case table `t1`, for both the subquery's `FROM` clause and the update target.

Usually, failure of the subquery causes the entire statement to fail.

6.4.2.10 Optimising Subqueries

Development is ongoing, so no optimisation tip is reliable for the long term. Some interesting tricks that you might want to play with are:

- Using subquery clauses which affect the number or order of the rows in the subquery, for example

  ```
  SELECT * FROM t1 WHERE t1.column1 IN
    (SELECT column1 FROM t2 ORDER BY column1);
  SELECT * FROM t1 WHERE t1.column1 IN
    (SELECT DISTINCT column1 FROM t2);
  SELECT * FROM t1 WHERE EXISTS
    (SELECT * FROM t2 LIMIT 1);
  ```

- Replacing a join with a subquery, for example

  ```
  SELECT DISTINCT column1 FROM t1 WHERE t1.column1 IN (
    SELECT column1 FROM t2);
  ```

  instead of

  ```
  SELECT DISTINCT t1.column1 FROM t1, t2
    WHERE t1.column1 = t2.column1;
  ```

- Moving clauses from outside to inside the subquery, for example:

  ```
  SELECT * FROM t1
    WHERE s1 IN (SELECT s1 FROM t1 UNION ALL SELECT s1 FROM t2);
  ```

  instead of

  ```
  SELECT * FROM t1
  ```
  ```

```
  WHERE s1 IN (SELECT s1 FROM t1) OR s1 IN (SELECT s1 FROM t2);
```

For another example:

```
SELECT (SELECT column1 + 5 FROM t1) FROM t2;
```

instead of

```
SELECT (SELECT column1 FROM t1) + 5 FROM t2;
```

- Using a row subquery instead of a correlated subquery, for example:

```
SELECT * FROM t1
  WHERE (column1,column2) IN (SELECT column1,column2 FROM t2);
```

instead of

```
SELECT * FROM t1
  WHERE EXISTS (SELECT * FROM t2 WHERE t2.column1=t1.column1
  AND t2.column2=t1.column2);
```

- Using `NOT (a = ANY (...))` rather than `a <> ALL (...)`.
- Using `x = ANY (table containing {1,2})` rather than `x=1 OR x=2`.
- Using `= ANY` rather than `EXISTS`

The above tricks may cause programs to go faster or slower. Using MySQL facilities like the `BENCHMARK()` function, you can get an idea about what helps in your own situation. Don't worry too much about transforming to joins except for compatibility with older versions.

Some optimisations that MySQL itself will make are:

1. MySQL will execute non-correlated subqueries only once, (use `EXPLAIN` to make sure that a given subquery really is non-correlated),
2. MySQL will rewrite `IN/ALL/ANY/SOME` subqueries in an attempt to take advantage of the possibility that the select-list columns in the subquery are indexed,
3. MySQL will replace subqueries of the form

   ```
   ... IN (SELECT indexed_column FROM single_table ...)
   ```

   with an index-lookup function, which `EXPLAIN` will describe as a special join type,
4. MySQL will enhance expressions of the form

   ```
   value {ALL|ANY|SOME} {> | < | >= | <=} (non-correlated subquery)
   ```

   with an expression involving `MIN` or `MAX` (unless `NULL`s or empty sets are involved). For example,

   ```
   WHERE 5 > ALL (SELECT x FROM t)
   ```

   might be treated as

   ```
   WHERE 5 > (SELECT MAX(x) FROM t)
   ```

There is a chapter titled "How MySQL Transforms Subqueries" in the MySQL Internals Manual, which you can find by downloading the MySQL source package and looking for a file named '`internals.texi`'.

6.4.2.11 Rewriting Subqueries for Earlier MySQL Versions

Up to version 4.0, only nested queries of the form `INSERT ... SELECT ...` and `REPLACE ... SELECT ...` are supported. The `IN()` construct can be used in other contexts.

It is often possible to rewrite a query without a subquery:

```
SELECT * FROM t1 WHERE id IN (SELECT id FROM t2);
```

This can be rewritten as:

```
SELECT t1.* FROM t1,t2 WHERE t1.id=t2.id;
```

The queries:

```
SELECT * FROM t1 WHERE id NOT IN (SELECT id FROM t2);
SELECT * FROM t1 WHERE NOT EXISTS (SELECT id FROM t2 WHERE t1.id=t2.id);
```

Can be rewritten as:

```
SELECT table1.* FROM table1 LEFT JOIN table2 ON table1.id=table2.id
                                      WHERE table2.id IS NULL;
```

A `LEFT [OUTER] JOIN` can be faster than an equivalent subquery because the server might be able to optimise it better – a fact that is not specific to MySQL Server alone. Prior to SQL-92, outer joins did not exist, so subqueries were the only way to do certain things in those bygone days. Today, MySQL Server and many other modern database systems offer a whole range of outer joins types.

For more complicated subqueries you can often create temporary tables to hold the subquery. In some cases, however, this option will not work. The most frequently encountered of these cases arises with `DELETE` statements, for which standard SQL does not support joins (except in subqueries). For this situation there are three options available:

- The first option is to upgrade to MySQL version 4.1.
- The second option is to use a procedural programming language (such as Perl or PHP) to submit a `SELECT` query to obtain the primary keys for the records to be deleted, and then use these values to construct the `DELETE` statement (`DELETE FROM ... WHERE ... IN (key1, key2, ...)`).
- The third option is to use interactive SQL to construct a set of `DELETE` statements automatically, using the MySQL extension `CONCAT()` (in lieu of the standard `||` operator). For example:

  ```
  SELECT CONCAT('DELETE FROM tab1 WHERE pkid = ', "'", tab1.pkid, "'", ';')
    FROM tab1, tab2
   WHERE tab1.col1 = tab2.col2;
  ```

  You can place this query in a script file and redirect input from it to the `mysql` command-line interpreter, piping its output back to a second instance of the interpreter:

  ```
  shell> mysql --skip-column-names mydb < myscript.sql | mysql mydb
  ```

MySQL Server 4.0 supports multi-table `DELETE`s that can be used to efficiently delete rows based on information from one table or even from many tables at the same time. Multi-table `UPDATE`s are also supported from version 4.0.

6.4.3 `INSERT` Syntax

```
INSERT [LOW_PRIORITY | DELAYED] [IGNORE]
    [INTO] tbl_name [(col_name,...)]
    VALUES ((expression | DEFAULT),...),(...),...
    [ ON DUPLICATE KEY UPDATE col_name=expression, ... ]
```

```
or  INSERT [LOW_PRIORITY | DELAYED] [IGNORE]
        [INTO] tbl_name [(col_name,...)]
        SELECT ...
or  INSERT [LOW_PRIORITY | DELAYED] [IGNORE]
        [INTO] tbl_name
        SET col_name=(expression | DEFAULT), ...
        [ ON DUPLICATE KEY UPDATE col_name=expression, ... ]
```

`INSERT` inserts new rows into an existing table. The `INSERT ... VALUES` form of the statement inserts rows based on explicitly specified values. The `INSERT ... SELECT` form inserts rows selected from another table or tables. The `INSERT ... VALUES` form with multiple value lists is supported in MySQL Version 3.22.5 or later. The `col_name=expression` syntax is supported in MySQL Version 3.22.10 or later.

`tbl_name` is the table into which rows should be inserted. The column name list or the `SET` clause indicates which columns the statement specifies values for:

- If you specify no column list for `INSERT ... VALUES` or `INSERT ... SELECT`, values for all columns in the table must be provided in the `VALUES()` list or by the `SELECT`. If you don't know the order of the columns in the table, use `DESCRIBE tbl_name` to find out.
- Any column not explicitly given a value is set to its default value. For example, if you specify a column list that doesn't name all the columns in the table, unnamed columns are set to their default values. Default value assignment is described in Section 6.5.3 [`CREATE TABLE`], page 564.

  You can also use the keyword `DEFAULT` to set a column to its default value. (New in MySQL 4.0.3.) This makes it easier to write `INSERT` statements that assign values to all but a few columns, because it allows you to avoid writing an incomplete `VALUES()` list (a list that does not include a value for each column in the table). Otherwise, you would have to write out the list of column names corresponding to each value in the `VALUES()` list.

  MySQL always has a default value for all fields. This is something that is imposed on MySQL to be able to work with both transactional and non-transactional tables.

  Our view is that checking of fields content should be done in the application and not in the database server.
- An `expression` may refer to any column that was set earlier in a value list. For example, you can say this:

  ```
  mysql> INSERT INTO tbl_name (col1,col2) VALUES(15,col1*2);
  ```

  But not this:

  ```
  mysql> INSERT INTO tbl_name (col1,col2) VALUES(col2*2,15);
  ```
- If you specify the keyword `DELAYED`, the server puts the row or rows to be inserted into a buffer, and the client issuing the `INSERT DELAYED` statement then may continue on. If the table is busy, the server holds the rows. When the table becomes free, it begins inserting rows, checking periodically to see if there are new read requests for the table. If there are, the delayed row queue is suspended until the table becomes free again.

- If you specify the keyword `LOW_PRIORITY`, execution of the `INSERT` is delayed until no other clients are reading from the table. This includes other clients that began reading while existing clients are reading, and while the `INSERT LOW_PRIORITY` statement is waiting. It is possible therefore for a client that issues an `INSERT LOW_PRIORITY` statement to wait for a very long time (or even forever) in a read-heavy environment. (This is in contrast to `INSERT DELAYED`, which lets the client continue at once.) See Section 6.4.3.2 [INSERT DELAYED], page 550. Note that `LOW_PRIORITY` should normally not be used with `MyISAM` tables as this disables concurrent inserts. See Section 7.1 [MyISAM], page 595.
- If you specify the keyword `IGNORE` in an `INSERT` with many rows, any rows that duplicate an existing `PRIMARY` or `UNIQUE` key in the table are ignored and are not inserted. If you do not specify `IGNORE`, the insert is aborted if there is any row that duplicates an existing key value. You can determine with the C API function `mysql_info()` how many rows were inserted into the table.
- If you specify `ON DUPLICATE KEY UPDATE` clause (new in MySQL 4.1.0), and a row is inserted that would cause a duplicate value in a `PRIMARY` or `UNIQUE` key, an `UPDATE` of the old row is performed. For example, the command:

  ```
  mysql> INSERT INTO table (a,b,c) VALUES (1,2,3)
      -> ON DUPLICATE KEY UPDATE c=c+1;
  ```

  in case of column `a` is declared as `UNIQUE` and already holds `1` once, would be identical to the

  ```
  mysql> UPDATE table SET c=c+1 WHERE a=1;
  ```

  Note: that if column `b` is unique too, the `UPDATE` command would be written as

  ```
  mysql> UPDATE table SET c=c+1 WHERE a=1 OR b=2 LIMIT 1;
  ```

  and if `a=1 OR b=2` matches several rows, only **one** row will be updated! In general, one should try to avoid using `ON DUPLICATE KEY` clause on tables with multiple `UNIQUE` keys.

  Since MySQL 4.1.1 one can use function `VALUES(col_name)` to refer to the column value in the `INSERT` part of the `INSERT ... UPDATE` command - that is the value that would be inserted if there would be no duplicate key conflict. This function especially useful in multiple-row inserts. Naturally `VALUES()` function is only meaningful in `INSERT ... UPDATE` command and returns `NULL` otherwise.

  Example:

  ```
  mysql> INSERT INTO table (a,b,c) VALUES (1,2,3),(4,5,6)
      -> ON DUPLICATE KEY UPDATE c=VALUES(a)+VALUES(b);
  ```

  The command above is identical to

  ```
  mysql> INSERT INTO table (a,b,c) VALUES (1,2,3)
      -> ON DUPLICATE KEY UPDATE c=3;
  mysql> INSERT INTO table (a,b,c) VALUES (4,5,6)
      -> ON DUPLICATE KEY UPDATE c=9;
  ```

  When one uses `ON DUPLICATE KEY UPDATE`, the `DELAYED` option is ignored.
- If MySQL was configured using the `DONT_USE_DEFAULT_FIELDS` option, `INSERT` statements generate an error unless you explicitly specify values for all columns that require a non-`NULL` value. See Section 2.3.3 [`configure` options], page 91.

- You can find the value used for an AUTO_INCREMENT column with the mysql_insert_id function. See Section 11.1.3.31 [mysql_insert_id()], page 743.

If you use INSERT ... SELECT or an INSERT ... VALUES statement with multiple value lists, you can use the C API function mysql_info() to get information about the query. The format of the information string is shown here:

```
Records: 100 Duplicates: 0 Warnings: 0
```

Duplicates indicates the number of rows that couldn't be inserted because they would duplicate some existing unique index value. Warnings indicates the number of attempts to insert column values that were problematic in some way. Warnings can occur under any of the following conditions:

- Inserting NULL into a column that has been declared NOT NULL. The column is set to the default value appropriate for the column type. This is 0 for numeric types, the empty string ('') for string types, and the "zero" value for date and time types.
- Setting a numeric column to a value that lies outside the column's range. The value is clipped to the appropriate endpoint of the range.
- Setting a numeric column to a value such as '10.34 a'. The trailing garbage is stripped and the remaining numeric part is inserted. If the value doesn't make sense as a number at all, the column is set to 0.
- Inserting a string into a CHAR, VARCHAR, TEXT, or BLOB column that exceeds the column's maximum length. The value is truncated to the column's maximum length.
- Inserting a value into a date or time column that is illegal for the column type. The column is set to the appropriate zero value for the type.

6.4.3.1 INSERT ... SELECT Syntax

```
INSERT [LOW_PRIORITY] [IGNORE] [INTO] tbl_name [(column list)] SELECT ...
```

With INSERT ... SELECT statement you can quickly insert many rows into a table from one or many tables.

```
INSERT INTO tblTemp2 (fldID) SELECT tblTemp1.fldOrder_ID FROM tblTemp1 WHERE
tblTemp1.fldOrder_ID > 100;
```

The following conditions hold for an INSERT ... SELECT statement:

- Prior to MySQL 4.0.1, INSERT ... SELECT implicitly operates in IGNORE mode. As of MySQL 4.0.1, you should specify IGNORE explicitly to ignore records that would cause duplicate-key violations.
- Prior to MySQL 4.0.14, the target table of the INSERT statement cannot appear in the FROM clause of the SELECT part of the query. This limitation is lifted in 4.0.14.
- AUTO_INCREMENT columns work as usual.
- In C programs, you can use the C API function mysql_info() to get information about the query. See Section 6.4.3 [INSERT], page 546.
- To ensure that the binary log can be used to re-create the original tables, MySQL will not allow concurrent inserts during INSERT ... SELECT.

You can use REPLACE instead of INSERT to overwrite old rows. REPLACE is the counterpart to INSERT IGNORE in the treatment of new rows that contain unique key values that duplicate old rows: The new rows are used to replace the old rows rather than being discarded.

6.4.3.2 INSERT DELAYED Syntax

```
INSERT DELAYED ...
```

The DELAYED option for the INSERT statement is a MySQL-specific option that is very useful if you have clients that can't wait for the INSERT to complete. This is a common problem when you use MySQL for logging and you also periodically run SELECT and UPDATE statements that take a long time to complete. DELAYED was introduced in MySQL Version 3.22.15. It is a MySQL extension to SQL-92.

INSERT DELAYED only works with ISAM and MyISAM tables. Note that as MyISAM tables supports concurrent SELECT and INSERT, if there is no free blocks in the middle of the datafile, you very seldom need to use INSERT DELAYED with MyISAM. See Section 7.1 [MyISAM], page 595.

When you use INSERT DELAYED, the client will get an OK at once and the row will be inserted when the table is not in use by any other thread.

Another major benefit of using INSERT DELAYED is that inserts from many clients are bundled together and written in one block. This is much faster than doing many separate inserts.

Note that currently the queued rows are only stored in memory until they are inserted into the table. This means that if you kill mysqld the hard way (kill -9) or if mysqld dies unexpectedly, any queued rows that weren't written to disk are lost!

The following describes in detail what happens when you use the DELAYED option to INSERT or REPLACE. In this description, the "thread" is the thread that received an INSERT DELAYED command and "handler" is the thread that handles all INSERT DELAYED statements for a particular table.

- When a thread executes a DELAYED statement for a table, a handler thread is created to process all DELAYED statements for the table, if no such handler already exists.
- The thread checks whether the handler has acquired a DELAYED lock already; if not, it tells the handler thread to do so. The DELAYED lock can be obtained even if other threads have a READ or WRITE lock on the table. However, the handler will wait for all ALTER TABLE locks or FLUSH TABLES to ensure that the table structure is up to date.
- The thread executes the INSERT statement, but instead of writing the row to the table, it puts a copy of the final row into a queue that is managed by the handler thread. Any syntax errors are noticed by the thread and reported to the client program.
- The client can't report the number of duplicates or the AUTO_INCREMENT value for the resulting row; it can't obtain them from the server, because the INSERT returns before the insert operation has been completed. If you use the C API, the mysql_info() function doesn't return anything meaningful, for the same reason.
- The binary log is updated by the handler thread when the row is inserted into the table. In case of multiple-row inserts, the binary log is updated when the first row is inserted.
- After every delayed_insert_limit rows are written, the handler checks whether any SELECT statements are still pending. If so, it allows these to execute before continuing.
- When the handler has no more rows in its queue, the table is unlocked. If no new INSERT DELAYED commands are received within delayed_insert_timeout seconds, the handler terminates.

- If more than `delayed_queue_size` rows are pending already in a specific handler queue, the thread requesting `INSERT DELAYED` waits until there is room in the queue. This is done to ensure that the `mysqld` server doesn't use all memory for the delayed memory queue.
- The handler thread will show up in the MySQL process list with `delayed_insert` in the `Command` column. It will be killed if you execute a `FLUSH TABLES` command or kill it with `KILL thread_id`. However, it will first store all queued rows into the table before exiting. During this time it will not accept any new `INSERT` commands from another thread. If you execute an `INSERT DELAYED` command after this, a new handler thread will be created.

  Note that the above means that `INSERT DELAYED` commands have higher priority than normal `INSERT` commands if there is an `INSERT DELAYED` handler already running! Other update commands will have to wait until the `INSERT DELAYED` queue is empty, someone kills the handler thread (with `KILL thread_id`), or someone executes `FLUSH TABLES`.
- The following status variables provide information about `INSERT DELAYED` commands:

Variable	Meaning
`Delayed_insert_threads`	Number of handler threads
`Delayed_writes`	Number of rows written with `INSERT DELAYED`
`Not_flushed_delayed_rows`	Number of rows waiting to be written

  You can view these variables by issuing a `SHOW STATUS` statement or by executing a `mysqladmin extended-status` command.

Note that `INSERT DELAYED` is slower than a normal INSERT if the table is not in use. There is also the additional overhead for the server to handle a separate thread for each table on which you use `INSERT DELAYED`. This means that you should only use `INSERT DELAYED` when you are really sure you need it!

6.4.4 `UPDATE` Syntax

```
UPDATE [LOW_PRIORITY] [IGNORE] tbl_name
    SET col_name1=expr1 [, col_name2=expr2 ...]
    [WHERE where_definition]
    [ORDER BY ...]
    [LIMIT row_count]

or

UPDATE [LOW_PRIORITY] [IGNORE] tbl_name [, tbl_name ...]
    SET col_name1=expr1 [, col_name2=expr2 ...]
    [WHERE where_definition]
```

`UPDATE` updates columns in existing table rows with new values. The `SET` clause indicates which columns to modify and the values they should be given. The `WHERE` clause, if given, specifies which rows should be updated. Otherwise, all rows are updated. If the `ORDER BY` clause is specified, the rows will be updated in the order that is specified.

If you specify the keyword `LOW_PRIORITY`, execution of the `UPDATE` is delayed until no other clients are reading from the table.

If you specify the keyword `IGNORE`, the update statement will not abort even if we get duplicate key errors during the update. Rows that would cause conflicts will not be updated.

If you access a column from `tbl_name` in an expression, `UPDATE` uses the current value of the column. For example, the following statement sets the `age` column to one more than its current value:

```
mysql> UPDATE persondata SET age=age+1;
```

`UPDATE` assignments are evaluated from left to right. For example, the following statement doubles the `age` column, then increments it:

```
mysql> UPDATE persondata SET age=age*2, age=age+1;
```

If you set a column to the value it currently has, MySQL notices this and doesn't update it.

`UPDATE` returns the number of rows that were actually changed. In MySQL Version 3.22 or later, the C API function `mysql_info()` returns the number of rows that were matched and updated and the number of warnings that occurred during the `UPDATE`. If you update a column that has been declared `NOT NULL` by setting to `NULL`, the column is set to the default value appropriate for the column type and the warning count is incremented. The default value is is `0` for numeric types, the empty string (`''`) for string types, and the "zero" value for date and time types.

Starting from MySQL version 3.23, you can use `LIMIT row_count` to ensure that only a given number of rows are changed. MySQL will stop the update as soon as it has found `LIMIT` rows that satisfies the `WHERE` clause, independent of the rows changed content or not.

If an `ORDER BY` clause is used (available from MySQL 4.0.0), the rows will be updated in that order. This is really only useful in conjunction with `LIMIT`.

Starting with MySQL Version 4.0.4, you can also perform `UPDATE` operations that cover multiple tables:

```
UPDATE items,month SET items.price=month.price
WHERE items.id=month.id;
```

Note: you can not use `ORDER BY` or `LIMIT` with multi-table `UPDATE`.

6.4.5 DELETE Syntax

```
DELETE [LOW_PRIORITY] [QUICK] FROM table_name
       [WHERE where_definition]
       [ORDER BY ...]
       [LIMIT row_count]

or

DELETE [LOW_PRIORITY] [QUICK] table_name[.*] [, table_name[.*] ...]
       FROM table-references
       [WHERE where_definition]
```

```
or

DELETE [LOW_PRIORITY] [QUICK]
       FROM table_name[.*] [, table_name[.*] ...]
       USING table-references
       [WHERE where_definition]
```

`DELETE` deletes rows from `table_name` that satisfy the condition given by `where_definition`, and returns the number of records deleted.

If you issue a `DELETE` with no `WHERE` clause, all rows are deleted. If you do this in `AUTOCOMMIT` mode, this works as `TRUNCATE`. See Section 6.4.6 [TRUNCATE], page 554. In MySQL 3.23, `DELETE` without a `WHERE` clause will return zero as the number of affected records.

If you really want to know how many records are deleted when you are deleting all rows, and are willing to suffer a speed penalty, you can use a `DELETE` statement of this form:

```
mysql> DELETE FROM table_name WHERE 1>0;
```

Note that this is much slower than `DELETE FROM table_name` with no `WHERE` clause, because it deletes rows one at a time.

If you specify the keyword `LOW_PRIORITY`, execution of the `DELETE` is delayed until no other clients are reading from the table.

For MyISAM tables, if you specify the word `QUICK` then the storage engine will not merge index leaves during delete, which may speed up certain kind of deletes.

The speed of delete operations may also be affected by factors discussed in Section 5.2.12 [Delete speed], page 415.

In `MyISAM` tables, deleted records are maintained in a linked list and subsequent `INSERT` operations reuse old record positions. To reclaim unused space and reduce file-sizes, use the `OPTIMIZE TABLE` statement or the `myisamchk` utility to reorganise tables. `OPTIMIZE TABLE` is easier, but `myisamchk` is faster. See Section 4.6.1 [OPTIMIZE TABLE], page 281 and Section 4.5.6.10 [Optimisation], page 274.

The first multi-table delete format is supported starting from MySQL 4.0.0. The second multi-table delete format is supported starting from MySQL 4.0.2.

The idea is that only matching rows from the tables listed **before** the `FROM` or before the `USING` clause are deleted. The effect is that you can delete rows from many tables at the same time and also have additional tables that are used for searching.

The `.*` after the table names is there just to be compatible with `Access`:

```
DELETE t1,t2 FROM t1,t2,t3 WHERE t1.id=t2.id AND t2.id=t3.id

or

DELETE FROM t1,t2 USING t1,t2,t3 WHERE t1.id=t2.id AND t2.id=t3.id
```

In the above case we delete matching rows just from tables `t1` and `t2`.

If an `ORDER BY` clause is used (available from MySQL 4.0.0), the rows will be deleted in that order. This is really only useful in conjunction with `LIMIT`. For example:

```
DELETE FROM somelog
WHERE user = 'jcole'
```

```
ORDER BY timestamp
LIMIT 1
```

This will delete the oldest entry (by `timestamp`) where the row matches the `WHERE` clause.

The MySQL-specific `LIMIT row_count` option to `DELETE` tells the server the maximum number of rows to be deleted before control is returned to the client. This can be used to ensure that a specific `DELETE` command doesn't take too much time. You can simply repeat the `DELETE` command until the number of affected rows is less than the `LIMIT` value.

From MySQL 4.0, you can specify multiple tables in the `DELETE` statement to delete rows from one or more tables depending on a particular condition in multiple tables. However, you can not use `ORDER BY` or `LIMIT` in a multi-table `DELETE`.

6.4.6 `TRUNCATE` Syntax

```
TRUNCATE TABLE table_name
```

In 3.23 `TRUNCATE TABLE` is mapped to `COMMIT; DELETE FROM table_name`. See Section 6.4.5 [DELETE], page 552.

`TRUNCATE TABLE` differs from `DELETE FROM ...` in the following ways:

- Truncate operations drop and re-create the table, which is much faster than deleting rows one by one.
- Truncate operations are not transaction-safe; you will get an error if you have an active transaction or an active table lock.
- The number of deleted rows is not returned.
- As long as the table definition file '`table_name.frm`' is valid, the table can be re-created this way, even if the data or index files have become corrupted.

`TRUNCATE TABLE` is an Oracle SQL extension. This statement was added in MySQL 3.23.28, although from 3.23.28 to 3.23.32, the keyword `TABLE` must be omitted.

6.4.7 `REPLACE` Syntax

```
    REPLACE [LOW_PRIORITY | DELAYED]
        [INTO] tbl_name [(col_name,...)]
        VALUES (expression,...),(...),...
or  REPLACE [LOW_PRIORITY | DELAYED]
        [INTO] tbl_name [(col_name,...)]
        SELECT ...
or  REPLACE [LOW_PRIORITY | DELAYED]
        [INTO] tbl_name
        SET col_name=expression, col_name=expression,...
```

`REPLACE` works exactly like `INSERT`, except that if an old record in the table has the same value as a new record on a `UNIQUE` index or `PRIMARY KEY`, the old record is deleted before the new record is inserted. See Section 6.4.3 [INSERT], page 546.

In other words, you can't access the values of the old row from a `REPLACE` statement. In some old MySQL versions it appeared that you could do this, but that was a bug that has been corrected.

To be able to use REPLACE you must have INSERT and DELETE privileges for the table.

When you use a REPLACE command, mysql_affected_rows() will return 2 if the new row replaced an old row. This is because one row was inserted after the duplicate was deleted.

This fact makes it easy to determine whether REPLACE added or replaced a row: check whether the affected-rows value is 1 (added) or 2 (replaced).

Note that unless the table has a UNIQUE index or PRIMARY KEY, using a REPLACE command makes no sense. It becomes equivalent to INSERT, because there is no index to be used to determine whether a new row duplicates another.

Here follows the used algorithm in more detail: (This is also used with LOAD DATA ... REPLACE.

```
- Insert the row into the table
  - While duplicate key error for primary or unique key
    - Revert changed keys
    - Read conflicting row from the table through the duplicate key value
    - Delete conflicting row
    - Try again to insert the original primary key and unique keys in the tree
```

6.4.8 LOAD DATA INFILE Syntax

```
LOAD DATA [LOW_PRIORITY | CONCURRENT] [LOCAL] INFILE 'file_name.txt'
    [REPLACE | IGNORE]
    INTO TABLE tbl_name
    [FIELDS
        [TERMINATED BY '\t']
        [[OPTIONALLY] ENCLOSED BY '']
        [ESCAPED BY '\\' ]
    ]
    [LINES
        [STARTING BY '']
        [TERMINATED BY '\n']
    ]
    [IGNORE number LINES]
    [(col_name,...)]
```

The LOAD DATA INFILE statement reads rows from a text file into a table at a very high speed. If the LOCAL keyword is specified, it is interpreted with respect to the client end of the connection. When LOCAL is specified, the file is read by the client program on the client host and sent to the server. If LOCAL is not specified, the file must be located on the server host and is read directly by the server. (LOCAL is available in MySQL Version 3.22.6 or later.)

For security reasons, when reading text files located on the server, the files must either reside in the database directory or be readable by all. Also, to use LOAD DATA INFILE on server files, you must have the FILE privilege on the server host. See Section 4.3.7 [Privileges provided], page 222.

In MySQL 3.23.49 and MySQL 4.0.2 `LOCAL` will only work if you have not started `mysqld` with `--local-infile=0` or if you have not enabled your client to support `LOCAL`. See Section 4.3.4 [LOAD DATA LOCAL], page 218.

If you specify the keyword `LOW_PRIORITY`, execution of the `LOAD DATA` statement is delayed until no other clients are reading from the table.

If you specify the keyword `CONCURRENT` with a `MyISAM` table, then other threads can retrieve data from the table while `LOAD DATA` is executing. Using this option will of course affect the performance of `LOAD DATA` a bit even if no other thread is using the table at the same time.

Using `LOCAL` will be a bit slower than letting the server access the files directly, because the contents of the file must be sent over the connection by the client to the server. On the other hand, you do not need the `FILE` privilege to load local files.

If you are using MySQL before Version 3.23.24 you can't read from a FIFO with `LOAD DATA INFILE`. If you need to read from a FIFO (for example the output from gunzip), use `LOAD DATA LOCAL INFILE` instead.

You can also load datafiles by using the `mysqlimport` utility; it operates by sending a `LOAD DATA INFILE` command to the server. The `--local` option causes `mysqlimport` to read datafiles from the client host. You can specify the `--compress` option to get better performance over slow networks if the client and server support the compressed protocol.

When locating files on the server host, the server uses the following rules:

- If an absolute pathname is given, the server uses the pathname as is.
- If a relative pathname with one or more leading components is given, the server searches for the file relative to the server's data directory.
- If a filename with no leading components is given, the server looks for the file in the database directory of the current database.

Note that these rules mean a file named as '`./myfile.txt`' is read from the server's data directory, whereas the same file named as '`myfile.txt`' is read from the database directory of the current database. For example, the following `LOAD DATA` statement reads the file '`data.txt`' from the database directory for `db1` because `db1` is the current database, even though the statement explicitly loads the file into a table in the `db2` database:

```
mysql> USE db1;
mysql> LOAD DATA INFILE "data.txt" INTO TABLE db2.my_table;
```

The `REPLACE` and `IGNORE` keywords control handling of input records that duplicate existing records on unique key values.

If you specify `REPLACE`, input rows replace existing rows (in other words rows that has the same value for a primary or unique index as an existing row). See Section 6.4.7 [REPLACE], page 554.

If you specify `IGNORE`, input rows that duplicate an existing row on a unique key value are skipped. If you don't specify either option, the behaviour depends on whether or not the `LOCAL` keyword is specified. Without `LOCAL`, an error occurs when a duplicate key value is found, and the rest of the text file is ignored. With `LOCAL`, the default behaviour is the same as if `IGNORE` is specified; this is because the server has no way to stop transmission of the file in the middle of the operation.

If you want to ignore foreign key constraints during load you can do `SET FOREIGN_KEY_CHECKS=0` before executing `LOAD DATA`.

If you use `LOAD DATA INFILE` on an empty `MyISAM` table, all non-unique indexes are created in a separate batch (like in `REPAIR`). This normally makes `LOAD DATA INFILE` much faster when you have many indexes. Normally this is very fast, but in some extreme cases you can create the indexes even faster by turning them off with `ALTER TABLE .. DISABLE KEYS` and use `ALTER TABLE .. ENABLE KEYS` to recreate the indexes. See Section 4.5.6 [Table maintenance], page 264.

`LOAD DATA INFILE` is the complement of `SELECT ... INTO OUTFILE`. See Section 6.4.1 [SELECT], page 530. To write data from a table to a file, use `SELECT ... INTO OUTFILE`. To read the file back into a table, use `LOAD DATA INFILE`. The syntax of the `FIELDS` and `LINES` clauses is the same for both commands. Both clauses are optional, but `FIELDS` must precede `LINES` if both are specified.

If you specify a `FIELDS` clause, each of its subclauses (`TERMINATED BY`, `[OPTIONALLY] ENCLOSED BY`, and `ESCAPED BY`) is also optional, except that you must specify at least one of them.

If you don't specify a `FIELDS` clause, the defaults are the same as if you had written this:

```
FIELDS TERMINATED BY '\t' ENCLOSED BY '' ESCAPED BY '\\'
```

If you don't specify a `LINES` clause, the default is the same as if you had written this:

```
LINES TERMINATED BY '\n'
```

Note: If you have generated the text file on a Windows system you may have to change the above to: `LINES TERMINATED BY '\r\n'` as Windows uses two characters as a line terminator. Some programs, like `wordpad`, may use `\r` as a line terminator.

If all the lines you want to read in has a common prefix that you want to skip, you can use `LINES STARTING BY prefix_string` for this.

In other words, the defaults cause `LOAD DATA INFILE` to act as follows when reading input:

- Look for line boundaries at newlines.
- If `LINES STARTING BY prefix` is used, read until prefix is found and start reading at character after prefix. If line doesn't include prefix it will be skipped.
- Break lines into fields at tabs.
- Do not expect fields to be enclosed within any quoting characters.
- Interpret occurrences of tab, newline, or '\' preceded by '\' as literal characters that are part of field values.

Conversely, the defaults cause `SELECT ... INTO OUTFILE` to act as follows when writing output:

- Write tabs between fields.
- Do not enclose fields within any quoting characters.
- Use '\' to escape instances of tab, newline or '\' that occur within field values.
- Write newlines at the ends of lines.

Note that to write `FIELDS ESCAPED BY '\\'`, you must specify two backslashes for the value to be read as a single backslash.

The `IGNORE number LINES` option can be used to ignore lines at the start of the file. For example, you can use `IGNORE 1 LINES` to skip over an initial header line containing column names:

```
mysql> LOAD DATA INFILE "/tmp/file_name" INTO TABLE test IGNORE 1 LINES;
```

When you use `SELECT ... INTO OUTFILE` in tandem with `LOAD DATA INFILE` to write data from a database into a file and then read the file back into the database later, the field and line handling options for both commands must match. Otherwise, `LOAD DATA INFILE` will not interpret the contents of the file properly. Suppose you use `SELECT ... INTO OUTFILE` to write a file with fields delimited by commas:

```
mysql> SELECT * INTO OUTFILE 'data.txt'
    ->          FIELDS TERMINATED BY ','
    ->          FROM ...;
```

To read the comma-delimited file back in, the correct statement would be:

```
mysql> LOAD DATA INFILE 'data.txt' INTO TABLE table2
    ->           FIELDS TERMINATED BY ',';
```

If instead you tried to read in the file with the statement shown here, it wouldn't work because it instructs `LOAD DATA INFILE` to look for tabs between fields:

```
mysql> LOAD DATA INFILE 'data.txt' INTO TABLE table2
    ->           FIELDS TERMINATED BY '\t';
```

The likely result is that each input line would be interpreted as a single field.

`LOAD DATA INFILE` can be used to read files obtained from external sources, too. For example, a file in dBASE format will have fields separated by commas and enclosed in double quotes. If lines in the file are terminated by newlines, the command shown here illustrates the field and line handling options you would use to load the file:

```
mysql> LOAD DATA INFILE 'data.txt' INTO TABLE tbl_name
    ->           FIELDS TERMINATED BY ',' ENCLOSED BY '"'
    ->           LINES TERMINATED BY '\n';
```

Any of the field or line handling options may specify an empty string (`''`). If not empty, the `FIELDS [OPTIONALLY] ENCLOSED BY` and `FIELDS ESCAPED BY` values must be a single character. The `FIELDS TERMINATED BY` and `LINES TERMINATED BY` values may be more than one character. For example, to write lines that are terminated by carriage return-linefeed pairs, or to read a file containing such lines, specify a `LINES TERMINATED BY '\r\n'` clause.

For example, to read a file of jokes, that are separated with a line of `%%`, into an SQL table you can do:

```
CREATE TABLE jokes (a INT NOT NULL AUTO_INCREMENT PRIMARY KEY, joke TEXT
NOT NULL);
LOAD DATA INFILE "/tmp/jokes.txt" INTO TABLE jokes FIELDS TERMINATED BY ""
LINES TERMINATED BY "\n%%\n" (joke);
```

`FIELDS [OPTIONALLY] ENCLOSED BY` controls quoting of fields. For output (`SELECT ... INTO OUTFILE`), if you omit the word `OPTIONALLY`, all fields are enclosed by the `ENCLOSED BY` character. An example of such output (using a comma as the field delimiter) is shown here:

```
"1","a string","100.20"
"2","a string containing a , comma","102.20"
"3","a string containing a \" quote","102.20"
"4","a string containing a \", quote and comma","102.20"
```

If you specify `OPTIONALLY`, the `ENCLOSED BY` character is used only to enclose `CHAR` and `VARCHAR` fields:

```
1,"a string",100.20
2,"a string containing a , comma",102.20
3,"a string containing a \" quote",102.20
4,"a string containing a \", quote and comma",102.20
```

Note that occurrences of the `ENCLOSED BY` character within a field value are escaped by prefixing them with the `ESCAPED BY` character. Also note that if you specify an empty `ESCAPED BY` value, it is possible to generate output that cannot be read properly by `LOAD DATA INFILE`. For example, the preceding output just shown would appear as follows if the escape character is empty. Observe that the second field in the fourth line contains a comma following the quote, which (erroneously) appears to terminate the field:

```
1,"a string",100.20
2,"a string containing a , comma",102.20
3,"a string containing a " quote",102.20
4,"a string containing a ", quote and comma",102.20
```

For input, the `ENCLOSED BY` character, if present, is stripped from the ends of field values. (This is true whether `OPTIONALLY` is specified; `OPTIONALLY` has no effect on input interpretation.) Occurrences of the `ENCLOSED BY` character preceded by the `ESCAPED BY` character are interpreted as part of the current field value.

If the field begins with the `ENCLOSED BY` character, instances of that character are recognized as terminating a field value only if followed by the field or line `TERMINATED BY` sequence. To avoid ambiguity, occurrences of the `ENCLOSED BY` character within a field value can be doubled and will be interpreted as a single instance of the character. For example, if `ENCLOSED BY '"'` is specified, quotes are handled as shown here:

```
"The ""BIG"" boss"  -> The "BIG" boss
The "BIG" boss      -> The "BIG" boss
The ""BIG"" boss    -> The ""BIG"" boss
```

`FIELDS ESCAPED BY` controls how to write or read special characters. If the `FIELDS ESCAPED BY` character is not empty, it is used to prefix the following characters on output:

- The `FIELDS ESCAPED BY` character
- The `FIELDS [OPTIONALLY] ENCLOSED BY` character
- The first character of the `FIELDS TERMINATED BY` and `LINES TERMINATED BY` values
- ASCII `0` (what is actually written following the escape character is ASCII `'0'`, not a zero-valued byte)

If the `FIELDS ESCAPED BY` character is empty, no characters are escaped. It is probably not a good idea to specify an empty escape character, particularly if field values in your data contain any of the characters in the list just given.

For input, if the `FIELDS ESCAPED BY` character is not empty, occurrences of that character are stripped and the following character is taken literally as part of a field value. The exceptions are an escaped '`0`' or '`N`' (for example, `\0` or `\N` if the escape character is '`\`'). These sequences are interpreted as ASCII `0` (a zero-valued byte) and `NULL`. See below for the rules on `NULL` handling.

For more information about '`\`'-escape syntax, see Section 6.1.1 [Literals], page 441.

In certain cases, field and line handling options interact:

- If `LINES TERMINATED BY` is an empty string and `FIELDS TERMINATED BY` is non-empty, lines are also terminated with `FIELDS TERMINATED BY`.
- If the `FIELDS TERMINATED BY` and `FIELDS ENCLOSED BY` values are both empty (`''`), a fixed-row (non-delimited) format is used. With fixed-row format, no delimiters are used between fields (but you can still have a line terminator). Instead, column values are written and read using the "display" widths of the columns. For example, if a column is declared as `INT(7)`, values for the column are written using 7-character fields. On input, values for the column are obtained by reading 7 characters.

  `LINES TERMINATED BY` is still used to separate lines. If a line doesn't contain all fields, the rest of the fields will be set to their default values. If you don't have a line terminator, you should set this to `''`. In this case the text file must contain all fields for each row.

  Fixed-row format also affects handling of `NULL` values; see below. Note that fixed-size format will not work if you are using a multi-byte character set.

Handling of `NULL` values varies, depending on the `FIELDS` and `LINES` options you use:

- For the default `FIELDS` and `LINES` values, `NULL` is written as `\N` for output and `\N` is read as `NULL` for input (assuming the `ESCAPED BY` character is '\').
- If `FIELDS ENCLOSED BY` is not empty, a field containing the literal word `NULL` as its value is read as a `NULL` value (this differs from the word `NULL` enclosed within `FIELDS ENCLOSED BY` characters, which is read as the string `'NULL'`).
- If `FIELDS ESCAPED BY` is empty, `NULL` is written as the word `NULL`.
- With fixed-row format (which happens when `FIELDS TERMINATED BY` and `FIELDS ENCLOSED BY` are both empty), `NULL` is written as an empty string. Note that this causes both `NULL` values and empty strings in the table to be indistinguishable when written to the file because they are both written as empty strings. If you need to be able to tell the two apart when reading the file back in, you should not use fixed-row format.

Some cases are not supported by `LOAD DATA INFILE`:

- Fixed-size rows (`FIELDS TERMINATED BY` and `FIELDS ENCLOSED BY` both empty) and `BLOB` or `TEXT` columns.
- If you specify one separator that is the same as or a prefix of another, `LOAD DATA INFILE` won't be able to interpret the input properly. For example, the following `FIELDS` clause would cause problems:

  ```
  FIELDS TERMINATED BY '"' ENCLOSED BY '"'
  ```

- If `FIELDS ESCAPED BY` is empty, a field value that contains an occurrence of `FIELDS ENCLOSED BY` or `LINES TERMINATED BY` followed by the `FIELDS TERMINATED BY` value will cause `LOAD DATA INFILE` to stop reading a field or line too early. This happens because `LOAD DATA INFILE` cannot properly determine where the field or line value ends.

The following example loads all columns of the `persondata` table:

```
mysql> LOAD DATA INFILE 'persondata.txt' INTO TABLE persondata;
```

No field list is specified, so `LOAD DATA INFILE` expects input rows to contain a field for each table column. The default `FIELDS` and `LINES` values are used.

If you wish to load only some of a table's columns, specify a field list:

```
mysql> LOAD DATA INFILE 'persondata.txt'
    ->           INTO TABLE persondata (col1,col2,...);
```

You must also specify a field list if the order of the fields in the input file differs from the order of the columns in the table. Otherwise, MySQL cannot tell how to match up input fields with table columns.

If a row has too few fields, the columns for which no input field is present are set to default values. Default value assignment is described in Section 6.5.3 [`CREATE TABLE`], page 564.

An empty field value is interpreted differently than if the field value is missing:

- For string types, the column is set to the empty string.
- For numeric types, the column is set to `0`.
- For date and time types, the column is set to the appropriate "zero" value for the type. See Section 6.2.2 [Date and time types], page 460.

Note that these are the same values that result if you assign an empty string explicitly to a string, numeric, or date or time type explicitly in an `INSERT` or `UPDATE` statement.

`TIMESTAMP` columns are only set to the current date and time if there is a `NULL` value for the column (that is, `\N`), or (for the first `TIMESTAMP` column only) if the `TIMESTAMP` column is omitted from the field list when a field list is specified.

If an input row has too many fields, the extra fields are ignored and the number of warnings is incremented. Note that before MySQL 4.1.1 the warnings is just a number to indicate that something went wrong. In MySQL 4.1.1 you can do `SHOW WARNINGS` to get more information for what went wrong.

`LOAD DATA INFILE` regards all input as strings, so you can't use numeric values for `ENUM` or `SET` columns the way you can with `INSERT` statements. All `ENUM` and `SET` values must be specified as strings!

If you are using the C API, you can get information about the query by calling the API function `mysql_info()` when the `LOAD DATA INFILE` query finishes. The format of the information string is shown here:

```
Records: 1  Deleted: 0  Skipped: 0  Warnings: 0
```

Warnings occur under the same circumstances as when values are inserted via the `INSERT` statement (see Section 6.4.3 [`INSERT`], page 546), except that `LOAD DATA INFILE` also generates warnings when there are too few or too many fields in the input row. The warnings are not stored anywhere; the number of warnings can only be used as an indication if everything went well.

If you get warnings and want to know exactly why you got them, one way to do this is to use `SELECT ... INTO OUTFILE` into another file and compare this to your original input file.

If you need `LOAD DATA` to read from a pipe, you can use the following trick:

```
mkfifo /mysql/db/x/x
chmod 666 /mysql/db/x/x
cat < /dev/tcp/10.1.1.12/4711 > /nt/mysql/db/x/x
mysql -e "LOAD DATA INFILE 'x' INTO TABLE x" x
```

If you are using a version of MySQL older than 3.23.25 you can only do the above with `LOAD DATA LOCAL INFILE`.

In MySQL 4.1.1 you can use `SHOW WARNINGS` to get a list of the first `max_error_count` warnings. See Section 4.6.8.9 [SHOW WARNINGS], page 303.

For more information about the efficiency of `INSERT` versus `LOAD DATA INFILE` and speeding up `LOAD DATA INFILE`, See Section 5.2.10 [Insert speed], page 413.

6.4.9 `HANDLER` Syntax

```
HANDLER tbl_name OPEN [ AS alias ]
HANDLER tbl_name READ index_name { = | >= | <= | < } (value1,value2,...)
    [ WHERE ... ] [LIMIT ... ]
HANDLER tbl_name READ index_name { FIRST | NEXT | PREV | LAST }
    [ WHERE ... ] [LIMIT ... ]
HANDLER tbl_name READ { FIRST | NEXT }
    [ WHERE ... ] [LIMIT ... ]
HANDLER tbl_name CLOSE
```

The `HANDLER` statement provides direct access to the `MyISAM` table storage engine interface.

The first form of `HANDLER` statement opens a table, making it accessible via subsequent `HANDLER ... READ` statements. This table object is not shared by other threads and will not be closed until the thread calls `HANDLER tbl_name CLOSE` or the thread dies.

The second form fetches one row (or more, specified by `LIMIT` clause) where the index specified satisfies the given values and the `WHERE` condition is met. If you have a multiple-column index, specify the index column values as a comma-separated list. Either specify values for all the columns in the index, or specify values for a leftmost prefix of the index columns. Suppose an index includes three columns named `col_a`, `col_b`, and `col_c`, in that order. The `HANDLER` statement can specify values for all three columns in the index, or for the columns in a leftmost prefix. For example:

```
HANDLER ... index_name = (col_a_val,col_b_val,col_c_val) ...
HANDLER ... index_name = (col_a_val,col_b_val) ...
HANDLER ... index_name = (col_a_val) ...
```

The third form fetches one row (or more, specified by `LIMIT` clause) from the table in index order, matching `WHERE` condition.

The fourth form (without index specification) fetches one row (or more, specified by `LIMIT` clause) from the table in natural row order (as stored in datafile) matching `WHERE` condition. It is faster than `HANDLER tbl_name READ index_name` when a full table scan is desired.

`HANDLER ... CLOSE` closes a table that was opened with `HANDLER ... OPEN`.

Note: If you're using `HANDLER` interface for `PRIMARY KEY` you should remember to quote the keyword PRIMARY with backticks: `HANDLER tbl READ ‘PRIMARY‘ > (...)`

`HANDLER` is a somewhat low-level statement. For example, it does not provide consistency. That is, `HANDLER ... OPEN` does **NOT** take a snapshot of the table, and does **NOT** lock the table. This means that after a `HANDLER ... OPEN` is issued, table data can be modified (by this or any other thread) and these modifications may appear only partially in `HANDLER ... NEXT` or `HANDLER ... PREV` scans.

The reasons to use this interface instead of normal SQL are:

- It's faster than `SELECT` because:
  - A designated storage engine is allocated for the thread in `HANDLER OPEN`.
  - There is less parsing involved.
  - No optimiser and no query checking overhead.
  - The used table doesn't have to be locked between two handler requests.
  - The handler interface doesn't have to provide a consistent look of the data (for example, dirty-reads are allowed), so the storage engine can do optimisations that SQL doesn't normally allow.
- It makes it much easier to port applications that uses an ISAM like interface to MySQL.
- It allows one to traverse a database in a manner that is not easy (in some cases impossible) to do with SQL. The handler interface is more natural way to look at data when working with applications that provide an interactive user interfaces to the database.

6.4.10 `DO` Syntax

```
DO expression, [expression, ...]
```

Execute the expression but don't return any results. This is a shorthand of `SELECT expression, expression`, but has the advantage that it's slightly faster when you don't care about the result.

This is mainly useful with functions that has side effects, like `RELEASE_LOCK`.

6.5 Data Definition: `CREATE`, `DROP`, `ALTER`

6.5.1 `CREATE DATABASE` Syntax

```
CREATE DATABASE [IF NOT EXISTS] db_name
```

`CREATE DATABASE` creates a database with the given name.

Rules for allowable database names are given in Section 6.1.2 [Legal names], page 444. An error occurs if the database already exists and you didn't specify `IF NOT EXISTS`.

Databases in MySQL are implemented as directories containing files that correspond to tables in the database. Because there are no tables in a database when it is initially created, the `CREATE DATABASE` statement only creates a directory under the MySQL data directory.

You can also create databases with `mysqladmin`. See Section 4.9 [Client-Side Scripts], page 325.

6.5.2 `DROP DATABASE` Syntax

```
DROP DATABASE [IF EXISTS] db_name
```

`DROP DATABASE` drops all tables in the database and deletes the database. If you do a `DROP DATABASE` on a symbolic linked database, both the link and the original database is deleted. **Be VERY careful with this command!**

`DROP DATABASE` returns the number of files that were removed from the database directory. For `MyISAM` tables, this is three times the number of tables, because normally each table corresponds to a '`.MYD`' file, a '`.MYI`' file, and a '`.frm`' file.

The `DROP DATABASE` command removes from the given database directory all files with the following extensions:

Ext	Ext	Ext	Ext
.BAK	.DAT	.HSH	.ISD
.ISM	.ISM	.MRG	.MYD
.MYI	.db	.frm	

All subdirectories that consists of 2 digits (`RAID` directories) are also removed.

In MySQL Version 3.22 or later, you can use the keywords `IF EXISTS` to prevent an error from occurring if the database doesn't exist.

You can also drop databases with `mysqladmin`. See Section 4.9 [Client-Side Scripts], page 325.

6.5.3 `CREATE TABLE` Syntax

```
CREATE [TEMPORARY] TABLE [IF NOT EXISTS] tbl_name [(create_definition,...)]
[table_options] [select_statement]

or

CREATE [TEMPORARY] TABLE [IF NOT EXISTS] tbl_name [(] LIKE old_tbl_name [)];

create_definition:
    col_name type [NOT NULL | NULL] [DEFAULT default_value] [AUTO_INCREMENT]
            [[PRIMARY] KEY] [COMMENT 'string'] [reference_definition]
  | PRIMARY KEY (index_col_name,...)
  | KEY [index_name] (index_col_name,...)
  | INDEX [index_name] (index_col_name,...)
  | UNIQUE [INDEX] [index_name] (index_col_name,...)
  | FULLTEXT [INDEX] [index_name] (index_col_name,...)
  | [CONSTRAINT symbol] FOREIGN KEY [index_name] (index_col_name,...)
            [reference_definition]
  | CHECK (expr)

type:
    TINYINT[(length)] [UNSIGNED] [ZEROFILL]
  | SMALLINT[(length)] [UNSIGNED] [ZEROFILL]
  | MEDIUMINT[(length)] [UNSIGNED] [ZEROFILL]
  | INT[(length)] [UNSIGNED] [ZEROFILL]
  | INTEGER[(length)] [UNSIGNED] [ZEROFILL]
  | BIGINT[(length)] [UNSIGNED] [ZEROFILL]
  | REAL[(length,decimals)] [UNSIGNED] [ZEROFILL]
  | DOUBLE[(length,decimals)] [UNSIGNED] [ZEROFILL]
  | FLOAT[(length,decimals)] [UNSIGNED] [ZEROFILL]
```

```
  | DECIMAL(length,decimals) [UNSIGNED] [ZEROFILL]
  | NUMERIC(length,decimals) [UNSIGNED] [ZEROFILL]
  | CHAR(length) [BINARY | ASCII | UNICODE]
  | VARCHAR(length) [BINARY]
  | DATE
  | TIME
  | TIMESTAMP
  | DATETIME
  | TINYBLOB
  | BLOB
  | MEDIUMBLOB
  | LONGBLOB
  | TINYTEXT
  | TEXT
  | MEDIUMTEXT
  | LONGTEXT
  | ENUM(value1,value2,value3,...)
  | SET(value1,value2,value3,...)

index_col_name:
        col_name [(length)] [ASC | DESC]

reference_definition:
        REFERENCES tbl_name [(index_col_name,...)]
                   [MATCH FULL | MATCH PARTIAL]
                   [ON DELETE reference_option]
                   [ON UPDATE reference_option]

reference_option:
        RESTRICT | CASCADE | SET NULL | NO ACTION | SET DEFAULT

table_options: table_option [table_option] ...

table_option:
    TYPE = {BDB | HEAP | ISAM | InnoDB | MERGE | MRG_MYISAM | MYISAM }
  | AUTO_INCREMENT = #
  | AVG_ROW_LENGTH = #
  | CHECKSUM = {0 | 1}
  | COMMENT = 'string'
  | MAX_ROWS = #
  | MIN_ROWS = #
  | PACK_KEYS = {0 | 1 | DEFAULT}
  | PASSWORD = 'string'
  | DELAY_KEY_WRITE = {0 | 1}
  | ROW_FORMAT = { DEFAULT | DYNAMIC | FIXED | COMPRESSED }
  | RAID_TYPE = { 1 | STRIPED | RAID0 } RAID_CHUNKS=#  RAID_CHUNKSIZE=#
  | UNION = (table_name,[table_name...])
```

```
  | INSERT_METHOD = { NO | FIRST | LAST }
  | DATA DIRECTORY = 'absolute path to directory'
  | INDEX DIRECTORY = 'absolute path to directory'
  | DEFAULT CHARACTER SET character_set_name [COLLATE collation_name]

select_statement:
    [IGNORE | REPLACE] [AS] SELECT ...     (Some legal select statement)
```

`CREATE TABLE` creates a table with the given name. Rules for allowable table names are given in Section 6.1.2 [Legal names], page 444. By default, the table is created in the current database. An error occurs if the table already exists, if there is no current database, or if the database does not exist.

In MySQL Version 3.22 or later, the table name can be specified as `db_name.tbl_name` to create the table in a specific database. This works regardless of whether there is a current database.

From MySQL Version 3.23, you can use the `TEMPORARY` keyword when you create a table. The temporary table is visible only to the current connection, and will be deleted automatically when the connection is closed. This means that two different connections can both use the same temporary table name without conflicting with each other or with an existing table of the same name. (The existing table is hidden until the temporary table is deleted.) From MySQL 4.0.2 on, you must have the `CREATE TEMPORARY TABLES` privilege to be able to create temporary tables.

In MySQL Version 3.23 or later, you can use the keywords `IF NOT EXISTS` so that an error does not occur if the table already exists. Note that there is no verification that the existing table has a structure identical to that indicated by the `CREATE TABLE` statement.

From version 4.1.0, the attribute `SERIAL` can be used as an alias for `BIGINT NOT NULL AUTO_INCREMENT UNIQUE`. This is compatibility feature.

As of MySQL 3.23, you can create one table from another by adding a `SELECT` statement at the end of the `CREATE TABLE` statement:

```
CREATE TABLE new_tbl SELECT * FROM orig_tbl;
```

Indexes are not carried over to the new table, and some conversion of column types may occur. For example, the `AUTO_INCREMENT` attribute is not preserved, and `VARCHAR` columns may become `CHAR` columns.

As of MySQL 4.1, you can explicitly specify the type for a generated column:

```
CREATE TABLE foo (a tinyint not null) SELECT b+1 AS 'a' FROM bar;
```

In MySQL 4.1, you can also use `LIKE` to create a table based on the definition of another table, including any column attributes and indexes the original table has:

```
CREATE TABLE new_tbl LIKE orig_tbl;
```

`CREATE TABLE ... LIKE` does not copy any `DATA DIRECTORY` or `INDEX DIRECTORY` table options that were specified for the original table.

Each table `tbl_name` is represented by some files in the database directory. In the case of `MyISAM`-type tables you will get:

File	Purpose
`tbl_name.frm`	Table format (definition) file

`tbl_name.MYD` Datafile
`tbl_name.MYI` Index file

For more information on the properties of the various column types, see Section 6.2 [Column types], page 453:

- If neither `NULL` nor `NOT NULL` is specified, the column is treated as though `NULL` had been specified.
- An integer column may have the additional attribute `AUTO_INCREMENT`. When you insert a value of `NULL` (recommended) or `0` into an indexed `AUTO_INCREMENT` column, the column is set to the next sequence value. Typically this is `value+1`, where `value` is the largest value for the column currently in the table. `AUTO_INCREMENT` sequences begin with `1`. See Section 11.1.3.31 [`mysql_insert_id()`], page 743.

  If you delete the row containing the maximum value for an `AUTO_INCREMENT` column, the value will be reused for an `ISAM` or `BDB` table, but not for a `MyISAM` or `InnoDB` table. If you delete all rows in the table with `DELETE FROM table_name` (without a `WHERE`) in `AUTOCOMMIT` mode, the sequence starts over for all table types except `InnoDB`. See Section 7.5.12.5 [InnoDB auto-increment column], page 634.

  Note: there can be only one `AUTO_INCREMENT` column per table, it must be indexed and it can't have a `DEFAULT` value. In MySQL Version 3.23, an `AUTO_INCREMENT` column will work properly only if it contains only positive values. Inserting a negative number is regarded as inserting a very large positive number. This is done to avoid precision problems when numbers "wrap" over from positive to negative and also to ensure that one doesn't accidentally get an `AUTO_INCREMENT` column that contains 0.

  In `MyISAM` and `BDB` tables you can specify `AUTO_INCREMENT` secondary column in a multiple-column key. See Section 3.6.9 [example-AUTO_INCREMENT], page 189.

  To make MySQL compatible with some ODBC applications, you can find the `AUTO_INCREMENT` value for the last inserted row with the following query:

  ```
  SELECT * FROM tbl_name WHERE auto_col IS NULL
  ```

- `NULL` values are handled differently for `TIMESTAMP` columns than for other column types. You cannot store a literal `NULL` in a `TIMESTAMP` column; setting the column to `NULL` sets it to the current date and time. Because `TIMESTAMP` columns behave this way, the `NULL` and `NOT NULL` attributes do not apply in the normal way and are ignored if you specify them.

  On the other hand, to make it easier for MySQL clients to use `TIMESTAMP` columns, the server reports that such columns may be assigned `NULL` values (which is true), even though `TIMESTAMP` never actually will contain a `NULL` value. You can see this when you use `DESCRIBE tbl_name` to get a description of your table.

  Note that setting a `TIMESTAMP` column to `0` is not the same as setting it to `NULL`, because `0` is a valid `TIMESTAMP` value.

- A `DEFAULT` value has to be a constant, it cannot be a function or an expression.

  If no `DEFAULT` value is specified for a column, MySQL automatically assigns one, as follows.

  If the column may take `NULL` as a value, the default value is `NULL`.

  If the column is declared as `NOT NULL`, the default value depends on the column type:

  - For numeric types other than those declared with the `AUTO_INCREMENT` attribute, the default is `0`. For an `AUTO_INCREMENT` column, the default value is the next value in the sequence.
  - For date and time types other than `TIMESTAMP`, the default is the appropriate zero value for the type. For the first `TIMESTAMP` column in a table, the default value is the current date and time. See Section 6.2.2 [Date and time types], page 460.
  - For string types other than `ENUM`, the default value is the empty string. For `ENUM`, the default is the first enumeration value.

  Default values must be constants. This means, for example, that you cannot set the default for a date column to be the value of a function such as `NOW()` or `CURRENT_DATE`.
- A comment for a column may be specified with the `COMMENT` option. The comment is displayed by the `SHOW CREATE TABLE` statement, and by `SHOW FULL COLUMNS`. This option is available as of MySQL 4.1. (It is allowed but ignored in earlier versions.)
- `KEY` is normally a synonym for `INDEX`. From version 4.1, the key attribute `PRIMARY KEY` may also be specified as just `KEY`. This was implemented for compatibility with other databases.
- In MySQL, a `UNIQUE` key can have only distinct values. An error occurs if you try to add a new row with a key that matches an existing row.
- A `PRIMARY KEY` is a unique `KEY` where all key columns must be defined as `NOT NULL`. If they are not explicitly declared as `NOT NULL`, it will be done implicitly (and quietly). In MySQL the key is named `PRIMARY`. A table can have only one `PRIMARY KEY`. If you don't have a `PRIMARY KEY` and some applications ask for the `PRIMARY KEY` in your tables, MySQL will return the first `UNIQUE` key, which doesn't have any `NULL` columns, as the `PRIMARY KEY`.
- A `PRIMARY KEY` can be a multiple-column index. However, you cannot create a multiple-column index using the `PRIMARY KEY` key attibute in a column specification. Doing so will mark only that single column as primary. You must use a separate `PRIMARY KEY(index_col_name, ...)` clause.
- A `UNIQUE` index is one in which all values in the index must be distinct. The exception to this is that if a column in the index is allowed to contain `NULL` values, it may contain multiple `NULL` values. This exception does not apply to `BDB` tables, which allow only a single `NULL`.
- If the `PRIMARY` or `UNIQUE` key consists of only one column and this is of type integer, you can also refer to it as `_rowid` (new in Version 3.23.11).
- If you don't assign a name to an index that is not a `PRIMARY KEY`, the index will be assigned the same name as the first `index_col_name`, with an optional suffix (`_2`, `_3`, `...`) to make it unique. You can see index names for a table using `SHOW INDEX FROM tbl_name`. See Section 4.6.8.1 [Show database info], page 285.
- Only the `MyISAM`, `InnoDB`, and `BDB` table types support indexes on columns that can have `NULL` values. In other cases you must declare such columns `NOT NULL` or an error results.
- With `col_name(length)` syntax in an index specification, you can create an index that uses only the first `length` bytes of a `CHAR` or `VARCHAR` column. This can make the index file much smaller. See Section 5.4.4 [Indexes], page 423.

- Only the `MyISAM` and (as of MySQL 4.0.14) `InnoDB` table types support indexing on `BLOB` and `TEXT` columns. When putting an index on a `BLOB` or `TEXT` column you MUST always specify the length of the index, up to 255 bytes. For example:

```
CREATE TABLE test (blob_col BLOB, INDEX(blob_col(10)));
```

- An `index_col_name` specification may end with `ASC` or `DESC`. These keywords are allowed for future extensions for specifying ascending or descending index value storage. Currently they are parsed but ignored; index values are always stored in ascending order.
- When you use `ORDER BY` or `GROUP BY` with a `TEXT` or `BLOB` column, the server sorts values using only the initial number of bytes indicated by the `max_sort_length` server variable. See Section 6.2.3.2 [BLOB], page 468.
- In MySQL Version 3.23.23 or later, you can also create special `FULLTEXT` indexes. They are used for full-text search. Only the `MyISAM` table type supports `FULLTEXT` indexes. They can be created only from `CHAR`, `VARCHAR`, and `TEXT` columns. Indexing always happens over the entire column; partial indexing is not supported. See Section 6.8 [Fulltext Search], page 584 for details of operation.
- In MySQL Version 3.23.44 or later, `InnoDB` tables support checking of foreign key constraints. See Section 7.5 [InnoDB], page 606. Note that the `FOREIGN KEY` syntax in `InnoDB` is more restrictive than the syntax presented above: The columns of the referenced table must always be explicitly named. InnoDB supports both `ON DELETE` and `ON UPDATE` actions on foreign keys as of MySQL 3.23.50 and 4.0.8, respectively. See the `InnoDB` manual section for the precise syntax. See Section 7.5.5.2 [InnoDB foreign key constraints], page 615. For other table types, MySQL Server does parse the `FOREIGN KEY`, `CHECK`, and `REFERENCES` syntax in `CREATE TABLE` commands, but without further action being taken. See Section 1.7.4.5 [ANSI diff Foreign Keys], page 40.
- For `MyISAM` and `ISAM` tables, each `NULL` column takes one bit extra, rounded up to the nearest byte. The maximum record length in bytes can be calculated as follows:

```
row length = 1
             + (sum of column lengths)
             + (number of NULL columns + delete_flag + 7)/8
             + (number of variable-length columns)
```

  `delete_flag` is 1 for tables with static record format. Static tables use a bit in the row record for a flag that indicates whether the row has been deleted. `delete_flag` is 0 for dynamic tables because the flag is stored in the dynamic row header.

  These calculations do not apply for `InnoDB` tables, for which storage size is not different for `NULL` columns compared to `NOT NULL` columns.
- The `table_options` and `SELECT` options are only implemented in MySQL Version 3.23 and above.

  The `TYPE` option for specifying the table type takes the following values:

Table type	Description
`BDB` or `BerkeleyDB`	Transaction-safe tables with page locking. See Section 7.6 [BDB], page 654.
`HEAP`	The data for this table is only stored in memory. See Section 7.4 [HEAP], page 605.
`ISAM`	The original storage engine. See Section 7.3 [ISAM], page 604.

`InnoDB`	Transaction-safe tables with row locking. See Section 7.5 [InnoDB], page 606.
`MERGE`	A collection of `MyISAM` tables used as one table. See Section 7.2 [MERGE], page 601.
`MRG_MyISAM`	An alias for `MERGE`.
`MyISAM`	The new binary portable storage engine that is the replacement for `ISAM`. See Section 7.1 [`MyISAM`], page 595.

See Chapter 7 [Table types], page 594.

If a table type is specified, and that particular type is not available, MySQL will use `MyISAM` instead. For example, if a table definition includes the `TYPE=BDB` option but the MySQL server does not support `BDB` tables, the table will be created as a `MyISAM` table. This makes it possible to have a replication setup where you have transactional tables on the master but tables created on the slave are non-transactional (to get more speed). In MySQL 4.1.1 you get a warning if the specified table type is not honored.

The other table options are used to optimise the behaviour of the table. In most cases, you don't have to specify any of them. The options work for all table types, unless otherwise indicated:

Option	**Description**
`AUTO_INCREMENT`	The next `AUTO_INCREMENT` value you want to set for your table (`MyISAM` only; to set the first auto-increment value for an `InnoDB` table, insert a dummy row with a value one less, and delete the dummy row).
`AVG_ROW_LENGTH`	An approximation of the average row length for your table. You only need to set this for large tables with variable size records.
`CHECKSUM`	Set this to 1 if you want MySQL to maintain a checksum for all rows (makes the table a little slower to update but makes it easier to find corrupted tables) (`MyISAM` only).
`COMMENT`	A 60-character comment for your table.
`MAX_ROWS`	Maximum number of rows you plan to store in the table.
`MIN_ROWS`	Minimum number of rows you plan to store in the table.
`PACK_KEYS`	Set this to 1 if you want to have a smaller index. This usually makes updates slower and reads faster (`MyISAM` and `ISAM` only). Setting this to 0 will disable all packing of keys. Setting this to `DEFAULT` (MySQL 4.0) will tell the storage engine to only pack long `CHAR`/`VARCHAR` columns.
`PASSWORD`	Encrypt the '`.frm`' file with a password. This option doesn't do anything in the standard MySQL version.
`DELAY_KEY_WRITE`	Set this to 1 if want to delay key table updates until the table is closed (`MyISAM` only).
`ROW_FORMAT`	Defines how the rows should be stored. Currently this option only works with `MyISAM` tables, which supports the `DYNAMIC` and `FIXED` row formats. See Section 7.1.2 [MyISAM table formats], page 597.

When you use a `MyISAM` table, MySQL uses the product of `MAX_ROWS * AVG_ROW_LENGTH` to decide how big the resulting table will be. If you don't specify any of the above options, the maximum size for a table will be 4G (or 2G if your operating

systems only supports 2G tables). The reason for this is just to keep down the pointer sizes to make the index smaller and faster if you don't really need big files.

If you don't use `PACK_KEYS`, the default is to only pack strings, not numbers. If you use `PACK_KEYS=1`, numbers will be packed as well.

When packing binary number keys, MySQL will use prefix compression. This means that you will only get a big benefit from this if you have many numbers that are the same. Prefix compression means that every key needs one extra byte to indicate how many bytes of the previous key are the same for the next key (note that the pointer to the row is stored in high-byte-first order directly after the key, to improve compression). This means that if you have many equal keys on two consecutive rows, all following "same" keys will usually only take 2 bytes (including the pointer to the row). Compare this to the ordinary case where the following keys will take storage_size_for_key + pointer_size (usually 4). On the other hand, if all keys are totally different, you will use 1 byte more per key, if the key isn't a key that can have `NULL` values. (In this case the packed key length will be stored in the same byte that is used to mark if a key is `NULL`.)

- As of MySQL 3.23, if you specify a `SELECT` after the `CREATE` statement, MySQL will create new fields for all elements in the `SELECT`. For example:

```
mysql> CREATE TABLE test (a INT NOT NULL AUTO_INCREMENT,
    ->        PRIMARY KEY (a), KEY(b))
    ->        TYPE=MyISAM SELECT b,c FROM test2;
```

This will create a `MyISAM` table with three columns, a, b, and c. Notice that the columns from the `SELECT` statement are appended to the right side of the table, not overlapped onto it. Take the following example:

```
mysql> SELECT * FROM foo;
+---+
| n |
+---+
| 1 |
+---+

mysql> CREATE TABLE bar (m INT) SELECT n FROM foo;
Query OK, 1 row affected (0.02 sec)
Records: 1  Duplicates: 0  Warnings: 0

mysql> SELECT * FROM bar;
+------+---+
| m    | n |
+------+---+
| NULL | 1 |
+------+---+
1 row in set (0.00 sec)
```

For each row in table `foo`, a row is inserted in `bar` with the values from `foo` and default values for the new columns.

`CREATE TABLE ... SELECT` will not automatically create any indexes for you. This is done intentionally to make the command as flexible as possible. If you want to have indexes in the created table, you should specify these before the `SELECT` statement:

```
mysql> CREATE TABLE bar (UNIQUE (n)) SELECT n FROM foo;
```

If any errors occur while copying the data to the table, it will automatically be deleted.

You can precede the `SELECT` by `IGNORE` or `REPLACE` to indicate how to handle records that duplicate unique key values. With `IGNORE`, new records that duplicate an existing record on a unique key value are discarded. With `REPLACE`, new records replace records that have the same unique key value. If neither `IGNORE` nor `REPLACE` are specified, duplicate unique key values result in an error.

To ensure that the update log/binary log can be used to re-create the original tables, MySQL will not allow concurrent inserts during `CREATE TABLE ... SELECT`.

- The `RAID_TYPE` option will help you to exceed the 2G/4G limit for the MyISAM datafile (not the index file) on operating systems that don't support big files. Note that this option is not recommended for filesystem that supports big files!

  You can get more speed from the I/O bottleneck by putting `RAID` directories on different physical disks. `RAID_TYPE` will work on any operating system, as long as you have configured MySQL with `--with-raid`. For now the only allowed `RAID_TYPE` is `STRIPED` (`1` and `RAID0` are aliases for this).

  If you specify `RAID_TYPE=STRIPED` for a `MyISAM` table, `MyISAM` will create `RAID_CHUNKS` subdirectories named 00, 01, 02 in the database directory. In each of these directories `MyISAM` will create a `table_name.MYD`. When writing data to the datafile, the `RAID` handler will map the first `RAID_CHUNKSIZE` *1024 bytes to the first file, the next `RAID_CHUNKSIZE` *1024 bytes to the next file and so on.

- `UNION` is used when you want to use a collection of identical tables as one. This only works with `MERGE` tables. See Section 7.2 [`MERGE`], page 601.

  For the moment you need to have `SELECT`, `UPDATE`, and `DELETE` privileges on the tables you map to a `MERGE` table. All mapped tables must be in the same database as the `MERGE` table.

- If you want to insert data in a `MERGE` table, you have to specify with `INSERT_METHOD` into with table the row should be inserted. `INSERT_METHOD` is an option useful for `MERGE` tables only. See Section 7.2 [MERGE], page 601. This option was introduced in MySQL 4.0.0.

- In the created table the `PRIMARY` key will be placed first, followed by all `UNIQUE` keys and then the normal keys. This helps the MySQL optimiser to prioritise which key to use and also more quickly detect duplicated `UNIQUE` keys.

- By using `DATA DIRECTORY='directory'` or `INDEX DIRECTORY='directory'` you can specify where the storage engine should put its datafile and index file. Note that the directory should be a full path to the directory (not a relative path).

  This only works for `MyISAM` tables in `MySQL` 4.0, when you are not using the `--skip-symlink` option. See Section 5.6.1.2 [Symbolic links to tables], page 439.

6.5.3.1 Silent Column Specification Changes

In some cases, MySQL silently changes a column specification from that given in a `CREATE TABLE` statement. (This may also occur with `ALTER TABLE`.):

- `VARCHAR` columns with a length less than four are changed to `CHAR`.
- If any column in a table has a variable length, the entire row is variable-length as a result. Therefore, if a table contains any variable-length columns (`VARCHAR`, `TEXT`, or `BLOB`), all `CHAR` columns longer than three characters are changed to `VARCHAR` columns. This doesn't affect how you use the columns in any way; in MySQL, `VARCHAR` is just a different way to store characters. MySQL performs this conversion because it saves space and makes table operations faster. See Chapter 7 [Table types], page 594.
- From version 4.1.0, if a `CHAR` or `VARCHAR` field with a length specification greater than 255 is converted to `TEXT`. This is a compatibility feature.
- `TIMESTAMP` display sizes must be even and in the range from 2 to 14. If you specify a display size of 0 or greater than 14, the size is coerced to 14. Odd-valued sizes in the range from 1 to 13 are coerced to the next higher even number.
- You cannot store a literal `NULL` in a `TIMESTAMP` column; setting it to `NULL` sets it to the current date and time. Because `TIMESTAMP` columns behave this way, the `NULL` and `NOT NULL` attributes do not apply in the normal way and are ignored if you specify them. `DESCRIBE tbl_name` always reports that a `TIMESTAMP` column may be assigned `NULL` values.
- MySQL maps certain column types used by other SQL database vendors to MySQL types. See Section 6.2.5 [Other-vendor column types], page 472.

If you want to see whether MySQL used a column type other than the one you specified, issue a `DESCRIBE tbl_name` statement after creating or altering your table.

Certain other column type changes may occur if you compress a table using `myisampack`. See Section 7.1.2.3 [Compressed format], page 599.

6.5.4 `ALTER TABLE` Syntax

```
ALTER [IGNORE] TABLE tbl_name alter_specification [, alter_specification ...]

alter_specification:
    ADD [COLUMN] create_definition [FIRST | AFTER column_name ]
  | ADD [COLUMN] (create_definition, create_definition,...)
  | ADD INDEX [index_name] (index_col_name,...)
  | ADD PRIMARY KEY (index_col_name,...)
  | ADD UNIQUE [index_name] (index_col_name,...)
  | ADD FULLTEXT [index_name] (index_col_name,...)
  | ADD [CONSTRAINT symbol] FOREIGN KEY [index_name] (index_col_name,...)
          [reference_definition]
  | ALTER [COLUMN] col_name {SET DEFAULT literal | DROP DEFAULT}
  | CHANGE [COLUMN] old_col_name create_definition
          [FIRST | AFTER column_name]
  | MODIFY [COLUMN] create_definition [FIRST | AFTER column_name]
```

```
    | DROP [COLUMN] col_name
    | DROP PRIMARY KEY
    | DROP INDEX index_name
    | DISABLE KEYS
    | ENABLE KEYS
    | RENAME [TO] new_tbl_name
    | ORDER BY col
    | CHARACTER SET character_set_name [COLLATE collation_name]
    | table_options
```

`ALTER TABLE` allows you to change the structure of an existing table. For example, you can add or delete columns, create or destroy indexes, change the type of existing columns, or rename columns or the table itself. You can also change the comment for the table and type of the table. See Section 6.5.3 [`CREATE TABLE`], page 564.

If you use `ALTER TABLE` to change a column specification but `DESCRIBE tbl_name` indicates that your column was not changed, it is possible that MySQL ignored your modification for one of the reasons described in Section 6.5.3.1 [Silent column changes], page 573. For example, if you try to change a `VARCHAR` column to `CHAR`, MySQL will still use `VARCHAR` if the table contains other variable-length columns.

`ALTER TABLE` works by making a temporary copy of the original table. The alteration is performed on the copy, then the original table is deleted and the new one is renamed. This is done in such a way that all updates are automatically redirected to the new table without any failed updates. While `ALTER TABLE` is executing, the original table is readable by other clients. Updates and writes to the table are stalled until the new table is ready.

Note that if you use any other option to `ALTER TABLE` than `RENAME`, MySQL will always create a temporary table, even if the data wouldn't strictly need to be copied (like when you change the name of a column). We plan to fix this in the future, but as one doesn't normally do `ALTER TABLE` that often this isn't that high on our TODO. For MyISAM tables, you can speed up the index recreation part (which is the slowest part of the recreation process) by setting the `myisam_sort_buffer_size` variable to a high value.

- To use `ALTER TABLE`, you need `ALTER`, `INSERT`, and `CREATE` privileges on the table.
- `IGNORE` is a MySQL extension to SQL-92. It controls how `ALTER TABLE` works if there are duplicates on unique keys in the new table. If `IGNORE` isn't specified, the copy is aborted and rolled back. If `IGNORE` is specified, then for rows with duplicates on a unique key, only the first row is used; the others are deleted.
- You can issue multiple `ADD`, `ALTER`, `DROP`, and `CHANGE` clauses in a single `ALTER TABLE` statement. This is a MySQL extension to SQL-92, which allows only one of each clause per `ALTER TABLE` statement.
- `CHANGE col_name`, `DROP col_name`, and `DROP INDEX` are MySQL extensions to SQL-92.
- `MODIFY` is an Oracle extension to `ALTER TABLE`.
- The optional word `COLUMN` is a pure noise word and can be omitted.
- If you use `ALTER TABLE tbl_name RENAME TO new_name` without any other options, MySQL simply renames the files that correspond to the table `tbl_name`. There is no need to create the temporary table. See Section 6.5.5 [`RENAME TABLE`], page 577.

- `create_definition` clauses use the same syntax for `ADD` and `CHANGE` as for `CREATE TABLE`. Note that this syntax includes the column name, not just the column type. See Section 6.5.3 [`CREATE TABLE`], page 564.
- You can rename a column using a `CHANGE old_col_name create_definition` clause. To do so, specify the old and new column names and the type that the column currently has. For example, to rename an `INTEGER` column from `a` to `b`, you can do this:

  ```
  mysql> ALTER TABLE t1 CHANGE a b INTEGER;
  ```

  If you want to change a column's type but not the name, `CHANGE` syntax still requires an old and new column name, even if they are the same. For example:

  ```
  mysql> ALTER TABLE t1 CHANGE b b BIGINT NOT NULL;
  ```

  However, as of MySQL Version 3.22.16a, you can also use `MODIFY` to change a column's type without renaming it:

  ```
  mysql> ALTER TABLE t1 MODIFY b BIGINT NOT NULL;
  ```
- If you use `CHANGE` or `MODIFY` to shorten a column for which an index exists on part of the column (for instance, if you have an index on the first 10 characters of a `VARCHAR` column), you cannot make the column shorter than the number of characters that are indexed.
- When you change a column type using `CHANGE` or `MODIFY`, MySQL tries to convert data to the new type as well as possible.
- In MySQL Version 3.22 or later, you can use `FIRST` or `ADD ... AFTER col_name` to add a column at a specific position within a table row. The default is to add the column last. From MySQL Version 4.0.1, you can also use the `FIRST` and `AFTER` keywords in `CHANGE` or `MODIFY`.
- `ALTER COLUMN` specifies a new default value for a column or removes the old default value. If the old default is removed and the column can be `NULL`, the new default is `NULL`. If the column cannot be `NULL`, MySQL assigns a default value, as described in Section 6.5.3 [`CREATE TABLE`], page 564.
- `DROP INDEX` removes an index. This is a MySQL extension to SQL-92. See Section 6.5.8 [DROP INDEX], page 579.
- If columns are dropped from a table, the columns are also removed from any index of which they are a part. If all columns that make up an index are dropped, the index is dropped as well.
- If a table contains only one column, the column cannot be dropped. If what you intend is to remove the table, use `DROP TABLE` instead.
- `DROP PRIMARY KEY` drops the primary index. If no such index exists, it drops the first `UNIQUE` index in the table. (MySQL marks the first `UNIQUE` key as the `PRIMARY KEY` if no `PRIMARY KEY` was specified explicitly.)

  If you add a `UNIQUE INDEX` or `PRIMARY KEY` to a table, this is stored before any not `UNIQUE` index so that MySQL can detect duplicate keys as early as possible.
- `ORDER BY` allows you to create the new table with the rows in a specific order. Note that the table will not remain in this order after inserts and deletes. In some cases, it may make sorting easier for MySQL if the table is in order by the column that you wish to order it by later. This option is mainly useful when you know that you are mostly

going to query the rows in a certain order; by using this option after big changes to the table, you may be able to get higher performance.

- If you use `ALTER TABLE` on a `MyISAM` table, all non-unique indexes are created in a separate batch (like in `REPAIR`). This should make `ALTER TABLE` much faster when you have many indexes.
- Since **MySQL 4.0** the above feature can be activated explicitly. `ALTER TABLE ... DISABLE KEYS` makes MySQL to stop updating non-unique indexes for `MyISAM` table. `ALTER TABLE ... ENABLE KEYS` then should be used to recreate missing indexes. As MySQL does it with a special algorithm which is much faster then inserting keys one by one, disabling keys could give a considerable speedup on bulk inserts.
- With the C API function `mysql_info()`, you can find out how many records were copied, and (when `IGNORE` is used) how many records were deleted due to duplication of unique key values.
- The `FOREIGN KEY`, `CHECK`, and `REFERENCES` clauses don't actually do anything, except for InnoDB type tables which support `... ADD [CONSTRAINT symbol] FOREIGN KEY (...) REFERENCES ... (...)` and `... DROP FOREIGN KEY ...`. See Section 7.5.5.2 [InnoDB foreign key constraints], page 615. The syntax for other table types is provided only for compatibility, to make it easier to port code from other SQL servers and to run applications that create tables with references. See Section 1.7.4 [Differences from ANSI], page 36.
- `ALTER TABLE` ignores the `DATA DIRECTORY` and `INDEX DIRECTORY` table options.
- If you want to change all CHAR/VARCHAR/TEXT columns to a new character set (for example after upgrading from MySQL 4.0.x to 4.1.1) you can do:

  ```
  ALTER TABLE table_name CHARACTER SET character_set_name;
  ```

  Note that the following command will only change the `default character set` for a table:

  ```
  ALTER TABLE table_name DEFAULT CHARACTER SET character_set_name;
  ```

  The `default character set` is the character set that is used if you don't specify the character set for a new column you add to a table (for example with `ALTER TABLE ... ADD column`).

Here is an example that shows some of the uses of `ALTER TABLE`. We begin with a table `t1` that is created as shown here:

```
mysql> CREATE TABLE t1 (a INTEGER,b CHAR(10));
```

To rename the table from `t1` to `t2`:

```
mysql> ALTER TABLE t1 RENAME t2;
```

To change column `a` from `INTEGER` to `TINYINT NOT NULL` (leaving the name the same), and to change column `b` from `CHAR(10)` to `CHAR(20)` as well as renaming it from `b` to `c`:

```
mysql> ALTER TABLE t2 MODIFY a TINYINT NOT NULL, CHANGE b c CHAR(20);
```

To add a new `TIMESTAMP` column named `d`:

```
mysql> ALTER TABLE t2 ADD d TIMESTAMP;
```

To add an index on column `d`, and make column `a` the primary key:

```
mysql> ALTER TABLE t2 ADD INDEX (d), ADD PRIMARY KEY (a);
```

To remove column `c`:

```
mysql> ALTER TABLE t2 DROP COLUMN c;
```

To add a new AUTO_INCREMENT integer column named c:

```
mysql> ALTER TABLE t2 ADD c INT UNSIGNED NOT NULL AUTO_INCREMENT,
           ADD INDEX (c);
```

Note that we indexed c, because AUTO_INCREMENT columns must be indexed, and also that we declare c as NOT NULL, because indexed columns cannot be NULL.

When you add an AUTO_INCREMENT column, column values are filled in with sequence numbers for you automatically. You can set the first sequence number by executing SET INSERT_ID=# before ALTER TABLE or using the AUTO_INCREMENT = # table option. See Section 5.5.6 [SET OPTION], page 432.

With MyISAM tables, if you don't change the AUTO_INCREMENT column, the sequence number will not be affected. If you drop an AUTO_INCREMENT column and then add another AUTO_INCREMENT column, the numbers will start from 1 again.

See Section A.7.1 [ALTER TABLE problems], page 871.

6.5.5 RENAME TABLE Syntax

```
RENAME TABLE tbl_name TO new_tbl_name[, tbl_name2 TO new_tbl_name2,...]
```

The rename is done atomically, which means that no other thread can access any of the tables while the rename is running. This makes it possible to replace a table with an empty one :

```
CREATE TABLE new_table (...);
RENAME TABLE old_table TO backup_table, new_table TO old_table;
```

The rename is done from left to right, which means that if you want to swap two table names, you have to:

```
RENAME TABLE old_table    TO backup_table,
             new_table    TO old_table,
             backup_table TO new_table;
```

As long as two databases are on the same disk you can also rename from one database to another:

```
RENAME TABLE current_db.tbl_name TO other_db.tbl_name;
```

When you execute RENAME, you can't have any locked tables or active transactions. You must also have the ALTER and DROP privileges on the original table, and the CREATE and INSERT privileges on the new table.

If MySQL encounters any errors in a multiple-table rename, it will do a reverse rename for all renamed tables to get everything back to the original state.

RENAME TABLE was added in MySQL 3.23.23.

6.5.6 DROP TABLE Syntax

```
DROP [TEMPORARY] TABLE [IF EXISTS] tbl_name [, tbl_name,...] [RESTRICT | CASCADE]
```

DROP TABLE removes one or more tables. All table data and the table definition are *removed*, so **be careful** with this command!

In MySQL Version 3.22 or later, you can use the keywords `IF EXISTS` to prevent an error from occurring for tables that don't exist. In 4.1 one gets a `NOTE` for all not existing tables when using `IF EXISTS`. See Section 4.6.8.9 [SHOW WARNINGS], page 303.

`RESTRICT` and `CASCADE` are allowed to make porting easier. For the moment they don't do anything.

Note: `DROP TABLE` will automatically commit current active transaction (except if you are using 4.1 and the `TEMPORARY` key word.

Option `TEMPORARY` is ignored in 4.0. In 4.1 this option works as follows:

- Only drops temporary tables.
- It doesn't end a running transactions.
- No access rights is checked.

Using `TEMPORARY` is a good way to ensure that you don't accidently drop a real table.

6.5.7 `CREATE INDEX` Syntax

```
CREATE [UNIQUE|FULLTEXT] INDEX index_name
       ON tbl_name (index_col_name,...)

index_col_name:
        col_name [(length)] [ASC | DESC]
```

The `CREATE INDEX` statement doesn't do anything in MySQL prior to Version 3.22. In Version 3.22 or later, `CREATE INDEX` is mapped to an `ALTER TABLE` statement to create indexes. See Section 6.5.4 [`ALTER TABLE`], page 573.

Normally, you create all indexes on a table at the time the table itself is created with `CREATE TABLE`. See Section 6.5.3 [`CREATE TABLE`], page 564. `CREATE INDEX` allows you to add indexes to existing tables.

A column list of the form `(col1,col2,...)` creates a multiple-column index. Index values are formed by concatenating the values of the given columns.

For `CHAR` and `VARCHAR` columns, indexes can be created that use only part of a column, using `col_name(length)` syntax to index the first `length` bytes of each column value. (For `BLOB` and `TEXT` columns, a prefix length is required; `length` may be a value up to 255.) The statement shown here creates an index using the first 10 characters of the `name` column:

```
mysql> CREATE INDEX part_of_name ON customer (name(10));
```

Because most names usually differ in the first 10 characters, this index should not be much slower than an index created from the entire `name` column. Also, using partial columns for indexes can make the index file much smaller, which could save a lot of disk space and might also speed up `INSERT` operations!

Note that you can add an index on a column that can have `NULL` values only if you are using MySQL Version 3.23.2 or newer and are using the `MyISAM`, `InnoDB`, or `BDB` table type. You can only add an index on a `BLOB/TEXT` column if you are using MySQL Version 3.23.2 or newer and are using the `MyISAM` or `BDB` table type, or MySQL Version 4.0.14 or newer and the `InnoDB` table type. For an index on a`BLOB/TEXT` column, a prefix length must always be specified.

An `index_col_name` specification may end with `ASC` or `DESC`. These keywords are allowed for future extensions for specifying ascending or descending index value storage. Currently they are parsed but ignored; index values are always stored in ascending order.

For more information about how MySQL uses indexes, see Section 5.4.3 [MySQL indexes], page 421.

`FULLTEXT` indexes can index only `CHAR`, `VARCHAR`, and `TEXT` columns, and only in `MyISAM` tables. `FULLTEXT` indexes are available in MySQL Version 3.23.23 and later. Section 6.8 [Fulltext Search], page 584.

6.5.8 `DROP INDEX` Syntax

```
DROP INDEX index_name ON tbl_name
```

`DROP INDEX` drops the index named `index_name` from the table `tbl_name`. `DROP INDEX` doesn't do anything in MySQL prior to Version 3.22. In Version 3.22 or later, `DROP INDEX` is mapped to an `ALTER TABLE` statement to drop the index. See Section 6.5.4 [`ALTER TABLE`], page 573.

6.6 Basic MySQL User Utility Commands

6.6.1 `USE` Syntax

```
USE db_name
```

The `USE db_name` statement tells MySQL to use the `db_name` database as the default database for subsequent queries. The database remains current until the end of the session or until another `USE` statement is issued:

```
mysql> USE db1;
mysql> SELECT COUNT(*) FROM mytable;      # selects from db1.mytable
mysql> USE db2;
mysql> SELECT COUNT(*) FROM mytable;      # selects from db2.mytable
```

Making a particular database current by means of the `USE` statement does not preclude you from accessing tables in other databases. The following example accesses the `author` table from the `db1` database and the `editor` table from the `db2` database:

```
mysql> USE db1;
mysql> SELECT author_name,editor_name FROM author,db2.editor
    ->        WHERE author.editor_id = db2.editor.editor_id;
```

The `USE` statement is provided for Sybase compatibility.

6.6.2 `DESCRIBE` Syntax (Get Information About Columns)

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

`DESCRIBE` is a shortcut for `SHOW COLUMNS FROM`. See Section 4.6.8.1 [Show database info], page 285.

`DESCRIBE` provides information about a table's columns. `col_name` may be a column name or a string containing the SQL '`%`' and '`_`' wildcard characters to obtain output only for the columns with names matching the string. There is no need to enclose the string in quotes.

If the column types are different from what you expect them to be based on a `CREATE TABLE` statement, note that MySQL sometimes changes column types. See Section 6.5.3.1 [Silent column changes], page 573.

This statement is provided for Oracle compatibility.

The `SHOW` statement provides similar information. See Section 4.6.8 [`SHOW`], page 284.

6.7 MySQL Transactional and Locking Commands

6.7.1 `START TRANSACTION`, `COMMIT`, and `ROLLBACK` Syntax

By default, MySQL runs in autocommit mode. This means that as soon as you execute a statement that updates (modifies) a table, MySQL will store the update on disk.

If you are using transaction-safe tables (like `InnoDB` or `BDB`), you can put MySQL into non-autocommit mode with the following command:

```
SET AUTOCOMMIT=0
```

After disabling autocommit mode by setting the `AUTOCOMMIT` variable to zero, you must use `COMMIT` to store your changes to disk or `ROLLBACK` if you want to ignore the changes you have made since the beginning of your transaction.

If you want to disable autocommit mode for a single series of statements, you can use the `START TRANSACTION` statement: :

```
START TRANSACTION;
SELECT @A:=SUM(salary) FROM table1 WHERE type=1;
UPDATE table2 SET summmary=@A WHERE type=1;
COMMIT;
```

`BEGIN` and `BEGIN WORK` can be used instead of `START TRANSACTION` to initiate a transaction. `START TRANSACTION` was added in MySQL 4.0.11; it is SQL-99 syntax and is the recommended way to start an ad-hoc transaction. `BEGIN` and `BEGIN WORK` are available from MySQL 3.23.17 and 3.23.19, respectively.

Note that if you are not using transaction-safe tables, any changes will be stored at once, regardless of the status of autocommit mode.

If you issue a `ROLLBACK` statement after updating a non-transactional table, you will get an error (`ER_WARNING_NOT_COMPLETE_ROLLBACK`) as a warning. All transaction-safe tables will be restored but any non-transaction-safe table will not change.

If you are using `START TRANSACTION` or `SET AUTOCOMMIT=0`, you should use the MySQL binary log for backups instead of the older update log. Transactions are stored in the binary log in one chunk, upon `COMMIT`, to ensure that transactions that are rolled back are not stored. See Section 4.10.4 [Binary log], page 351.

You can change the isolation level for transactions with `SET TRANSACTION ISOLATION LEVEL`. See Section 6.7.6 [SET TRANSACTION], page 583.

6.7.2 Statements That Cannot Be Rolled Back

Some statements cannot be rolled back. In general, these include data definition language (DDL) statements, such as those that create or drop databases, or those that create, drop, or alter tables.

You may wish to design your transactions not to include such statements. If you issue a statement that cannot be rolled back early in a transaction, and then another statement later fails, the full effect of the transaction cannot be rolled back by issuing a `ROLLBACK` statement.

6.7.3 Statements That Cause an Implicit Commit

The following commands implicitly end a transaction (as if you had done a `COMMIT` before executing the command):

Command	Command	Command
`ALTER TABLE`	`BEGIN`	`CREATE INDEX`
`DROP DATABASE`	`DROP INDEX`	`DROP TABLE`
`LOAD MASTER DATA`	`LOCK TABLES`	`RENAME TABLE`
`SET AUTOCOMMIT=1`	`START TRANSACTION`	`TRUNCATE`

`UNLOCK TABLES` also ends a transaction if any tables currently are locked. Prior to MySQL 4.0.13, `CREATE TABLE` ends a transaction if the binary update log is enabled.

Transactions cannot be nested. This is a consequence of the implicit `COMMIT` performed for any current transaction when you issue a `START TRANSACTION` statement or one of its synonyms.

6.7.4 `SAVEPOINT` and `ROLLBACK TO SAVEPOINT` Syntax

Starting from MySQL 4.0.14 and 4.1.1, `InnoDB` supports the SQL commands `SAVEPOINT` and `ROLLBACK TO SAVEPOINT`.

```
SAVEPOINT identifier
```

This statement sets a named transaction savepoint whose name is `identifier`. If the current transaction already has a savepoint with the same name, the old savepoint is deleted and a new one is set.

```
ROLLBACK TO SAVEPOINT identifier
```

This statement rolls back a transaction to the named savepoint. Modifications that this transaction made to rows after the savepoint was set are undone in the rollback, but `InnoDB` does **not** release the row locks that were stored in memory after the savepoint. (Note that for a new inserted row, the lock information is carried by the transaction ID stored in the row; the lock is not separately stored in memory. In this case, the row lock is released in the undo.) Savepoints that were set at a later time than the named savepoint are deleted.

If the command returns the following error, it means that no savepoint with the specified name exists:

```
ERROR 1181: Got error 153 during ROLLBACK
```

All savepoints of the current transaction are deleted if you execute a `COMMIT`, or a `ROLLBACK` that does not name a savepoint.

6.7.5 LOCK TABLES and UNLOCK TABLES Syntax

```
LOCK TABLES tbl_name [AS alias] {READ [LOCAL] | [LOW_PRIORITY] WRITE}
            [, tbl_name [AS alias] {READ [LOCAL] | [LOW_PRIORITY] WRITE} ...]
...
UNLOCK TABLES
```

`LOCK TABLES` locks tables for the current thread. `UNLOCK TABLES` releases any locks held by the current thread. All tables that are locked by the current thread are implicitly unlocked when the thread issues another `LOCK TABLES`, or when the connection to the server is closed.

To use `LOCK TABLES` in MySQL 4.0.2 you need the global `LOCK TABLES` privilege and a `SELECT` privilege on the involved tables. In MySQL 3.23 you need to have `SELECT`, `insert`, `DELETE` and `UPDATE` privileges for the tables.

The main reasons to use `LOCK TABLES` are for emulating transactions or getting more speed when updating tables. This is explained in more detail later.

If a thread obtains a `READ` lock on a table, that thread (and all other threads) can only read from the table. If a thread obtains a `WRITE` lock on a table, then only the thread holding the lock can read from or write to the table. Other threads are blocked.

The difference between `READ LOCAL` and `READ` is that `READ LOCAL` allows non-conflicting `INSERT` statements to execute while the lock is held. This can't however be used if you are going to manipulate the database files outside MySQL while you hold the lock.

When you use `LOCK TABLES`, you must lock all tables that you are going to use and you must use the same alias that you are going to use in your queries! If you are using a table multiple times in a query (with aliases), you must get a lock for each alias!

`WRITE` locks normally have higher priority than `READ` locks, to ensure that updates are processed as soon as possible. This means that if one thread obtains a `READ` lock and then another thread requests a `WRITE` lock, subsequent `READ` lock requests will wait until the `WRITE` thread has gotten the lock and released it. You can use `LOW_PRIORITY WRITE` locks to allow other threads to obtain `READ` locks while the thread is waiting for the `WRITE` lock. You should only use `LOW_PRIORITY WRITE` locks if you are sure that there will eventually be a time when no threads will have a `READ` lock.

`LOCK TABLES` works as follows:

1. Sort all tables to be locked in a internally defined order (from the user standpoint the order is undefined).
2. If a table is locked with a read and a write lock, put the write lock before the read lock.
3. Lock one table at a time until the thread gets all locks.

This policy ensures that table locking is deadlock free. There is however other things one needs to be aware of with this schema:

If you are using a `LOW_PRIORITY WRITE` lock for a table, this means only that MySQL will wait for this particlar lock until there is no threads that wants a `READ` lock. When the thread has got the `WRITE` lock and is waiting to get the lock for the next table in the lock table list, all other threads will wait for the `WRITE` lock to be released. If this becomes a serious problem with your application, you should consider converting some of your tables to transaction safe tables.

You can safely kill a thread that is waiting for a table lock with `KILL`. See Section 4.6.7 [KILL], page 284.

Note that you should **not** lock any tables that you are using with `INSERT DELAYED`. This is because that in this case the `INSERT` is done by a separate thread.

Normally, you don't have to lock tables, as all single `UPDATE` statements are atomic; no other thread can interfere with any other currently executing SQL statement. There are a few cases when you would like to lock tables anyway:

- If you are going to run many operations on a bunch of tables, it's much faster to lock the tables you are going to use. The downside is, of course, that no thread can update a `READ`-locked table (including the one holding the lock) and no thread can read a `WRITE`-locked table other than the one holding the lock.

  The reason some things are faster under `LOCK TABLES` is that MySQL will not flush the key cache for the locked tables until `UNLOCK TABLES` is called (normally the key cache is flushed after each SQL statement). This speeds up inserting, updating, or deletes on `MyISAM` tables.
- If you are using a storage engine in MySQL that doesn't support transactions, you must use `LOCK TABLES` if you want to ensure that no other thread comes between a `SELECT` and an `UPDATE`. The example shown here requires `LOCK TABLES` in order to execute safely:

  ```
  mysql> LOCK TABLES trans READ, customer WRITE;
  mysql> SELECT SUM(value) FROM trans WHERE customer_id=some_id;
  mysql> UPDATE customer SET total_value=sum_from_previous_statement
      ->        WHERE customer_id=some_id;
  mysql> UNLOCK TABLES;
  ```

  Without `LOCK TABLES`, there is a chance that another thread might insert a new row in the `trans` table between execution of the `SELECT` and `UPDATE` statements.

By using incremental updates (`UPDATE customer SET value=value+new_value`) or the `LAST_INSERT_ID()` function, you can avoid using `LOCK TABLES` in many cases.

You can also solve some cases by using the user-level lock functions `GET_LOCK()` and `RELEASE_LOCK()`. These locks are saved in a hash table in the server and implemented with `pthread_mutex_lock()` and `pthread_mutex_unlock()` for high speed. See Section 6.3.6.2 [Miscellaneous functions], page 515.

See Section 5.3.1 [Internal locking], page 418, for more information on locking policy.

You can lock all tables in all databases with read locks with the `FLUSH TABLES WITH READ LOCK` command. See Section 4.6.4 [FLUSH], page 282. This is very convenient way to get backups if you have a filesystem, like Veritas, that can take snapshots in time.

NOTE: `LOCK TABLES` is not transaction-safe and will implicitly commit any active transactions before attempting to lock the tables.

6.7.6 `SET TRANSACTION` Syntax

```
SET [GLOBAL | SESSION] TRANSACTION ISOLATION LEVEL
{ READ UNCOMMITTED | READ COMMITTED | REPEATABLE READ | SERIALIZABLE }
```

Sets the transaction isolation level for the global, whole session or the next transaction.

The default behaviour is to set the isolation level for the next (not started) transaction. If you use the `GLOBAL` keyword, the statement sets the default transaction level globally for all new connections created from that point on (but not existing connections). You need the `SUPER` privilege to do this. Using the `SESSION` keyword sets the default transaction level for all future transactions performed on the current connection.

For description of each `InnoDB` transaction isolation level, see Section 7.5.9.1 [InnoDB transaction isolation], page 622. InnoDB supports each of these levels from MySQL 4.0.5 on. The default level is `REPEATABLE READ`.

You can set the default global isolation level for `mysqld` with `--transaction-isolation=...`. See Section 4.1.1 [Command-line options], page 195.

6.8 MySQL Full-text Search

As of Version 3.23.23, MySQL has support for full-text indexing and searching. Full-text indexes in MySQL are an index of type `FULLTEXT`. `FULLTEXT` indexes are used with `MyISAM` tables only and can be created from `CHAR`, `VARCHAR`, or `TEXT` columns at `CREATE TABLE` time or added later with `ALTER TABLE` or `CREATE INDEX`. For large datasets, it will be much faster to load your data into a table that has no `FULLTEXT` index, then create the index with `ALTER TABLE` (or `CREATE INDEX`). Loading data into a table that already has a `FULLTEXT` index could be significantly slower.

Full-text searching is performed with the `MATCH()` function.

```
mysql> CREATE TABLE articles (
    ->   id INT UNSIGNED AUTO_INCREMENT NOT NULL PRIMARY KEY,
    ->   title VARCHAR(200),
    ->   body TEXT,
    ->   FULLTEXT (title,body)
    -> );
Query OK, 0 rows affected (0.00 sec)

mysql> INSERT INTO articles VALUES
    -> (NULL,'MySQL Tutorial', 'DBMS stands for DataBase ...'),
    -> (NULL,'How To Use MySQL Efficiently', 'After you went through a ...'),
    -> (NULL,'Optimising MySQL','In this tutorial we will show ...'),
    -> (NULL,'1001 MySQL Tricks','1. Never run mysqld as root. 2. ...'),
    -> (NULL,'MySQL vs. YourSQL', 'In the following database comparison ...'),
    -> (NULL,'MySQL Security', 'When configured properly, MySQL ...');
Query OK, 6 rows affected (0.00 sec)
Records: 6  Duplicates: 0  Warnings: 0

mysql> SELECT * FROM articles
    ->          WHERE MATCH (title,body) AGAINST ('database');
+----+-------------------+------------------------------------------+
| id | title             | body                                     |
+----+-------------------+------------------------------------------+
|  5 | MySQL vs. YourSQL | In the following database comparison ... |
```

```
|  1 | MySQL Tutorial    | DBMS stands for DataBase ...             |
+----+-------------------+------------------------------------------+
2 rows in set (0.00 sec)
```

The `MATCH()` function performs a natural language search for a string against a text collection (a set of one or more columns included in a `FULLTEXT` index). The search string is given as the argument to `AGAINST()`. The search is performed in case-insensitive fashion. For every row in the table, `MATCH()` returns a relevance value, that is, a similarity measure between the search string and the text in that row in the columns named in the `MATCH()` list.

When `MATCH()` is used in a `WHERE` clause (see example above) the rows returned are automatically sorted with highest relevance first. Relevance values are non-negative floating-point numbers. Zero relevance means no similarity. Relevance is computed based on the number of words in the row, the number of unique words in that row, the total number of words in the collection, and the number of documents (rows) that contain a particular word.

It is also possible to perform a boolean mode search. This is explained later in the section.

The preceding example is a basic illustration showing how to use the `MATCH()` function. Rows are returned in order of decreasing relevance.

The next example shows how to retrieve the relevance values explicitly. As neither `WHERE` nor `ORDER BY` clauses are present, returned rows are not ordered.

```
mysql> SELECT id,MATCH (title,body) AGAINST ('Tutorial') FROM articles;
+----+----------------------------------------+
| id | MATCH (title,body) AGAINST ('Tutorial') |
+----+----------------------------------------+
|  1 |                  0.64840710366884 |
|  2 |                                 0 |
|  3 |                  0.66266459031789 |
|  4 |                                 0 |
|  5 |                                 0 |
|  6 |                                 0 |
+----+----------------------------------------+
6 rows in set (0.00 sec)
```

The following example is more complex. The query returns the relevance and still sorts the rows in order of decreasing relevance. To achieve this result, you should specify `MATCH()` twice. This will cause no additional overhead, because the MySQL optimiser will notice that the two `MATCH()` calls are identical and invoke the full-text search code only once.

```
mysql> SELECT id, body, MATCH (title,body) AGAINST
    -> ('Security implications of running MySQL as root') AS score
    -> FROM articles WHERE MATCH (title,body) AGAINST
    -> ('Security implications of running MySQL as root');
+----+-------------------------------------+-----------------+
| id | body                                | score           |
+----+-------------------------------------+-----------------+
|  4 | 1. Never run mysqld as root. 2. ... | 1.5055546709332 |
|  6 | When configured properly, MySQL ... |   1.31140957288 |
+----+-------------------------------------+-----------------+
```

```
2 rows in set (0.00 sec)
```

MySQL uses a very simple parser to split text into words. A "word" is any sequence of characters consisting of letters, digits, '', and '_'. Any "word" that is present in the stopword list or is just too short is ignored. The default minimum length of words that will be found by full-text searches is four characters. This can be changed as described in Section 6.8.2 [Fulltext Fine-tuning], page 588.

Every correct word in the collection and in the query is weighted according to its significance in the query or collection. This way, a word that is present in many documents will have lower weight (and may even have a zero weight), because it has lower semantic value in this particular collection. Otherwise, if the word is rare, it will receive a higher weight. The weights of the words are then combined to compute the relevance of the row.

Such a technique works best with large collections (in fact, it was carefully tuned this way). For very small tables, word distribution does not reflect adequately their semantic value, and this model may sometimes produce bizarre results.

```
mysql> SELECT * FROM articles WHERE MATCH (title,body) AGAINST ('MySQL');
Empty set (0.00 sec)
```

The search for the word `MySQL` produces no results in the above example, because that word is present in more than half the rows. As such, it is effectively treated as a stopword (that is, a word with zero semantic value). This is the most desirable behaviour — a natural language query should not return every second row from a 1 GB table.

A word that matches half of rows in a table is less likely to locate relevant documents. In fact, it will most likely find plenty of irrelevant documents. We all know this happens far too often when we are trying to find something on the Internet with a search engine. It is with this reasoning that such rows have been assigned a low semantic value in **this particular dataset**.

As of Version 4.0.1, MySQL can also perform boolean full-text searches using the `IN BOOLEAN MODE` modifier.

```
mysql> SELECT * FROM articles WHERE MATCH (title,body)
    ->     AGAINST ('+MySQL -YourSQL' IN BOOLEAN MODE);
+----+-------------------------------+-------------------------------------+
| id | title                         | body                                |
+----+-------------------------------+-------------------------------------+
|  1 | MySQL Tutorial                | DBMS stands for DataBase ...        |
|  2 | How To Use MySQL Efficiently | After you went through a ...        |
|  3 | Optimising MySQL              | In this tutorial we will show ...   |
|  4 | 1001 MySQL Tricks             | 1. Never run mysqld as root. 2. ... |
|  6 | MySQL Security                | When configured properly, MySQL ... |
+----+-------------------------------+-------------------------------------+
```

This query retrieved all the rows that contain the word `MySQL` (note: the 50% threshold is not used), but that do **not** contain the word `YourSQL`. Note that a boolean mode search does not automatically sort rows in order of decreasing relevance. You can see this from result of the preceding query, where the row with the highest relevance (the one that contains `MySQL` twice) is listed last, not first. A boolean full-text search can also work even without a `FULLTEXT` index, although it would be **slow**.

The boolean full-text search capability supports the following operators:

`+` A leading plus sign indicates that this word **must be** present in every row returned.

`-` A leading minus sign indicates that this word **must not be** present in any row returned.

By default (when neither plus nor minus is specified) the word is optional, but the rows that contain it will be rated higher. This mimicks the behaviour of `MATCH() ... AGAINST()` without the `IN BOOLEAN MODE` modifier.

`< >` These two operators are used to change a word's contribution to the relevance value that is assigned to a row. The `<` operator decreases the contribution and the `>` operator increases it. See the example below.

`( )` Parentheses are used to group words into subexpressions.

`~` A leading tilde acts as a negation operator, causing the word's contribution to the row relevance to be negative. It's useful for marking noise words. A row that contains such a word will be rated lower than others, but will not be excluded altogether, as it would be with the `-` operator.

`*` An asterisk is the truncation operator. Unlike the other operators, it should be **appended** to the word, not prepended.

`"` The phrase, that is enclosed in double quotes `"`, matches only rows that contain this phrase **literally, as it was typed**.

And here are some examples:

`apple banana`
find rows that contain at least one of these words.

`+apple +juice`
... both words.

`+apple macintosh`
... word "apple", but rank it higher if it also contain "macintosh".

`+apple -macintosh`
... word "apple" but not "macintosh".

`+apple +(>turnover <strudel)`
... "apple" and "turnover", or "apple" and "strudel" (in any order), but rank "apple pie" higher than "apple strudel".

`apple*` ... "apple", "apples", "applesauce", and "applet".

`"some words"`
... "some words of wisdom", but not "some noise words".

6.8.1 Full-text Restrictions

- Full-text searches are supported for `MyISAM` tables only.
- Full-text searches cannot be used with UCS-2 (but it works with UTF-8).

- All parameters to the `MATCH()` function must be columns from the same table that is part of the same `FULLTEXT` index, unless the `MATCH()` is `IN BOOLEAN MODE`.
- All columns in the `FULLTEXT` index must have the same character set.
- The `MATCH()` column list must exactly match the column list in some `FULLTEXT` index definition for the table, unless this `MATCH()` is `IN BOOLEAN MODE`.
- The argument to `AGAINST()` must be a constant string.

6.8.2 Fine-tuning MySQL Full-text Search

Unfortunately, full-text search has few user-tunable parameters yet, although adding some is very high on the TODO. If you have a MySQL source distribution (see Section 2.3 [Installing source], page 88), you can exert more control over full-text searching behaviour.

Note that full-text search was carefully tuned for the best searching effectiveness. Modifying the default behaviour will, in most cases, only make the search results worse. Do not alter the MySQL sources unless you know what you are doing!

The full-text variables described in the following list must be set at server startup time. You cannot modify them dynamically while the server is running.

- The minimum length of words to be indexed is defined by the MySQL variable `ft_min_word_len`. See Section 4.6.8.4 [`ft_min_word_len`], page 290. (This variable is only available from MySQL version 4.0.) The default value is four characters. Change it to the value you prefer, and rebuild your `FULLTEXT` indexes. For example, if you want three-character words to be searchable, you can set this variable by putting the following lines in an option file:

  ```
  [mysqld]
  ft_min_word_len=3
  ```

  Then restart the server and rebuild your `FULLTEXT` indexes.
- The stopword list can be loaded from the file specified by the `ft_stopword_file` variable. See Section 4.6.8.4 [`ft_stopword_file`], page 290. Rebuild your `FULLTEXT` indexes after modifying the stopword list. (This variable is only available from MySQL version 4.0.10 and onwards)
- The 50% threshold is determined by the particular weighting scheme chosen. To disable it, change the following line in '`myisam/ftdefs.h`':

  ```
  #define GWS_IN_USE GWS_PROB
  ```

  To:

  ```
  #define GWS_IN_USE GWS_FREQ
  ```

  Then recompile MySQL. There is no need to rebuild the indexes in this case. **Note**: by doing this you **severely** decrease MySQL's ability to provide adequate relevance values for the `MATCH()` function. If you really need to search for such common words, it would be better to search using `IN BOOLEAN MODE` instead, which does not observe the 50% threshold.
- Sometimes the search engine maintainer would like to change the operators used for boolean full-text searches. These are defined by the `ft_boolean_syntax` variable. See Section 4.6.8.4 [`ft_boolean_syntax`], page 290. Still, this variable is read-only; its value is set in '`myisam/ft_static.c`'.

For full-text changes that require you to rebuild your FULLTEXT indexes, the easiest way to do so for a MyISAM table is to use the following statement, which rebuilds the index file:

```
mysql> REPAIR TABLE tbl_name QUICK;
```

6.8.3 Full-text Search TODO

- Make all operations with FULLTEXT index **faster**.
- Proximity operators
- Support for "always-index words". They could be any strings the user wants to treat as words, examples are "C++", "AS/400", "TCP/IP", etc.
- Support for full-text search in MERGE tables.
- Support for UCS-2.
- Make stopword list to depend of the language of the data.
- Stemming (dependent of the language of the data, of course).
- Generic user-suppliable UDF preparser.
- Make the model more flexible (by adding some adjustable parameters to FULLTEXT in CREATE/ALTER TABLE).

6.9 MySQL Query Cache

From version 4.0.1, MySQL server features a Query Cache. When in use, the query cache stores the text of a SELECT query together with the corresponding result that was sent to the client. If an identical query is later received, the server will retrieve the results from the query cache rather than parsing and executing the same query again.

NOTE: The query cache does not return stale data. When data is modified, any relevant entries in the query cache are flushed.

The query cache is extremely useful in an environment where (some) tables don't change very often and you have a lot of identical queries. This is a typical situation for many web servers that use a lot of dynamic content.

Below is some performance data for the query cache. (These results were generated by running the MySQL benchmark suite on a Linux Alpha 2 x 500 MHz with 2 GB RAM and a 64 MB query cache):

- If all of the queries you're performing are simple (such as selecting a row from a table with one row); but still differ so that the queries can not be cached, the overhead for having the query cache active is 13%. This could be regarded as the worst case scenario. However, in real life, queries are much more complicated than our simple example so the overhead is normally significantly lower.
- Searches after one row in a one row table is 238% faster. This can be regarded as close to the minimum speedup to be expected for a query that is cached.
- If you want to disable the query cache code set query_cache_size=0. By disabling the query cache code there is no noticeable overhead. (query cache can be excluded from code with help of configure option --without-query-cache)

6.9.1 How the Query Cache Operates

Queries are compared before parsing, thus

```
SELECT * FROM tbl_name
```

and

```
Select * from tbl_name
```

are regarded as different queries for query cache, so queries need to be exactly the same (byte for byte) to be seen as identical. In addition, a query may be seen as different if for instance one client is using a new communication protocol format or another character set than another client.

Queries that uses different databases, uses different protocol versions or the uses different default character sets are considered different queries and cached separately.

The cache does work for `SELECT SQL_CALC_FOUND_ROWS ...` and `SELECT FOUND_ROWS() ...` type queries because the number of found rows is also stored in the cache.

If query result was returned from query cache then status variable `Com_select` will not be increased, but `Qcache_hits` will be. See Section 6.9.4 [Query Cache Status and Maintenance], page 592.

If a table changes (`INSERT`, `UPDATE`, `DELETE`, `TRUNCATE`, `ALTER` or `DROP TABLE|DATABASE`), then all cached queries that used this table (possibly through a `MRG_MyISAM` table!) become invalid and are removed from the cache.

Transactional `InnoDB` tables that have been changed will be invalidated when a `COMMIT` is performed.

In MySQL 4.0, the query cache is disabled inside of transactions (it does not return results). Beginning with MySQL 4.1.1, the query cache will also work inside of transactions when using `InnoDB` tables (it will use the table version number to detect if the data is still current or not).

Before MySQL 5.0, a query that begins with a leading comment might be cached, but could not be fetched from the cache. This problem is fixed in MySQL 5.0.

A query cannot be cached if it contains one of the functions:

Function	Function	Function
`User-Defined Functions`	`CONNECTION_ID`	`FOUND_ROWS`
`GET_LOCK`	`RELEASE_LOCK`	`LOAD_FILE`
`MASTER_POS_WAIT`	`NOW`	`SYSDATE`
`CURRENT_TIMESTAMP`	`CURDATE`	`CURRENT_DATE`
`CURTIME`	`CURRENT_TIME`	`DATABASE`
`ENCRYPT` (with one parameter)	`LAST_INSERT_ID`	`RAND`
`UNIX_TIMESTAMP` (without parameters)	`USER`	`BENCHMARK`

Nor can a query be cached if it contains user variables, references the mysql system database, is of the form `SELECT ... IN SHARE MODE`, `SELECT ... INTO OUTFILE ...`, `SELECT ... INTO DUMPFILE ...` or of the form `SELECT * FROM AUTOINCREMENT_FIELD IS NULL` (to retrieve last insert ID - ODBC work around).

However, `FOUND_ROWS()` will return the correct value, even if the preceding query was fetched from the cache.

In case a query does not use any tables, or uses temporary tables, or if the user has a column privilege for any of the involved tables, that query will not be cached.

Before a query is fetched from the query cache, MySQL will check that the user has SELECT privilege to all the involved databases and tables. If this is not the case, the cached result will not be used.

6.9.2 Query Cache Configuration

The query cache adds a few `MySQL` system variables for `mysqld` which may be set in a configuration file, on the command-line when starting `mysqld`.

- `query_cache_limit` Don't cache results that are bigger than this. (Default 1M).
- `query_cache_min_res_unit`

  This variable is present from version 4.1.

  The result of a query (the data that is also sent to the client) is stored in the query cache during result retrieval. Therefore the data is usually not handled in one big chunk. The query cache allocates blocks for storing this data on demand, so when one block is filled, a new block is allocated. Because memory allocation operation is costly (time wise), the query cache allocates blocks with a minimum size of `query_cache_min_res_unit`. When a query is executed, the last result block is trimmed to the actual data size, so that unused memory is freed.

  - The default value of `query_cache_min_res_unit` is 4 KB which should be adequate for most cases.
  - If you have a lot of queries with small results, the default block size may lead to memory fragmentation (indicated by a large number of free blocks (`Qcache_free_blocks`), which can cause the query cache to have to delete queries from the cache due to lack of memory (`Qcache_lowmem_prunes`)). In this case you should decrease `query_cache_min_res_unit`.
  - If you mostly have queres with big results (see `Qcache_total_blocks` and `Qcache_queries_in_cache`), you can increase performance by increasing `query_cache_min_res_unit`. However, be careful to not make it to large (see the previous point).
- `query_cache_size` The amount of memory (specified in bytes) allocated to store results from old queries. If this is 0, the query cache is disabled (default).
- `query_cache_type` This may be set (only numeric) to

Option	Description
0	(OFF, don't cache or retrieve results)
1	(ON, cache all results except `SELECT SQL_NO_CACHE ...` queries)
2	(DEMAND, cache only `SELECT SQL_CACHE ...` queries)

Inside a thread (connection), the behaviour of the query cache can be changed from the default. The syntax is as follows:

```
QUERY_CACHE_TYPE = OFF | ON | DEMAND QUERY_CACHE_TYPE = 0 | 1 | 2
```

Option	Description
0 or OFF	Don't cache or retrieve results.

1 or ON	Cache all results except `SELECT SQL_NO_CACHE ...` queries.
2 or DEMAND	Cache only `SELECT SQL_CACHE ...` queries.

6.9.3 Query Cache Options in `SELECT`

There are two possible query cache related parameters that may be specified in a `SELECT` query:

Option	Description
`SQL_CACHE`	If `QUERY_CACHE_TYPE` is `DEMAND`, allow the query to be cached. If `QUERY_CACHE_TYPE` is `ON`, this is the default. If `QUERY_CACHE_TYPE` is `OFF`, do nothing.
`SQL_NO_CACHE`	Make this query non-cachable, don't allow this query to be stored in the cache.

6.9.4 Query Cache Status and Maintenance

With the `FLUSH QUERY CACHE` command you can defragment the query cache to better utilise its memory. This command will not remove any queries from the cache. `FLUSH TABLES` also flushes the query cache.

The `RESET QUERY CACHE` command removes all query results from the query cache. You can check whether the query cache is present in your MySQL version:

```
mysql> SHOW VARIABLES LIKE 'have_query_cache';
+------------------+-------+
| Variable_name    | Value |
+------------------+-------+
| have_query_cache | YES   |
+------------------+-------+
1 row in set (0.00 sec)
```

You can monitor query cache performance in `SHOW STATUS`:

Variable	Description
`Qcache_queries_in_cache`	Number of queries registered in the cache.
`Qcache_inserts`	Number of queries added to the cache.
`Qcache_hits`	Number of cache hits.
`Qcache_lowmem_prunes`	Number of queries that were deleted from cache because of low memory.
`Qcache_not_cached`	Number of non-cached queries (not cachable, or due to `QUERY_CACHE_TYPE`).
`Qcache_free_memory`	Amount of free memory for query cache.
`Qcache_free_blocks`	Number of free memory blocks in query cache.
`Qcache_total_blocks`	Total number of blocks in query cache.

Total number of queries = `Qcache_inserts` + `Qcache_hits` + `Qcache_not_cached`.

The query cache uses variable length blocks, so `Qcache_total_blocks` and `Qcache_free_blocks` may indicate query cache memory fragmentation. After `FLUSH QUERY CACHE` only a single (big) free block remains.

Note: Every query needs a minimum of two blocks (one for the query text and one or more for the query results). Also, every table that is used by a query needs one block, but if two or more queries use same table only one block needs to be allocated.

You can use the `Qcache_lowmem_prunes` status variable to tune the query cache size. It counts the number of queries that have been removed from the cache to free up memory for caching new queries. The query cache uses a `least recently used` (`LRU`) strategy to decide which queries to remove from the cache.

7 MySQL Table Types

As of MySQL Version 3.23.6, you can choose between three basic table formats (`ISAM`, `HEAP` and `MyISAM`). Newer versions of MySQL support additional table types (`InnoDB`, or `BDB`), depending on how you compile it. A database may contain tables of different types.

When you create a new table, you can tell MySQL what type of table to create. The default table type is usually `MyISAM`.

MySQL will always create a '`.frm`' file to hold the table and column definitions. The table's index and data will be stored in one or more other files, depending on the table type.

If you try to use a table type that is not compiled-in or activated, MySQL will instead create a table of type `MyISAM`. This behaviour is convenient when you want to copy tables between MySQL servers that support different table types. (Perhaps your master server supports transactional storage engines for increased safety, while the slave servers use only non-transactional storage engines for greater speed.)

This automatic change of table types can be confusing for new MySQL users. We plan to fix this by introducing warnings in the new client/server protocol in version 4.1 and generating a warning when a table type is automatically changed.

You can convert tables between different types with the `ALTER TABLE` statement. See Section 6.5.4 [`ALTER TABLE`], page 573.

Note that MySQL supports two different kinds of tables: transaction-safe tables (`InnoDB` and `BDB`) and not transaction-safe tables (`HEAP`, `ISAM`, `MERGE`, and `MyISAM`).

Advantages of transaction-safe tables (TST):

- Safer. Even if MySQL crashes or you get hardware problems, you can get your data back, either by automatic recovery or from a backup + the transaction log.
- You can combine many statements and accept these all in one go with the `COMMIT` command.
- You can execute `ROLLBACK` to ignore your changes (if you are not running in auto-commit mode).
- If an update fails, all your changes will be restored. (With NTST tables all changes that have taken place are permanent)
- Can provide better concurrency if the table gets many updates concurrently with reads.

Note that to use `InnoDB` tables you have to use at least the `innodb_data_file_path` startup option. See Section 7.5.3 [InnoDB start], page 607.

Advantages of not transaction-safe tables (NTST):

- Much faster as there is no transaction overhead.
- Will use less disk space as there is no overhead of transactions.
- Will use less memory to do updates.

You can combine TST and NTST tables in the same statements to get the best of both worlds.

7.1 MyISAM Tables

MyISAM is the default table type in MySQL Version 3.23. It's based on the ISAM code and has a lot of useful extensions.

The index is stored in a file with the '.MYI' (MYIndex) extension, and the data is stored in a file with the '.MYD' (MYData) extension. You can check/repair MyISAM tables with the myisamchk utility. See Section 4.5.6.7 [Crash recovery], page 270. You can compress MyISAM tables with myisampack to take up much less space. See Section 4.8.4 [myisampack], page 317.

The following is new in MyISAM:

- There is a flag in the MyISAM file that indicates whether the table was closed correctly. If mysqld is started with --myisam-recover, MyISAM tables will automatically be checked and/or repaired on open if the table wasn't closed properly.
- You can INSERT new rows in a table that doesn't have free blocks in the middle of the datafile, at the same time other threads are reading from the table (concurrent insert). A free block can come from an update of a dynamic length row with much data to a row with less data or when deleting rows. When all free blocks are used up, all future inserts will be concurrent again.
- Support for big files (63-bit) on filesystems/operating systems that support big files.
- All data is stored with the low byte first. This makes the data machine and OS independent. The only requirement for binary portability is that the machine uses two's-complement signed integers (as every machine for the last 20 years has) and IEEE floating-point format (also totally dominant among mainstream machines). The only area of machines that may not support binary compatibility are embedded systems (because they sometimes have peculiar processors).

  There is no big speed penalty in storing data low byte first; the bytes in a table row is normally unaligned and it doesn't take that much more power to read an unaligned byte in order than in reverse order. The actual fetch-column-value code is also not time critical compared to other code.
- All number keys are stored with high byte first to give better index compression.
- Internal handling of one AUTO_INCREMENT column. MyISAM will automatically update this on INSERT/UPDATE. The AUTO_INCREMENT value can be reset with myisamchk. This will make AUTO_INCREMENT columns faster (at least 10%) and old numbers will not be reused as with the old ISAM. Note that when an AUTO_INCREMENT is defined on the end of a multi-part-key the old behaviour is still present.
- When inserted in sorted order (as when you are using an AUTO_INCREMENT column) the key tree will be split so that the high node only contains one key. This will improve the space utilisation in the key tree.
- BLOB and TEXT columns can be indexed.
- NULL values are allowed in indexed columns. This takes 0-1 bytes/key.
- Maximum key length is 500 bytes by default (can be changed by recompiling). In cases of keys longer than 250 bytes, a bigger key block size than the default of 1024 bytes is used for this key.

- Maximum number of keys/table is 32 as default. This can be enlarged to 64 without having to recompile `myisamchk`.
- `myisamchk` will mark tables as checked if one runs it with `--update-state`. `myisamchk --fast` will only check those tables that don't have this mark.
- `myisamchk -a` stores statistics for key parts (and not only for whole keys as in `ISAM`).
- Dynamic size rows will now be much less fragmented when mixing deletes with updates and inserts. This is done by automatically combining adjacent deleted blocks and by extending blocks if the next block is deleted.
- `myisampack` can pack `BLOB` and `VARCHAR` columns.
- You can use put the datafile and index file on different directories to get more speed (with the `DATA/INDEX DIRECTORY="path"` option to `CREATE TABLE`). See Section 6.5.3 [CREATE TABLE], page 564.

`MyISAM` also supports the following things, which MySQL will be able to use in the near future:

- Support for a true `VARCHAR` type; a `VARCHAR` column starts with a length stored in 2 bytes.
- Tables with `VARCHAR` may have fixed or dynamic record length.
- `VARCHAR` and `CHAR` may be up to 64K. All key segments have their own language definition. This will enable MySQL to have different language definitions per column.
- A hashed computed index can be used for `UNIQUE`. This will allow you to have `UNIQUE` on any combination of columns in a table. (You can't search on a `UNIQUE` computed index, however.)

Note that index files are usually much smaller with `MyISAM` than with `ISAM`. This means that `MyISAM` will normally use less system resources than `ISAM`, but will need more CPU time when inserting data into a compressed index.

The following options to `mysqld` can be used to change the behaviour of `MyISAM` tables. See Section 4.6.8.4 [SHOW VARIABLES], page 290.

Option	Description
`--myisam-recover=#`	Automatic recovery of crashed tables.
`-O myisam_sort_buffer_size=#`	Buffer used when recovering tables.
`--delay-key-write=ALL`	Don't flush key buffers between writes for any MyISAM table
`-O myisam_max_extra_sort_file_size=#`	Used to help MySQL to decide when to use the slow but safe key cache index create method. **Note** that this parameter is given in megabytes before 4.0.3 and in bytes beginning with this version.
`-O myisam_max_sort_file_size=#`	Don't use the fast sort index method to created index if the temporary file would get bigger than this. **Note** that this parameter is given in megabytes before 4.0.3 and in bytes beginning with this version.
`-O bulk_insert_buffer_size=#`	Size of tree cache used in bulk insert optimisation. **Note** that this is a limit **per thread**!

The automatic recovery is activated if you start `mysqld` with `--myisam-recover=#`. See Section 4.1.1 [Command-line options], page 195. On open, the table is checked if it's marked

as crashed or if the open count variable for the table is not 0 and you are running with `--skip-external-locking`. If either of the above is true the following happens.

- The table is checked for errors.
- If we found an error, try to do a fast repair (with sorting and without re-creating the datafile) of the table.
- If the repair fails because of an error in the datafile (for example a duplicate key error), we try again, but this time we re-create the datafile.
- If the repair fails, retry once more with the old repair option method (write row by row without sorting) which should be able to repair any type of error with little disk requirements..

If the recover wouldn't be able to recover all rows from a previous completed statement and you didn't specify `FORCE` as an option to `myisam-recover`, then the automatic repair will abort with an error message in the error file:

```
Error: Couldn't repair table: test.g00pages
```

If you in this case had used the `FORCE` option you would instead have got a warning in the error file:

```
Warning: Found 344 of 354 rows when repairing ./test/g00pages
```

Note that if you run automatic recover with the `BACKUP` option, you should have a `cron` script that automatically moves file with names like '`tablename-datetime.BAK`' from the database directories to a backup media.

See Section 4.1.1 [Command-line options], page 195.

7.1.1 Space Needed for Keys

MySQL can support different index types, but the normal type is ISAM or MyISAM. These use a B-tree index, and you can roughly calculate the size for the index file as `(key_length+4)/0.67`, summed over all keys. (This is for the worst case when all keys are inserted in sorted order and we don't have any compressed keys.)

String indexes are space compressed. If the first index part is a string, it will also be prefix compressed. Space compression makes the index file smaller than the above figures if the string column has a lot of trailing space or is a `VARCHAR` column that is not always used to the full length. Prefix compression is used on keys that start with a string. Prefix compression helps if there are many strings with an identical prefix.

In `MyISAM` tables, you can also prefix compress numbers by specifying `PACK_KEYS=1` when you create the table. This helps when you have many integer keys that have an identical prefix when the numbers are stored high-byte first.

7.1.2 `MyISAM` Table Formats

`MyISAM` supports 3 different table types. Two of them are chosen automatically depending on the type of columns you are using. The third, compressed tables, can only be created with the `myisampack` tool.

When you `CREATE` or `ALTER` a table you can for tables that doesn't have `BLOB`s force the table format to `DYNAMIC` or `FIXED` with the `ROW_FORMAT=#` table option. In the future you will

be able to compress/decompress tables by specifying `ROW_FORMAT=compressed | default` to `ALTER TABLE`. See Section 6.5.3 [CREATE TABLE], page 564.

7.1.2.1 Static (Fixed-length) Table Characteristics

This is the default format. It's used when the table contains no `VARCHAR`, `BLOB`, or `TEXT` columns.

This format is the simplest and most secure format. It is also the fastest of the on-disk formats. The speed comes from the easy way data can be found on disk. When looking up something with an index and static format it is very simple. Just multiply the row number by the row length.

Also, when scanning a table it is very easy to read a constant number of records with each disk read.

The security is evidenced if your computer crashes when writing to a fixed-size MyISAM file, in which case `myisamchk` can easily figure out where each row starts and ends. So it can usually reclaim all records except the partially written one. Note that in MySQL all indexes can always be reconstructed:

- All `CHAR`, `NUMERIC`, and `DECIMAL` columns are space-padded to the column width.
- Very quick.
- Easy to cache.
- Easy to reconstruct after a crash, because records are located in fixed positions.
- Doesn't have to be reorganised (with `myisamchk`) unless a huge number of records are deleted and you want to return free disk space to the operating system.
- Usually requires more disk space than dynamic tables.

7.1.2.2 Dynamic Table Characteristics

This format is used if the table contains any `VARCHAR`, `BLOB`, or `TEXT` columns or if the table was created with `ROW_FORMAT=dynamic`.

This format is a little more complex because each row has to have a header that says how long it is. One record can also end up at more than one location when it is made longer at an update.

You can use `OPTIMIZE table` or `myisamchk` to defragment a table. If you have static data that you access/change a lot in the same table as some `VARCHAR` or `BLOB` columns, it might be a good idea to move the dynamic columns to other tables just to avoid fragmentation:

- All string columns are dynamic (except those with a length less than 4).
- Each record is preceded by a bitmap indicating which columns are empty (`''`) for string columns, or zero for numeric columns. (This isn't the same as columns containing `NULL` values.) If a string column has a length of zero after removal of trailing spaces, or a numeric column has a value of zero, it is marked in the bit map and not saved to disk. Non-empty strings are saved as a length byte plus the string contents.
- Usually takes much less disk space than fixed-length tables.

- Each record uses only as much space as is required. If a record becomes larger, it is split into as many pieces as are required. This results in record fragmentation.
- If you update a row with information that extends the row length, the row will be fragmented. In this case, you may have to run `myisamchk -r` from time to time to get better performance. Use `myisamchk -ei tbl_name` for some statistics.
- Not as easy to reconstruct after a crash, because a record may be fragmented into many pieces and a link (fragment) may be missing.
- The expected row length for dynamic sized records is:

```
3
+ (number of columns + 7) / 8
+ (number of char columns)
+ packed size of numeric columns
+ length of strings
+ (number of NULL columns + 7) / 8
```

  There is a penalty of 6 bytes for each link. A dynamic record is linked whenever an update causes an enlargement of the record. Each new link will be at least 20 bytes, so the next enlargement will probably go in the same link. If not, there will be another link. You may check how many links there are with `myisamchk -ed`. All links may be removed with `myisamchk -r`.

7.1.2.3 Compressed Table Characteristics

This is a read-only type that is generated with the optional `myisampack` tool (`pack_isam` for `ISAM` tables):

- All MySQL distributions, even those that existed before MySQL went `GPL`, can read tables that were compressed with `myisampack`.
- Compressed tables take very little disk space. This minimises disk usage, which is very nice when using slow disks (like CD-ROMs).
- Each record is compressed separately (very little access overhead). The header for a record is fixed (1-3 bytes) depending on the biggest record in the table. Each column is compressed differently. Some of the compression types are:
  - There is usually a different Huffman table for each column.
  - Suffix space compression.
  - Prefix space compression.
  - Numbers with value `0` are stored using 1 bit.
  - If values in an integer column have a small range, the column is stored using the smallest possible type. For example, a `BIGINT` column (8 bytes) may be stored as a `TINYINT` column (1 byte) if all values are in the range `0` to `255`.
  - If a column has only a small set of possible values, the column type is converted to `ENUM`.
  - A column may use a combination of the above compressions.
- Can handle fixed- or dynamic-length records.
- Can be uncompressed with `myisamchk`.

7.1.3 MyISAM Table Problems

The file format that MySQL uses to store data has been extensively tested, but there are always circumstances that may cause database tables to become corrupted.

7.1.3.1 Corrupted MyISAM Tables

Even if the MyISAM table format is very reliable (all changes to a table is written before the SQL statements returns) , you can still get corrupted tables if some of the following things happens:

- The `mysqld` process being killed in the middle of a write.
- Unexpected shutdown of the computer (for example, if the computer is turned off).
- A hardware error.
- You are using an external program (like myisamchk) on a live table.
- A software bug in the MySQL or MyISAM code.

Typial typical symptoms for a corrupt table is:

- You get the error `Incorrect key file for table: '...'. Try to repair it` while selecting data from the table.
- Queries doesn't find rows in the table or returns incomplete data.

You can check if a table is ok with the command `CHECK TABLE`. See Section 4.5.4 [CHECK TABLE], page 262.

You can repair a corrupted table with `REPAIR TABLE`. See Section 4.5.5 [REPAIR TABLE], page 263. You can also repair a table, when `mysqld` is not running with the `myisamchk` command. `myisamchk syntax`.

If your tables get corrupted a lot you should try to find the reason for this! See Section A.4.1 [Crashing], page 859.

In this case the most important thing to know is if the table got corrupted if the `mysqld` died (one can easily verify this by checking if there is a recent row `restarted mysqld` in the mysqld error file). If this isn't the case, then you should try to make a test case of this. See Section E.1.6 [Reproduceable test case], page 1012.

7.1.3.2 Clients is using or hasn't closed the table properly

Each `MyISAM` '`.MYI`' file has in the header a counter that can be used to check if a table has been closed properly.

If you get the following warning from `CHECK TABLE` or `myisamchk`:

```
# clients is using or hasn't closed the table properly
```

this means that this counter has come out of sync. This doesn't mean that the table is corrupted, but means that you should at least do a check on the table to verify that it's okay.

The counter works as follows:

- The first time a table is updated in MySQL, a counter in the header of the index files is incremented.
- The counter is not changed during further updates.
- When the last instance of a table is closed (because of a `FLUSH` or because there isn't room in the table cache) the counter is decremented if the table has been updated at any point.
- When you repair the table or check the table and it was okay, the counter is reset to 0.
- To avoid problems with interaction with other processes that may do a check on the table, the counter is not decremented on close if it was 0.

In other words, the only ways this can go out of sync are:

- The `MyISAM` tables are copied without a `LOCK` and `FLUSH TABLES`.
- MySQL has crashed between an update and the final close. (Note that the table may still be okay, as MySQL always issues writes for everything between each statement.)
- Someone has done a `myisamchk --recover` or `myisamchk --update-state`on a table that was in use by `mysqld`.
- Many `mysqld` servers are using the table and one has done a `REPAIR` or `CHECK` of the table while it was in use by another server. In this setup the `CHECK` is safe to do (even if you will get the warning from other servers), but `REPAIR` should be avoided as it currently replaces the datafile with a new one, which is not signaled to the other servers.

7.2 `MERGE` Tables

`MERGE` tables are new in MySQL Version 3.23.25. The code is still in gamma, but should be reasonable stable.

A `MERGE` table (also known as a `MRG_MyISAM` table) is a collection of identical `MyISAM` tables that can be used as one. You can only `SELECT`, `DELETE`, and `UPDATE` from the collection of tables. If you `DROP` the `MERGE` table, you are only dropping the `MERGE` specification.

Note that `DELETE FROM merge_table` used without a `WHERE` will only clear the mapping for the table, not delete everything in the mapped tables. (We plan to fix this in 4.1).

With identical tables we mean that all tables are created with identical column and key information. You can't merge tables in which the columns are packed differently, doesn't have exactly the same columns, or have the keys in different order. However, some of the tables can be compressed with `myisampack`. See Section 4.8.4 [`myisampack`], page 317.

When you create a `MERGE` table, you will get a '`.frm`' table definition file and a '`.MRG`' table list file. The '`.MRG`' just contains a list of the index files ('`.MYI`' files) that should be used as one. Before 4.1.1 all used tables had to be in the same database as the `MERGE` table itself.

For the moment, you need to have `SELECT`, `UPDATE`, and `DELETE` privileges on the tables you map to a `MERGE` table.

`MERGE` tables can help you solve the following problems:

- Easily manage a set of log tables. For example, you can put data from different months into separate files, compress some of them with `myisampack`, and then create a `MERGE` to use these as one.

- Give you more speed. You can split a big read-only table based on some criteria and then put the different table part on different disks. A `MERGE` table on this could be much faster than using the big table. (You can, of course, also use a RAID to get the same kind of benefits.)
- Do more efficient searches. If you know exactly what you are looking after, you can search in just one of the split tables for some queries and use a `MERGE` table for others. You can even have many different `MERGE` tables active, with possible overlapping files.
- More efficient repairs. It's easier to repair the individual files that are mapped to a `MERGE` file than trying to repair a really big file.
- Instant mapping of many files as one. A `MERGE` table uses the index of the individual tables. It doesn't need to maintain an index of its one. This makes `MERGE` table collections VERY fast to make or remap. Note that you must specify the key definitions when you create a `MERGE` table!.
- If you have a set of tables that you join to a big table on demand or batch, you should instead create a `MERGE` table on them on demand. This is much faster and will save a lot of disk space.
- Go around the file-size limit for the operating system.
- You can create an alias/synonym for a table by just using `MERGE` over one table. There shouldn't be any really notable performance impacts of doing this (only a couple of indirect calls and `memcpy()` calls for each read).

The disadvantages with `MERGE` tables are:

- You can only use identical `MyISAM` tables for a `MERGE` table.
- `REPLACE` doesn't work.
- `MERGE` tables uses more file descriptors. If you are using a `MERGE` table that maps over 10 tables and 10 users are using this, you are using 10*10 + 10 file descriptors. (10 datafiles for 10 users and 10 shared index files.)
- Key reads are slower. When you do a read on a key, the `MERGE` storage engine will need to issue a read on all underlying tables to check which one most closely matches the given key. If you then do a `"read-next"` then the `MERGE` storage engine will need to search the read buffers to find the next key. Only when one key buffer is used up, the storage engine will need to read the next key block. This makes `MERGE` keys much slower on `eq_ref` searches, but not much slower on `ref` searches. See Section 5.2.1 [EXPLAIN], page 399.
- You can't do `DROP TABLE`, `ALTER TABLE`, `DELETE FROM table_name` without a `WHERE` clause, `REPAIR TABLE`, `TRUNCATE TABLE`, `OPTIMIZE TABLE`, or `ANALYZE TABLE` on any of the table that is mapped by a `MERGE` table that is `"open"`. If you do this, the `MERGE` table may still refer to the original table and you will get unexpected results. The easiest way to get around this deficiency is to issue the `FLUSH TABLES` command, ensuring no `MERGE` tables remain `"open"`.

When you create a `MERGE` table you have to specify with `UNION=(list-of-tables)` which tables you want to use as one. Optionally you can specify with `INSERT_METHOD` if you want insert for the `MERGE` table to happen in the first or last table in the `UNION` list. If you don't specify `INSERT_METHOD` or specify `NO`, then all `INSERT` commands on the `MERGE` table will return an error.

The following example shows you how to use MERGE tables:

```
CREATE TABLE t1 (a INT NOT NULL AUTO_INCREMENT PRIMARY KEY, message CHAR(20));
CREATE TABLE t2 (a INT NOT NULL AUTO_INCREMENT PRIMARY KEY, message CHAR(20));
INSERT INTO t1 (message) VALUES ("Testing"),("table"),("t1");
INSERT INTO t2 (message) VALUES ("Testing"),("table"),("t2");
CREATE TABLE total (a INT NOT NULL AUTO_INCREMENT, message CHAR(20), KEY(a))
             TYPE=MERGE UNION=(t1,t2) INSERT_METHOD=LAST;
SELECT * FROM total;
```

Note that we didn't create a UNIQUE or PRIMARY KEY in the total table as the key isn't going to be unique in the total table.

Note that you can also manipulate the '.MRG' file directly from the outside of the MySQL server:

```
shell> cd /mysql-data-directory/current-database
shell> ls -1 t1.MYI t2.MYI > total.MRG
shell> mysqladmin flush-tables
```

Now you can do things like:

```
mysql> SELECT * FROM total;
+---+---------+
| a | message |
+---+---------+
| 1 | Testing |
| 2 | table   |
| 3 | t1      |
| 1 | Testing |
| 2 | table   |
| 3 | t2      |
+---+---------+
```

Note that the a column, though declared as PRIMARY KEY, is not really unique, as MERGE table cannot enforce uniqueness over a set of underlying MyISAM tables.

To remap a MERGE table you can do one of the following:

- DROP the table and re-create it
- Use ALTER TABLE table_name UNION=(...)
- Change the '.MRG' file and issue a FLUSH TABLE on the MERGE table and all underlying tables to force the storage engine to read the new definition file.

7.2.1 MERGE Table Problems

The following are the known problems with MERGE tables:

- A MERGE table cannot maintain UNIQUE constraints over the whole table. When you do INSERT, the data goes into the first or last table (according to INSERT_METHOD=xxx) and this MyISAM table ensures that the data are unique, but it knows nothing about others MyISAM tables.
- DELETE FROM merge_table used without a WHERE will only clear the mapping for the table, not delete everything in the mapped tables.

- `RENAME TABLE` on a table used in an active `MERGE` table may corrupt the table. This will be fixed in MySQL 4.1.x.
- Creation of a table of type `MERGE` doesn't check if the underlying tables are of compatible types or if they exists. MySQL will do a quick check if the record length is equal between mapped tables when the `MERGE` table is used, but this is not a fullproof check.

  If you use `MERGE` tables in this fashion, you are very likely to run into strange problems.
- If you use `ALTER TABLE` to first add an `UNIQUE` index to a table used in a `MERGE` table and then use `ALTER TABLE` to add a normal index on the `MERGE` table, the key order will be different for the tables if there was an old non-unique key in the table. This is because `ALTER TABLE` puts `UNIQUE` keys before normal keys to be able to detect duplicate keys as early as possible.
- `DROP TABLE` on a table that is in use by a `MERGE` table will not work on Windows because the `MERGE` storage engine does the table mapping hidden from the upper layer of MySQL. Because Windows doesn't allow you to drop files that are open, you first must flush all `MERGE` tables (with `FLUSH TABLES`) or drop the `MERGE` table before dropping the table. We will fix this at the same time we introduce `VIEW`s.

7.3 `ISAM` Tables

The deprecated `ISAM` table type will disappear in MySQL version 5.0. In MySQL 4.1 it's included in the source but not compiled anymore. `MyISAM` is a better implementation of this table handler and you should convert all `ISAM` tables to `MySAM` tables as soon as possible.

`ISAM` uses a `B-tree` index. The index is stored in a file with the '`.ISM`' extension, and the data is stored in a file with the '`.ISD`' extension. You can check/repair `ISAM` tables with the `isamchk` utility. See Section 4.5.6.7 [Crash recovery], page 270.

`ISAM` has the following features/properties:

- Compressed and fixed-length keys
- Fixed and dynamic record length
- 16 keys with 16 key parts/key
- Max key length 256 (default)
- Data is stored in machine format; this is fast, but is machine/OS dependent.

Most of the things true for `MyISAM` tables are also true for `ISAM` tables. See Section 7.1 [`MyISAM` tables], page 595. The major differences compared to `MyISAM` tables are:

- `ISAM` tables are not binary portable across OS/Platforms.
- Can't handle tables > 4G.
- Only support prefix compression on strings.
- Smaller key limits.
- Dynamic tables get more fragmented.
- Tables are compressed with `pack_isam` rather than with `myisampack`.

If you want to convert an `ISAM` table to a `MyISAM` table so that you can use utilities such as `mysqlcheck`, use an `ALTER TABLE` statement:

```
mysql> ALTER TABLE tbl_name TYPE = MYISAM;
```

The embedded MySQL versions doesn't support `ISAM` tables.

7.4 HEAP Tables

HEAP tables use hashed indexes and are stored in memory. This makes them very fast, but if MySQL crashes you will lose all data stored in them. HEAP is very useful for temporary tables!

The MySQL internal HEAP tables use 100% dynamic hashing without overflow areas. There is no extra space needed for free lists. HEAP tables also don't have problems with delete + inserts, which normally is common with hashed tables:

```
mysql> CREATE TABLE test TYPE=HEAP SELECT ip,SUM(downloads) AS down
    ->                   FROM log_table GROUP BY ip;
mysql> SELECT COUNT(ip),AVG(down) FROM test;
mysql> DROP TABLE test;
```

Here are some things you should consider when you use HEAP tables:

- You should always use specify MAX_ROWS in the CREATE statement to ensure that you accidentally do not use all memory.
- Indexes will only be used with = and <=> (but are VERY fast).
- HEAP tables can only use whole keys to search for a row; compare this to MyISAM tables where any prefix of the key can be used to find rows.
- HEAP tables use a fixed record length format.
- HEAP doesn't support BLOB/TEXT columns.
- HEAP doesn't support AUTO_INCREMENT columns.
- Prior to MySQL 4.0.2, HEAP doesn't support an index on a NULL column.
- You can have non-unique keys in a HEAP table (this isn't common for hashed tables).
- HEAP tables are shared between all clients (just like any other table).
- You can't search for the next entry in order (that is, to use the index to do an ORDER BY).
- Data for HEAP tables are allocated in small blocks. The tables are 100% dynamic (on inserting). No overflow areas and no extra key space are needed. Deleted rows are put in a linked list and are reused when you insert new data into the table.
- You need enough extra memory for all HEAP tables that you want to use at the same time.
- To free memory, you should execute DELETE FROM heap_table, TRUNCATE heap_table or DROP TABLE heap_table.
- MySQL cannot find out approximately how many rows there are between two values (this is used by the range optimiser to decide which index to use). This may affect some queries if you change a MyISAM table to a HEAP table.
- To ensure that you accidentally don't do anything foolish, you can't create HEAP tables bigger than max_heap_table_size.

The memory needed for one row in a HEAP table is:

```
SUM_OVER_ALL_KEYS(max_length_of_key + sizeof(char*) * 2)
+ ALIGN(length_of_row+1, sizeof(char*))
```

sizeof(char*) is 4 on 32-bit machines and 8 on 64-bit machines.

7.5 InnoDB Tables

7.5.1 InnoDB Tables Overview

InnoDB provides MySQL with a transaction-safe (ACID compliant) storage engine with commit, rollback, and crash recovery capabilities. InnoDB does locking on row level and also provides an Oracle-style consistent non-locking read in SELECTs. These features increase multiuser concurrency and performance. There is no need for lock escalation in InnoDB, because row level locks in InnoDB fit in very small space. InnoDB is the first storage manager in MySQL to support FOREIGN KEY constraints.

InnoDB has been designed for maximum performance when processing large data volumes. Its CPU efficiency is probably not matched by any other disk-based relational database engine.

InnoDB is used in production at numerous large database sites requiring high performance. The famous Internet news site Slashdot.org runs on InnoDB. Mytrix, Inc. stores over 1 TB of data in InnoDB, and another site handles an average load of 800 inserts/updates per second in InnoDB.

Technically, InnoDB is a complete database backend placed under MySQL. InnoDB has its own buffer pool for caching data and indexes in main memory. InnoDB stores its tables and indexes in a tablespace, which may consist of several files (or raw disk partitions). This is different from, for example, MyISAM tables where each table is stored as a separate file. InnoDB tables can be of any size even on operating systems where file-size is limited to 2 GB.

You can find the latest information about InnoDB at http://www.innodb.com/. The most up-to-date version of the InnoDB manual is always placed there.

InnoDB is published under the same GNU GPL License Version 2 (of June 1991) as MySQL. If you distribute MySQL/InnoDB, and your application does not satisfy the restrictions of the GPL license, you have to buy a commercial **MySQL Pro** license from https://order.mysql.com/?sub=pg&pg_no=1.

7.5.2 InnoDB in MySQL Version 3.23

From MySQL version 4.0, InnoDB is enabled by default. The following information only applies to the 3.23 series.

InnoDB tables are included in the MySQL source distribution starting from 3.23.34a and are activated in the MySQL -Max binary of the 3.23 series. For Windows the -Max binaries are contained in the standard distribution.

If you have downloaded a binary version of MySQL that includes support for InnoDB, simply follow the instructions of the MySQL manual for installing a binary version of MySQL. If you already have MySQL-3.23 installed, then the simplest way to install MySQL -Max is to replace the server executable '`mysqld`' with the corresponding executable in the -Max distribution. MySQL and MySQL -Max differ only in the server executable. See Section 2.2.9 [Installing binary], page 85. See Section 4.8.5 [mysqld-max], page 323.

To compile MySQL with InnoDB support, download MySQL-3.23.34a or newer version from `http://www.mysql.com/` and configure MySQL with the `--with-innodb` option. See the MySQL manual about installing a MySQL source distribution. See Section 2.3 [Installing source], page 88.

```
cd /path/to/source/of/mysql-3.23.37
./configure --with-innodb
```

To use InnoDB tables in MySQL-Max-3.23 you **must** specify configuration parameters in the `[mysqld]` section of the configuration file '`my.cnf`', or on Windows optionally in '`my.ini`'.

At the minimum, in 3.23 you must specify `innodb_data_file_path` where you specify the names and the sizes of datafiles. If you do not mention `innodb_data_home_dir` in '`my.cnf`' the default is to create these files to the `datadir` of MySQL. If you specify `innodb_data_home_dir` as an empty string, then you can give absolute paths to your datafiles in `innodb_data_file_path`.

The minimal way to modify it is to add to the `[mysqld]` section the line

```
innodb_data_file_path=ibdata:30M
```

but to get good performance it is best that you specify options as recommended. See Section 7.5.3 [InnoDB start], page 607.

7.5.3 InnoDB Startup Options

To enable `InnoDB` tables in MySQL version 3.23, see Section 7.5.2 [InnoDB in MySQL 3.23], page 606.

In MySQL-4.0 you are not required to do anything specific to enable `InnoDB` tables.

The default behaviour in MySQL-4.0 and MySQL-4.1 is to create an auto-extending 10 MB file '`ibdata1`' in the `datadir` of MySQL and two 5 MB '`ib_logfile`'s to the `datadir`. (In MySQL-4.0.0 and 4.0.1 the datafile is 64 MB and not auto-extending.)

Note: To get good performance you **should** explicitly set the InnoDB parameters listed in the following examples.

If you don't want to use `InnoDB` tables, you can add the `skip-innodb` option to your MySQL option file.

Starting from versions 3.23.50 and 4.0.2, `InnoDB` allows the last datafile on the `innodb_data_file_path` line to be specified as **auto-extending**. The syntax for `innodb_data_file_path` is then the following:

```
pathtodatafile:sizespecification;pathtodatafile:sizespecification;...
...  ;pathtodatafile:sizespecification[:autoextend[:max:sizespecification]]
```

If you specify the last datafile with the `autoextend` option, `InnoDB` will extend the last datafile if it runs out of free space in the tablespace. The increment is 8 MB at a time. An example:

```
innodb_data_home_dir =
innodb_data_file_path = /ibdata/ibdata1:100M:autoextend
```

instructs `InnoDB` to create just a single datafile whose initial size is 100 MB and which is extended in 8 MB blocks when space runs out. If the disk becomes full you may want to add another datafile to another disk, for example. Then you have to look at the size of

'ibdata1', round the size downward to the closest multiple of 1024 * 1024 bytes (= 1 MB), and specify the rounded size of 'ibdata1' explicitly in innodb_data_file_path. After that you can add another datafile:

```
innodb_data_home_dir =
innodb_data_file_path = /ibdata/ibdata1:988M;/disk2/ibdata2:50M:autoextend
```

Be cautious on filesystems where the maximum file-size is 2 GB. InnoDB is not aware of the OS maximum file-size. On those filesystems you might want to specify the max size for the datafile:

```
innodb_data_home_dir =
innodb_data_file_path = /ibdata/ibdata1:100M:autoextend:max:2000M
```

A simple 'my.cnf' example. Suppose you have a computer with 128 MB RAM and one hard disk. Below is an example of possible configuration parameters in 'my.cnf' or 'my.ini' for InnoDB. We assume you are running MySQL-Max-3.23.50 or later, or MySQL-4.0.2 or later. This example suits most users, both on Unix and Windows, who do not want to distribute InnoDB datafiles and log files on several disks. This creates an auto-extending datafile 'ibdata1' and two InnoDB log files 'ib_logfile0' and 'ib_logfile1' to the datadir of MySQL (typically '/mysql/data'). Also the small archived InnoDB log file 'ib_arch_log_0000000000' ends up in the datadir.

```
[mysqld]
# You can write your other MySQL server options here
# ...
#                                  Datafile(s) must be able to
#                                  hold your data and indexes.
#                                  Make sure you have enough
#                                  free disk space.
innodb_data_file_path = ibdata1:10M:autoextend
#                                  Set buffer pool size to
#                                  50 - 80 % of your computer's
#                                  memory
set-variable = innodb_buffer_pool_size=70M
set-variable = innodb_additional_mem_pool_size=10M
#                                  Set the log file size to about
#                                  25 % of the buffer pool size
set-variable = innodb_log_file_size=20M
set-variable = innodb_log_buffer_size=8M
#                                  Set ..flush_log_at_trx_commit
#                                  to 0 if you can afford losing
#                                  some last transactions
innodb_flush_log_at_trx_commit=1
```

Check that the MySQL server has the rights to create files in datadir.

Note that datafiles must be < 2 GB in some file systems! The combined size of the log files must be < 4 GB. The combined size of datafiles must be >= 10 MB.

When you for the first time create an InnoDB database, it is best that you start the MySQL server from the command prompt. Then InnoDB will print the information about the database creation to the screen, and you see what is happening. See below next section what

the printout should look like. For example, in Windows you can start '`mysqld-max.exe`' with:

```
your-path-to-mysqld\mysqld-max --console
```

Where to put '`my.cnf`' or '`my.ini`' in Windows? The rules for Windows are the following:

- Only one of '`my.cnf`' or '`my.ini`' should be created.
- The '`my.cnf`' file should be placed in the root directory of the drive '`C:`'.
- The '`my.ini`' file should be placed in the WINDIR directory, e.g, '`C:\WINDOWS`' or '`C:\WINNT`'. You can use the `SET` command of MS-DOS to print the value of WINDIR.
- If your PC uses a boot loader where the '`C:`' drive is not the boot drive, then your only option is to use the '`my.ini`' file.

Where to specify options in Unix? On Unix '`mysqld`' reads options from the following files, if they exist, in the following order:

- '`/etc/my.cnf`' Global options.
- '`COMPILATION_DATADIR/my.cnf`' Server-specific options.
- '`defaults-extra-file`' The file specified with `--defaults-extra-file=...`.
- '`~/.my.cnf`' User-specific options.

'`COMPILATION_DATADIR`' is the MySQL data directory which was specified as a `./configure` option when '`mysqld`' was compiled (typically '`/usr/local/mysql/data`' for a binary installation or '`/usr/local/var`' for a source installation).

If you are not sure from where '`mysqld`' reads its '`my.cnf`' or '`my.ini`', you can give the path as the first command-line option to the server: `mysqld --defaults-file=your_path_to_my_cnf`.

InnoDB forms the directory path to a datafile by textually catenating `innodb_data_home_dir` to a datafile name or path in `innodb_data_file_path`, adding a possible slash or backslash in between if needed. If the keyword `innodb_data_home_dir` is not mentioned in '`my.cnf`' at all, the default for it is the 'dot' directory '`./`' which means the `datadir` of MySQL.

An advanced '`my.cnf`' example. Suppose you have a Linux computer with 2 GB RAM and three 60 GB hard disks (at directory paths '`/`', '`/dr2`' and '`/dr3`'). Below is an example of possible configuration parameters in '`my.cnf`' for InnoDB.

Note that InnoDB does not create directories: you have to create them yourself. Use the Unix or MS-DOS `mkdir` command to create the data and log group home directories.

```
[mysqld]
# You can write your other MySQL server options here
# ...
innodb_data_home_dir =
#                                   Datafiles must be able to
#                                   hold your data and indexes
innodb_data_file_path = /ibdata/ibdata1:2000M;/dr2/ibdata/ibdata2:2000M:autoextend
#                                   Set buffer pool size to
#                                   50 - 80 % of your computer's
#                                   memory, but make sure on Linux
#                                   x86 total memory usage is
```

```
#                                       < 2 GB
set-variable = innodb_buffer_pool_size=1G
set-variable = innodb_additional_mem_pool_size=20M
innodb_log_group_home_dir = /dr3/iblogs
#                                       .._log_arch_dir must be the same
#                                       as .._log_group_home_dir
innodb_log_arch_dir = /dr3/iblogs
set-variable = innodb_log_files_in_group=3
#                                       Set the log file size to about
#                                       15 % of the buffer pool size
set-variable = innodb_log_file_size=150M
set-variable = innodb_log_buffer_size=8M
#                                       Set ..flush_log_at_trx_commit to
#                                       0 if you can afford losing
#                                       some last transactions
innodb_flush_log_at_trx_commit=1
set-variable = innodb_lock_wait_timeout=50
#innodb_flush_method=fdatasync
#set-variable = innodb_thread_concurrency=5
```

Note that we have placed the two datafiles on different disks. InnoDB will fill the tablespace formed by the datafiles from bottom up. In some cases it will improve the performance of the database if all data is not placed on the same physical disk. Putting log files on a different disk from data is very often beneficial for performance. You can also use **raw disk partitions** (raw devices) as datafiles. In some Unixes they speed up I/O. See the manual section on InnoDB file space management about how to specify them in '`my.cnf`'.

Warning: on Linux x86 you must be careful you **do not set memory usage too high**. glibc will allow the process heap to grow over thread stacks, which will crash your server. It is a risk if the value of

```
innodb_buffer_pool_size + key_buffer +
max_connections * (sort_buffer + read_buffer_size) + max_connections * 2 MB
```

is close to 2 GB or exceeds 2 GB. Each thread will use a stack (often 2 MB, but in MySQL AB binaries only 256 KB) and in the worst case also `sort_buffer + read_buffer_size` additional memory.

How to tune other '`mysqld`' server parameters? Typical values which suit most users are:

```
skip-locking
set-variable = max_connections=200
set-variable = read_buffer_size=1M
set-variable = sort_buffer=1M
#                                       Set key_buffer to 5 - 50%
#                                       of your RAM depending on how
#                                       much you use MyISAM tables, but
#                                       keep key_buffer + InnoDB
#                                       buffer pool size < 80% of
#                                       your RAM
set-variable = key_buffer=...
```

Note that some parameters are given using the numeric '`my.cnf`' parameter format: `set-variable = innodb... = 123`, others (string and boolean parameters) with another format: `innodb_... = ...` .

The meanings of the configuration parameters are the following:

Option	Description
`innodb_data_home_dir`	The common part of the directory path for all InnoDB datafiles. If you do not mentioned this option in '`my.cnf`' the default is the `datadir` of MySQL. You can specify this also as an empty string, in which case you can use absolute file paths in `innodb_data_file_path`.
`innodb_data_file_path`	Paths to individual datafiles and their sizes. The full directory path to each datafile is acquired by concatenating innodb_data_home_dir to the paths specified here. The file sizes are specified in megabytes, hence the 'M' after the size specification above. InnoDB also understands the abbreviation 'G', 1 G meaning 1024 MB. Starting from 3.23.44 you can set the file-size bigger than 4 GB on those operating systems which support big files. On some operating systems files must be < 2 GB. If you do not specify `innodb_data_file_path`, the default behaviour starting from 4.0 is to create a 10 MB auto-extending datafile '`ibdata1`'. The sum of the sizes of the files must be at least 10 MB.
`innodb_mirrored_log_groups`	Number of identical copies of log groups we keep for the database. Currently this should be set to 1.
`innodb_log_group_home_dir`	Directory path to InnoDB log files. If you do not mentioned this option in '`my.cnf`' the default is the `datadir` of MySQL.
`innodb_log_files_in_group`	Number of log files in the log group. InnoDB writes to the files in a circular fashion. Value 2 is recommended here. The default is 2.
`innodb_log_file_size`	Size of each log file in a log group in megabytes. Sensible values range from 1M to 1/n-th of the size of the buffer pool specified below, where n is the number of log files in the group. The larger the value, the less checkpoint flush activity is needed in the buffer pool, saving disk I/O. But larger log files also mean that recovery will be slower in case of a crash. The combined size of log files must be less than 4 GB on 32-bit computers. The default is 5M.
`innodb_log_buffer_size`	The size of the buffer which InnoDB uses to write log to the log files on disk. Sensible values range from 1M to 8M. A big log buffer allows large transactions to run without a need to write the log to disk until the transaction commit. Thus, if you have big transactions, making the log buffer big will save disk I/O.

`innodb_flush_log_at_trx_commit`	Normally you set this to 1, meaning that at a transaction commit the log is flushed to disk, and the modifications made by the transaction become permanent, and survive a database crash. If you are willing to compromise this safety, and you are running small transactions, you may set this to 0 or 2 to reduce disk I/O to the logs. Value 0 means that the log is only written to the log file and the log file flushed to disk approximately once per second. Value 2 means the log is written to the log file at each commit, but the log file is only flushed to disk approximately once per second. The default value is 1 starting from MySQL-4.0.13; previously it was 0.
`innodb_log_arch_dir`	The directory where fully written log files would be archived if we used log archiving. The value of this parameter should currently be set the same as `innodb_log_group_home_dir`.
`innodb_log_archive`	This value should currently be set to 0. As recovery from a backup is done by MySQL using its own log files, there is currently no need to archive InnoDB log files.
`innodb_buffer_pool_size`	The size of the memory buffer InnoDB uses to cache data and indexes of its tables. The bigger you set this the less disk I/O is needed to access data in tables. On a dedicated database server you may set this parameter up to 80% of the machine physical memory size. Do not set it too large, though, because competition of the physical memory may cause paging in the operating system.
`innodb_buffer_pool_awe_mem_mb`	Size of the buffer pool in MB, if it is placed in the AWE memory of 32-bit Windows. Available starting from 4.1.0 and only relevant in 32-bit Windows. If your 32-bit Windows operating system supports > 4 GB memory, so-called Address Windowing Extensions, you can allocate the InnoDB buffer pool into the AWE physical memory using this parameter. The maximum possible value for this is 64000. If this parameter is specified, then innodb_buffer_pool_size is the window in the 32-bit address space of mysqld where InnoDB maps that AWE memory. A good value for innodb_buffer_pool_size is then 500M.
`innodb_additional_mem_pool_size`	Size of a memory pool InnoDB uses to store data dictionary information and other internal data structures. A sensible value for this might be 2M, but the more tables you have in your application the more you will need to allocate here. If InnoDB runs out of memory in this pool, it will start to allocate memory from the operating system, and write warning messages to the MySQL error log.
`innodb_file_io_threads`	Number of file I/O threads in InnoDB. Normally, this should be 4, but on Windows disk I/O may benefit from a larger number.

`innodb_lock_wait_timeout`	Timeout in seconds an InnoDB transaction may wait for a lock before being rolled back. InnoDB automatically detects transaction deadlocks in its own lock table and rolls back the transaction. If you use the `LOCK TABLES` command, or other transaction-safe storage engines than InnoDB in the same transaction, then a deadlock may arise which InnoDB cannot notice. In cases like this the timeout is useful to resolve the situation.
`innodb_flush_method`	(Available from 3.23.40 up.) The default value for this is `fdatasync`. Another option is `O_DSYNC`.
`innodb_force_recovery`	Warning: this option should only be defined in an emergency situation when you want to dump your tables from a corrupt database! Possible values are 1 - 6. See below at section 'Forcing recovery' about the meanings of the values. As a safety measure InnoDB prevents a user from modifying data when this option is > 0. This option is available starting from version 3.23.44.

7.5.4 Creating InnoDB Tablespace

Suppose you have installed MySQL and have edited '`my.cnf`' so that it contains the necessary InnoDB configuration parameters. Before starting MySQL you should check that the directories you have specified for InnoDB datafiles and log files exist and that you have access rights to those directories. InnoDB cannot create directories, only files. Check also you have enough disk space for the data and log files.

When you now start MySQL, InnoDB will start creating your datafiles and log files. InnoDB will print something like the following:

```
~/mysqlm/sql > mysqld
InnoDB: The first specified datafile /home/heikki/data/ibdata1
did not exist:
InnoDB: a new database to be created!
InnoDB: Setting file /home/heikki/data/ibdata1 size to 134217728
InnoDB: Database physically writes the file full: wait...
InnoDB: datafile /home/heikki/data/ibdata2 did not exist:
new to be created
InnoDB: Setting file /home/heikki/data/ibdata2 size to 262144000
InnoDB: Database physically writes the file full: wait...
InnoDB: Log file /home/heikki/data/logs/ib_logfile0 did not exist:
new to be created
InnoDB: Setting log file /home/heikki/data/logs/ib_logfile0 size to 5242880
InnoDB: Log file /home/heikki/data/logs/ib_logfile1 did not exist:
new to be created
InnoDB: Setting log file /home/heikki/data/logs/ib_logfile1 size to 5242880
InnoDB: Log file /home/heikki/data/logs/ib_logfile2 did not exist:
new to be created
InnoDB: Setting log file /home/heikki/data/logs/ib_logfile2 size to 5242880
InnoDB: Started
```

```
mysqld: ready for connections
```

A new InnoDB database has now been created. You can connect to the MySQL server with the usual MySQL client programs like `mysql`. When you shut down the MySQL server with '`mysqladmin shutdown`', InnoDB output will be like the following:

```
010321 18:33:34  mysqld: Normal shutdown
010321 18:33:34  mysqld: Shutdown Complete
InnoDB: Starting shutdown...
InnoDB: Shutdown completed
```

You can now look at the datafiles and logs directories and you will see the files created. The log directory will also contain a small file named '`ib_arch_log_0000000000`'. That file resulted from the database creation, after which InnoDB switched off log archiving. When MySQL is again started, the output will be like the following:

```
~/mysqlm/sql > mysqld
InnoDB: Started
mysqld: ready for connections
```

7.5.4.1 If Something Goes Wrong in Database Creation

If InnoDB prints an operating system error in a file operation, usually the problem is one of the following:

- You did not create InnoDB data or log directories.
- '`mysqld`' does not have the rights to create files in those directories.
- '`mysqld`' does not read the right '`my.cnf`' or '`my.ini`' file, and consequently does not see the options you specified.
- The disk is full or a disk quota is exceeded.
- You have created a subdirectory whose name is equal to a datafile you specified.
- There is a syntax error in `innodb_data_home_dir` or `innodb_data_file_path`.

If something goes wrong in an InnoDB database creation, you should delete all files created by InnoDB. This means all datafiles, all log files, the small archived log file, and in the case you already did create some InnoDB tables, delete also the corresponding '`.frm`' files for these tables from the MySQL database directories. Then you can try the InnoDB database creation again.

7.5.5 Creating InnoDB Tables

Suppose you have started the MySQL client with the command `mysql test`. To create a table in the InnoDB format you must specify `TYPE = InnoDB` in the table creation SQL command:

```
CREATE TABLE CUSTOMER (A INT, B CHAR (20), INDEX (A)) TYPE = InnoDB;
```

This SQL command will create a table and an index on column `A` into the InnoDB tablespace consisting of the datafiles you specified in '`my.cnf`'. In addition MySQL will create a file '`CUSTOMER.frm`' to the MySQL database directory '`test`'. Internally, InnoDB will add to its own data dictionary an entry for table `'test/CUSTOMER'`. Thus you can create a table

of the same name `CUSTOMER` in another database of MySQL, and the table names will not collide inside InnoDB.

You can query the amount of free space in the InnoDB tablespace by issuing the table status command of MySQL for any table you have created with `TYPE = InnoDB`. Then the amount of free space in the tablespace appears in the table comment section in the output of `SHOW`. An example:

```
SHOW TABLE STATUS FROM test LIKE 'CUSTOMER'
```

Note that the statistics `SHOW` gives about InnoDB tables are only approximate: they are used in SQL optimisation. Table and index reserved sizes in bytes are accurate, though.

7.5.5.1 Converting MyISAM Tables to InnoDB

InnoDB does not have a special optimisation for separate index creation. Therefore it does not pay to export and import the table and create indexes afterwards. The fastest way to alter a table to InnoDB is to do the inserts directly to an InnoDB table, that is, use `ALTER TABLE ... TYPE=INNODB`, or create an empty InnoDB table with identical definitions and insert the rows with `INSERT INTO ... SELECT * FROM ...`.

To get better control over the insertion process, it may be good to insert big tables in pieces:

```
INSERT INTO newtable SELECT * FROM oldtable
   WHERE yourkey > something AND yourkey <= somethingelse;
```

After all data has been inserted you can rename the tables.

During the conversion of big tables you should set the InnoDB buffer pool size big to reduce disk I/O. Not bigger than 80% of the physical memory, though. You should set InnoDB log files big, and also the log buffer large.

Make sure you do not run out of tablespace: InnoDB tables take a lot more space than MyISAM tables. If an `ALTER TABLE` runs out of space, it will start a rollback, and that can take hours if it is disk-bound. In inserts InnoDB uses the insert buffer to merge secondary index records to indexes in batches. That saves a lot of disk I/O. In rollback no such mechanism is used, and the rollback can take 30 times longer than the insertion.

In the case of a runaway rollback, if you do not have valuable data in your database, it is better that you kill the database process and delete all InnoDB datafiles and log files and all InnoDB table '`.frm`' files, and start your job again, rather than wait for millions of disk I/Os to complete.

7.5.5.2 `FOREIGN KEY` Constraints

Starting from version 3.23.43b InnoDB features foreign key constraints. InnoDB is the first MySQL table type which allows you to define foreign key constraints to guard the integrity of your data.

The syntax of a foreign key constraint definition in InnoDB:

```
[CONSTRAINT symbol] FOREIGN KEY (index_col_name, ...)
                    REFERENCES table_name (index_col_name, ...)
                    [ON DELETE {CASCADE | SET NULL | NO ACTION
                                | RESTRICT}]
```

```
                    [ON UPDATE {CASCADE | SET NULL | NO ACTION
                                | RESTRICT}]
```

Both tables have to be InnoDB type, **in the table there must be an INDEX where the foreign key columns are listed as the FIRST columns in the same order,** and **in the referenced table there must be an INDEX where the referenced columns are listed as the FIRST columns in the same order.** InnoDB does not auto-create indexes on foreign keys or referenced keys: you have to create them explicitly. The indexes are needed for foreign key checks to be fast and not require a table scan.

Corresponding columns in the foreign key and the referenced key must have similar internal datatypes inside InnoDB so that they can be compared without a type conversion. The **size and the signedness of integer types has to be the same**. The length of string types need not be the same. If you specify a `SET NULL` action, make sure you have **not declared the columns in the child table** `NOT NULL`.

If MySQL gives the error number 1005 from a `CREATE TABLE` statement, and the error message string refers to errno 150, then the table creation failed because a foreign key constraint was not correctly formed. Similarly, if an `ALTER TABLE` fails and it refers to errno 150, that means a foreign key definition would be incorrectly formed for the altered table. Starting from version 4.0.13, you can use `SHOW INNODB STATUS` to look at a detailed explanation of the latest InnoDB foreign key error in the server.

Starting from version 3.23.50, InnoDB does not check foreign key constraints on those foreign key or referenced key values which contain a NULL column.

A deviation from SQL standards: if in the parent table there are several rows which have the same referenced key value, then InnoDB acts in foreign key checks like the other parent rows with the same key value would not exist. For example, if you have defined a `RESTRICT` type constraint, and there is a child row with several parent rows, InnoDB does not allow the deletion of any of those parent rows.

Starting from version 3.23.50, you can also associate the `ON DELETE CASCADE` or `ON DELETE SET NULL` clause with the foreign key constraint. Corresponding `ON UPDATE` options are available starting from 4.0.8. If `ON DELETE CASCADE` is specified, and a row in the parent table is deleted, then InnoDB automatically deletes also all those rows in the child table whose foreign key values are equal to the referenced key value in the parent row. If `ON DELETE SET NULL` is specified, the child rows are automatically updated so that the columns in the foreign key are set to the SQL `NULL` value.

A deviation from SQL standards: if `ON UPDATE CASCADE` or `ON UPDATE SET NULL` recurses to update the SAME TABLE it has already updated during the cascade, it acts like `RESTRICT`. This is to prevent infinite loops resulting from cascaded updates. A self-referential `ON DELETE SET NULL`, on the other hand, works starting from 4.0.13. A self-referential `ON DELETE CASCADE` has always worked.

An example:

```
CREATE TABLE parent(id INT NOT NULL, PRIMARY KEY (id)) TYPE=INNODB;
CREATE TABLE child(id INT, parent_id INT, INDEX par_ind (parent_id),
            FOREIGN KEY (parent_id) REFERENCES parent(id)
            ON DELETE SET NULL
) TYPE=INNODB;
```

A complex example:

```
CREATE TABLE product (category INT NOT NULL, id INT NOT NULL,
                      price DECIMAL,
                      PRIMARY KEY(category, id)) TYPE=INNODB;
CREATE TABLE customer (id INT NOT NULL,
                      PRIMARY KEY (id)) TYPE=INNODB;
CREATE TABLE product_order (no INT NOT NULL AUTO_INCREMENT,
                      product_category INT NOT NULL,
                      product_id INT NOT NULL,
                      customer_id INT NOT NULL,
                      PRIMARY KEY(no),
                      INDEX (product_category, product_id),
                      FOREIGN KEY (product_category, product_id)
                        REFERENCES product(category, id)
                        ON UPDATE CASCADE ON DELETE RESTRICT,
                      INDEX (customer_id),
                      FOREIGN KEY (customer_id)
                        REFERENCES customer(id)) TYPE=INNODB;
```

Starting from version 3.23.50, InnoDB allows you to add a new foreign key constraint to a table through

```
ALTER TABLE yourtablename
ADD [CONSTRAINT symbol] FOREIGN KEY (...) REFERENCES anothertablename(...)
[on_delete_and_on_update_actions]
```

Remember to create the required indexes first, though.

Starting from version 4.0.13, InnoDB supports

```
ALTER TABLE yourtablename DROP FOREIGN KEY internally_generated_foreign_key_id
```

You have to use `SHOW CREATE TABLE` to determine the internally generated foreign key ID when you want to drop a foreign key.

In InnoDB versions < 3.23.50 `ALTER TABLE` or `CREATE INDEX` should not be used in connection with tables which have foreign key constraints or which are referenced in foreign key constraints: Any `ALTER TABLE` removes all foreign key constraints defined for the table. You should not use `ALTER TABLE` to the referenced table either, but use `DROP TABLE` and `CREATE TABLE` to modify the schema. When MySQL does an `ALTER TABLE` it may internally use `RENAME TABLE`, and that will confuse the foreign key costraints which refer to the table. A `CREATE INDEX` statement is in MySQL processed as an `ALTER TABLE`, and these restrictions apply also to it.

When doing foreign key checks, InnoDB sets shared row level locks on child or parent records it has to look at. InnoDB checks foreign key constraints immediately: the check is not deferred to transaction commit.

If you want to ignore foreign key constraints during, for example for a `LOAD DATA` operation, you can do `SET FOREIGN_KEY_CHECKS=0`.

InnoDB allows you to drop any table even though that would break the foreign key constraints which reference the table. When you drop a table the constraints which were defined in its create statement are also dropped.

If you re-create a table which was dropped, it has to have a definition which conforms to the foreign key constraints referencing it. It must have the right column names and types,

and it must have indexes on the referenced keys, as stated above. If these are not satisfied, MySQL returns error number 1005 and refers to errno 150 in the error message string.

Starting from version 3.23.50 InnoDB returns the foreign key definitions of a table when you call

```
SHOW CREATE TABLE yourtablename
```

Then also '`mysqldump`' produces correct definitions of tables to the dump file, and does not forget about the foreign keys.

You can also list the foreign key constraints for a table `T` with

```
SHOW TABLE STATUS FROM yourdatabasename LIKE 'T'
```

The foreign key constraints are listed in the table comment of the output.

7.5.6 Adding and Removing InnoDB Data and Log Files

From version 3.23.50 and 4.0.2 you can specify the last InnoDB datafile to `autoextend`. Alternatively, you can increase to your tablespace by specifying an additional datafile. To do this you have to shut down the MySQL server, edit the '`my.cnf`' file adding a new datafile to `innodb_data_file_path`, and then start the MySQL server again.

Currently you cannot remove a datafile from InnoDB. To decrease the size of your database you have to use '`mysqldump`' to dump all your tables, create a new database, and import your tables to the new database.

If you want to change the number or the size of your InnoDB log files, you have to shut down MySQL and make sure that it shuts down without errors. Then copy the old log files into a safe place just in case something went wrong in the shutdown and you will need them to recover the database. Delete then the old log files from the log file directory, edit '`my.cnf`', and start MySQL again. InnoDB will tell you at the startup that it is creating new log files.

7.5.7 Backing up and Recovering an InnoDB Database

The key to safe database management is taking regular backups.

InnoDB Hot Backup is an online backup tool you can use to backup your InnoDB database while it is running. InnoDB Hot Backup does not require you to shut down your database and it does not set any locks or disturb your normal database processing. InnoDB Hot Backup is a non-free additional tool which is not included in the standard MySQL distribution. See the InnoDB Hot Backup homepage `http://www.innodb.com/hotbackup.html` for detailed information and screenshots.

If you are able to shut down your MySQL server, then to take a 'binary' backup of your database you have to do the following:

- Shut down your MySQL database and make sure it shuts down without errors.
- Copy all your datafiles into a safe place.
- Copy all your InnoDB log files to a safe place.
- Copy your '`my.cnf`' configuration file(s) to a safe place.
- Copy all the '`.frm`' files for your InnoDB tables into a safe place.

In addition to taking the binary backups described above, you should also regularly take dumps of your tables with '`mysqldump`'. The reason to this is that a binary file may be corrupted without you noticing it. Dumped tables are stored into text files which are human-readable and much simpler than database binary files. Seeing table corruption from dumped files is easier, and since their format is simpler, the chance for serious data corruption in them is smaller.

A good idea is to take the dumps at the same time you take a binary backup of your database. You have to shut out all clients from your database to get a consistent snapshot of all your tables into your dumps. Then you can take the binary backup, and you will then have a consistent snapshot of your database in two formats.

To be able to recover your InnoDB database to the present from the binary backup described above, you have to run your MySQL database with the general logging and log archiving of MySQL switched on. Here by the general logging we mean the logging mechanism of the MySQL server which is independent of InnoDB logs.

To recover from a crash of your MySQL server process, the only thing you have to do is to restart it. InnoDB will automatically check the logs and perform a roll-forward of the database to the present. InnoDB will automatically roll back uncommitted transactions which were present at the time of the crash. During recovery, InnoDB will print out something like the following:

```
~/mysqlm/sql > mysqld
InnoDB: Database was not shut down normally.
InnoDB: Starting recovery from log files...
InnoDB: Starting log scan based on checkpoint at
InnoDB: log sequence number 0 13674004
InnoDB: Doing recovery: scanned up to log sequence number 0 13739520
InnoDB: Doing recovery: scanned up to log sequence number 0 13805056
InnoDB: Doing recovery: scanned up to log sequence number 0 13870592
InnoDB: Doing recovery: scanned up to log sequence number 0 13936128
...
InnoDB: Doing recovery: scanned up to log sequence number 0 20555264
InnoDB: Doing recovery: scanned up to log sequence number 0 20620800
InnoDB: Doing recovery: scanned up to log sequence number 0 20664692
InnoDB: 1 uncommitted transaction(s) which must be rolled back
InnoDB: Starting rollback of uncommitted transactions
InnoDB: Rolling back trx no 16745
InnoDB: Rolling back of trx no 16745 completed
InnoDB: Rollback of uncommitted transactions completed
InnoDB: Starting an apply batch of log records to the database...
InnoDB: Apply batch completed
InnoDB: Started
mysqld: ready for connections
```

If your database gets corrupted or your disk fails, you have to do the recovery from a backup. In the case of corruption, you should first find a backup which is not corrupted. From a backup do the recovery from the general log files of MySQL according to instructions in the MySQL manual.

7.5.7.1 Forcing recovery

If there is database page corruption, you may want to dump your tables from the database with `SELECT INTO OUTFILE`, and usually most of the data is intact and correct. But the corruption may cause `SELECT * FROM table`, or InnoDB background operations to crash or assert, or even the InnoDB roll-forward recovery to crash. Starting from the InnoDB version 3.23.44, there is a '`my.cnf`' option with which you can force InnoDB to start up, and you can also prevent background operations from running, so that you will be able to dump your tables. For example, you can set

```
set-variable = innodb_force_recovery = 4
```

in '`my.cnf`'.

The alternatives for `innodb_force_recovery` are listed below. The database must not otherwise be used with these options! As a safety measure InnoDB prevents a user from doing `INSERT`, `UPDATE`, or `DELETE` when this option is > 0.

Starting from version 3.23.53 and 4.0.4, you are allowed to `DROP` or `CREATE` a table even if forced recovery is used. If you know that a certain table is causing a crash in rollback, you can drop it. You can use this also to stop a runaway rollback caused by a failing mass import or `ALTER TABLE`. You can kill the mysqld process and use the '`my.cnf`' option `innodb_force_recovery=3` to bring your database up without the rollback. Then `DROP` the table which is causing the runaway rollback.

A bigger number below means that all precautions of lower numbers are included. If you are able to dump your tables with an option at most 4, then you are relatively safe that only some data on corrupt individual pages is lost. Option 6 is more dramatic, because database pages are left in an obsolete state, which in turn may introduce more corruption into B-trees and other database structures.

- 1 (SRV_FORCE_IGNORE_CORRUPT) let the server run even if it detects a corrupt page; try to make `SELECT * FROM table` jump over corrupt index records and pages, which helps in dumping tables;
- 2 (SRV_FORCE_NO_BACKGROUND) prevent the main thread from running: if a crash would occur in purge, this prevents it;
- 3 (SRV_FORCE_NO_TRX_UNDO) do not run transaction rollbacks after recovery;
- 4 (SRV_FORCE_NO_IBUF_MERGE) prevent also insert buffer merge operations: if they would cause a crash, better not do them; do not calculate table statistics;
- 5 (SRV_FORCE_NO_UNDO_LOG_SCAN) do not look at undo logs when starting the database: InnoDB will treat even incomplete transactions as committed;
- 6 (SRV_FORCE_NO_LOG_REDO) do not do the log roll-forward in connection with recovery.

7.5.7.2 Checkpoints

InnoDB implements a checkpoint mechanism called a fuzzy checkpoint. InnoDB will flush modified database pages from the buffer pool in small batches, there is no need to flush the buffer pool in one single batch, which would in practice stop processing of user SQL statements for a while.

In crash recovery InnoDB looks for a checkpoint label written to the log files. It knows that all modifications to the database before the label are already present on the disk image of the database. Then InnoDB scans the log files forward from the place of the checkpoint applying the logged modifications to the database.

InnoDB writes to the log files in a circular fashion. All committed modifications which make the database pages in the buffer pool different from the images on disk must be available in the log files in case InnoDB has to do a recovery. This means that when InnoDB starts to reuse a log file in the circular fashion, it has to make sure that the database page images on disk already contain the modifications logged in the log file InnoDB is going to reuse. In other words, InnoDB has to make a checkpoint and often this involves flushing of modified database pages to disk.

The above explains why making your log files very big may save disk I/O in checkpointing. It can make sense to set the total size of the log files as big as the buffer pool or even bigger. The drawback in big log files is that crash recovery can last longer because there will be more log to apply to the database.

7.5.8 Moving an InnoDB Database to Another Machine

On Windows InnoDB stores the database names and table names internally always in lower case. To move databases in a binary format from Unix to Windows or from Windows to Unix you should have all table and database names in lower case. A convenient way to accomplish this is to add on Unix the line

```
set-variable=lower_case_table_names=1
```

to the `[mysqld]` section of your '`my.cnf`' before you start creating your tables. On Windows the setting 1 is the default.

InnoDB data and log files are binary-compatible on all platforms if the floating-point number format on the machines is the same. You can move an InnoDB database simply by copying all the relevant files, which we already listed in the previous section on backing up a database. If the floating-point formats on the machines are different but you have not used `FLOAT` or `DOUBLE` datatypes in your tables then the procedure is the same: just copy the relevant files. If the formats are different and your tables contain floating-point data, you have to use '`mysqldump`' and '`mysqlimport`' to move those tables.

A performance tip is to switch off auto-commit mode when you import data into your database, assuming your tablespace has enough space for the big rollback segment the big import transaction will generate. Do the commit only after importing a whole table or a segment of a table.

7.5.9 InnoDB Transaction Model and Locking

In the `InnoDB` transaction model the goal has been to combine the best properties of a multi-versioning database to traditional two-phase locking. InnoDB does locking on row level and runs queries by default as non-locking consistent reads, in the style of Oracle. The lock table in `InnoDB` is stored so space-efficiently that lock escalation is not needed: typically several users are allowed to lock every row in the database, or any random subset of the rows, without `InnoDB` running out of memory.

In InnoDB all user activity happens inside transactions. If the autocommit mode is used in MySQL, then each SQL statement forms a single transaction. MySQL always starts a new connection with the autocommit mode switched on.

If the autocommit mode is switched off with SET AUTOCOMMIT = 0, then we can think that a user always has a transaction open. If he issues the SQL COMMIT or ROLLBACK statement, it ends the current transaction, and a new one starts. Both statements will release all InnoDB locks that were set during the current transaction. A COMMIT means that the changes made in the current transaction are made permanent and become visible to other users. A ROLLBACK statement, on the other hand, cancels all modifications made by the current transaction.

If the connection has AUTOCOMMIT = 1, then the user can still perform a multi-statement transaction by starting it with START TRANSACTION or BEGIN and ending it with COMMIT or ROLLBACK.

7.5.9.1 InnoDB and SET ... TRANSACTION ISOLATION LEVEL ...

In terms of the SQL-92 transaction isolation levels, the InnoDB default is REPEATABLE READ. Starting from version 4.0.5, InnoDB offers all 4 different transaction isolation levels described by the SQL-92 standard. You can set the default isolation level for all connections in the [mysqld] section of 'my.cnf':

```
transaction-isolation = {READ-UNCOMMITTED | READ-COMMITTED
                         | REPEATABLE-READ | SERIALIZABLE}
```

A user can change the isolation level of a single session or all new incoming connections with the SET TRANSACTION statement. Its syntax is as follows:

```
SET [SESSION | GLOBAL] TRANSACTION ISOLATION LEVEL
                       {READ UNCOMMITTED | READ COMMITTED
                        | REPEATABLE READ | SERIALIZABLE}
```

Note that there are no hyphens in level names in the SQL syntax.

The default behaviour is to set the isolation level for the next (not started) transaction. If you use the GLOBAL keyword, the statement sets the default transaction level globally for all new connections created from that point on (but not existing connections). You need the SUPER privilege to do this. Using the SESSION keyword sets the default transaction level for all future transactions performed on the current connection. Any client is free to change the session isolation level (even in the middle of a transaction), or the isolation level for the next transaction. In versions earlier than 3.23.50, SET TRANSACTION had no effect on InnoDB tables. In versions < 4.0.5 only REPEATABLE READ and SERIALIZABLE were available.

You can query the global and session transaction isolation levels with:

```
SELECT @@global.tx_isolation;
SELECT @@tx_isolation;
```

In row level locking InnoDB uses so-called next-key locking. That means that besides index records, InnoDB can also lock the "gap" before an index record to block insertions by other users immediately before the index record. A next-key lock means a lock which locks an index record and the gap before it. A gap lock means a lock which only locks a gap before some index record.

A detailed description of each isolation level in `InnoDB`:

- `READ UNCOMMITTED` This is also called "dirty read": non-locking `SELECT`s are performed so that we do not look at a possible earlier version of a record; thus they are not 'consistent' reads under this isolation level; otherwise this level works like `READ COMMITTED`.
- `READ COMMITTED` Somewhat Oracle-like isolation level. All `SELECT ... FOR UPDATE` and `SELECT ... LOCK IN SHARE MODE` statements only lock the index records, **not** the gaps before them, and thus allow free inserting of new records next to locked records. `UPDATE` and `DELETE` which use a unique index with a unique search condition, only lock the index record found, not the gap before it. But still in range type `UPDATE` and `DELETE`, `InnoDB` must set next-key or gap locks and block insertions by other users to the gaps covered by the range. This is necessary since "phantom rows" have to be blocked for MySQL replication and recovery to work. **Consistent reads** behave as in Oracle: each consistent read, even within the same transaction, sets and reads its own fresh snapshot.
- `REPEATABLE READ` This is the default isolation level of `InnoDB`. `SELECT ... FOR UPDATE`, `SELECT ... LOCK IN SHARE MODE`, `UPDATE`, and `DELETE` which use a unique index with a unique search condition, only lock the index record found, not the gap before it. Otherwise these operations employ next-key locking, locking the index range scanned with next-key or gap locks, and block new insertions by other users. In **consistent reads** there is an important difference from the previous isolation level: in this level all consistent reads within the same transaction read the same snapshot established by the first read. This convention means that if you issue several plain `SELECT`s within the same transaction, these `SELECT`s are consistent also with respect to each other.
- `SERIALIZABLE` This level is like the previous one, but all plain `SELECT`s are implicitly converted to `SELECT ... LOCK IN SHARE MODE`.

7.5.9.2 Consistent Non-Locking Read

A consistent read means that InnoDB uses its multi-versioning to present to a query a snapshot of the database at a point in time. The query will see the changes made by exactly those transactions that committed before that point of time, and no changes made by later or uncommitted transactions. The exception to this rule is that the query will see the changes made by the transaction itself which issues the query.

If you are running with the default `REPEATABLE READ` isolation level, then all consistent reads within the same transaction read the snapshot established by the first such read in that transaction. You can get a fresher snapshot for your queries by committing the current transaction and after that issuing new queries.

Consistent read is the default mode in which InnoDB processes `SELECT` statements in `READ COMMITTED` and `REPEATABLE READ` isolation levels. A consistent read does not set any locks on the tables it accesses, and therefore other users are free to modify those tables at the same time a consistent read is being performed on the table.

7.5.9.3 Locking Reads SELECT ... FOR UPDATE and SELECT ... LOCK IN SHARE MODE

A consistent read is not convenient in some circumstances. Suppose you want to add a new row into your table CHILD, and make sure that the child already has a parent in table PARENT.

Suppose you use a consistent read to read the table PARENT and indeed see the parent of the child in the table. Can you now safely add the child row to table CHILD? No, because it may happen that meanwhile some other user has deleted the parent row from the table PARENT, and you are not aware of that.

The solution is to perform the SELECT in a locking mode, LOCK IN SHARE MODE.

```
SELECT * FROM PARENT WHERE NAME = 'Jones' LOCK IN SHARE MODE;
```

Performing a read in share mode means that we read the latest available data, and set a shared mode lock on the rows we read. If the latest data belongs to a yet uncommitted transaction of another user, we will wait until that transaction commits. A shared mode lock prevents others from updating or deleting the row we have read. After we see that the above query returns the parent 'Jones', we can safely add his child to table CHILD, and commit our transaction. This example shows how to implement referential integrity in your application code.

Let us look at another example: we have an integer counter field in a table CHILD_CODES which we use to assign a unique identifier to each child we add to table CHILD. Obviously, using a consistent read or a shared mode read to read the present value of the counter is not a good idea, since then two users of the database may see the same value for the counter, and we will get a duplicate key error when we add the two children with the same identifier to the table.

In this case there are two good ways to implement the reading and incrementing of the counter: (1) update the counter first by incrementing it by 1 and only after that read it, or (2) read the counter first with a lock mode FOR UPDATE, and increment after that:

```
SELECT COUNTER_FIELD FROM CHILD_CODES FOR UPDATE;
UPDATE CHILD_CODES SET COUNTER_FIELD = COUNTER_FIELD + 1;
```

A SELECT ... FOR UPDATE will read the latest available data setting exclusive locks on each row it reads. Thus it sets the same locks a searched SQL UPDATE would set on the rows.

7.5.9.4 Next-key Locking: Avoiding the Phantom Problem

In row level locking InnoDB uses an algorithm called next-key locking. InnoDB does the row level locking so that when it searches or scans an index of a table, it sets shared or exclusive locks on the index records it encounters. Thus the row level locks are more precisely called index record locks.

The locks InnoDB sets on index records also affect the 'gap' before that index record. If a user has a shared or exclusive lock on record R in an index, then another user cannot insert a new index record immediately before R in the index order. This locking of gaps is done to prevent the so-called phantom problem. Suppose I want to read and lock all children with identifier bigger than 100 from table CHILD, and update some field in the selected rows.

```
SELECT * FROM CHILD WHERE ID > 100 FOR UPDATE;
```

Suppose there is an index on table `CHILD` on column `ID`. Our query will scan that index starting from the first record where `ID` is bigger than 100. Now, if the locks set on the index records would not lock out inserts made in the gaps, a new child might meanwhile be inserted to the table. If now I in my transaction execute

```
SELECT * FROM CHILD WHERE ID > 100 FOR UPDATE;
```

again, I will see a new child in the result set the query returns. This is against the isolation principle of transactions: a transaction should be able to run so that the data it has read does not change during the transaction. If we regard a set of rows as a data item, then the new 'phantom' child would break this isolation principle.

When InnoDB scans an index it can also lock the gap after the last record in the index. Just that happens in the previous example: the locks set by InnoDB will prevent any insert to the table where `ID` would be bigger than 100.

You can use next-key locking to implement a uniqueness check in your application: if you read your data in share mode and do not see a duplicate for a row you are going to insert, then you can safely insert your row and know that the next-key lock set on the successor of your row during the read will prevent anyone meanwhile inserting a duplicate for your row. Thus the next-key locking allows you to 'lock' the non-existence of something in your table.

7.5.9.5 Locks Set by Different SQL Statements in `InnoDB`

- `SELECT ... FROM ...`: this is a consistent read, reading a snapshot of the database and setting no locks.
- `SELECT ... FROM ... LOCK IN SHARE MODE`: sets shared next-key locks on all index records the read encounters.
- `SELECT ... FROM ... FOR UPDATE`: sets exclusive next-key locks on all index records the read encounters.
- `INSERT INTO ... VALUES (...)`: sets an exclusive lock on the inserted row; note that this lock is not a next-key lock and does not prevent other users from inserting to the gap before the inserted row. If a duplicate key error occurs, sets a shared lock on the duplicate index record.
- `INSERT INTO T SELECT ... FROM S WHERE ...` sets an exclusive (non-next-key) lock on each row inserted into `T`. Does the search on `S` as a consistent read, but sets shared next-key locks on `S` if the MySQL logging is on. `InnoDB` has to set locks in the latter case because in roll-forward recovery from a backup every SQL statement has to be executed in exactly the same way as it was done originally.
- `CREATE TABLE ... SELECT ...` performs the `SELECT` as a consistent read or with shared locks, like in the previous item.
- `REPLACE` is done like an insert if there is no collision on a unique key. Otherwise, an exclusive next-key lock is placed on the row which has to be updated.
- `UPDATE ... SET ... WHERE ...`: sets an exclusive next-key lock on every record the search encounters.

- `DELETE FROM ... WHERE ...`: sets an exclusive next-key lock on every record the search encounters.
- If a `FOREIGN KEY` constraint is defined on a table, any insert, update, or delete which requires checking of the constraint condition sets shared record level locks on the records it looks at to check the constraint. Also in the case where the constraint fails, `InnoDB` sets these locks.
- `LOCK TABLES ...` : sets table locks. In the implementation the MySQL layer of code sets these locks. The automatic deadlock detection of `InnoDB` cannot detect deadlocks where such table locks are involved: see the following section. Also, since MySQL does know about row level locks, it is possible that you get a table lock on a table where another user currently has row level locks. But that does not put transaction integrity into danger. See Section 7.5.15 [InnoDB restrictions], page 637.

7.5.9.6 Deadlock Detection and Rollback

`InnoDB` automatically detects a deadlock of transactions and rolls back a transaction or transactions to prevent the deadlock. Starting from version 4.0.5, `InnoDB` will try to pick small transactions to roll back. The size of a transaction is determined by the number of rows it has inserted, updated, or deleted. Previous to 4.0.5, `InnoDB` always rolled back the transaction whose lock request was the last one to build a deadlock, that is, a cycle in the waits-for graph of transactions.

`InnoDB` cannot detect deadlocks where a lock set by a MySQL `LOCK TABLES` statement is involved, or if a lock set in another storage engine than `InnoDB` is involved. You have to resolve these situations using `innodb_lock_wait_timeout` set in '`my.cnf`'.

When `InnoDB` performs a complete rollback of a transaction, all the locks of the transaction are released. However, if just a single SQL statement is rolled back as a result of an error, some of the locks set by the SQL statement may be preserved. This is because `InnoDB` stores row locks in a format where it cannot afterwards know which was set by which SQL statement.

7.5.9.7 An Example of How the Consistent Read Works in `InnoDB`

Suppose you are running on the default `REPEATABLE READ` isolation level. When you issue a consistent read, that is, an ordinary `SELECT` statement, `InnoDB` will give your transaction a timepoint according to which your query sees the database. Thus, if transaction B deletes a row and commits after your timepoint was assigned, then you will not see the row deleted. Similarly with inserts and updates.

You can advance your timepoint by committing your transaction and then doing another `SELECT`.

This is called multi-versioned concurrency control.

```
                    User A                  User B

                SET AUTOCOMMIT=0;       SET AUTOCOMMIT=0;
    time
    |           SELECT * FROM t;
```

```
|             empty set
|                                INSERT INTO t VALUES (1, 2);
|
v             SELECT * FROM t;
              empty set
                                COMMIT;

              SELECT * FROM t;
              empty set;

              COMMIT;

              SELECT * FROM t;
              ---------------------
              |    1    |    2    |
              ---------------------
```

Thus user A sees the row inserted by B only when B has committed the insert, and A has committed his own transaction so that the timepoint is advanced past the commit of B.

If you want to see the "freshest" state of the database, you should use a locking read:

```
SELECT * FROM t LOCK IN SHARE MODE;
```

7.5.9.8 How to Cope With Deadlocks

Deadlocks are a classic problem in transactional databases, but they are not dangerous, unless they are so frequent that you cannot run certain transactions at all. Normally you have to write your applications so that they are always prepared to re-issue a transaction if it gets rolled back because of a deadlock.

`InnoDB` uses automatic row level locking. You can get deadlocks even in the case of transactions which just insert or delete a single row. That is because these operations are not really 'atomic': they automatically set locks on the (possibly several) index records of the row inserted/deleted.

You can cope with deadlocks and reduce the number of them with the following tricks:

- Use `SHOW INNODB STATUS` in MySQL versions >= 3.23.52 and >= 4.0.3 to determine the cause of the latest deadlock. That can help you to tune your application to avoid deadlocks.
- Always be prepared to re-issue a transaction if it fails in a deadlock. Deadlocks are not dangerous. Just try again.
- Commit your transactions often. Small transactions are less prone to collide.
- If you are using locking reads `SELECT ... FOR UPDATE` or `... LOCK IN SHARE MODE`, try using a lower isolation level `READ COMMITTED`.
- Access your tables and rows in a fixed order. Then transactions will form nice queues, and do not deadlock.
- Add well-chosen indexes to your tables. Then your queries need to scan fewer index records and consequently set fewer locks. Use `EXPLAIN SELECT` to determine that MySQL picks appropriate indexes for your queries.

- Use less locking: if you can afford a `SELECT` to return data from an old snapshot, do not add the clause `FOR UPDATE` or `LOCK IN SHARE MODE` to it. Using `READ COMMITTED` isolation level is good here, because each consistent read within the same transaction reads from its own fresh snapshot.
- If nothing helps, serialize your transactions with table level locks: `LOCK TABLES t1 WRITE, t2 READ, ... ; [do something with tables t1 and t2 here]; UNLOCK TABLES`. Table level locks make you transactions to queue nicely, and deadlocks are avoided. Note that `LOCK TABLES` implicitly starts a transaction, just like the command `BEGIN`, and `UNLOCK TABLES` implicitly ends the transaction in a `COMMIT`.
- Another solution to serialize transactions is to create an auxiliary 'semaphore' table where there is just a single row. Each transaction updates that row before accessing other tables. In that way all transactions happen in a serial fashion. Note that then also the `InnoDB` instant deadlock detection algorithm works, because the serializing lock is a row level lock. In MySQL table level locks we have to resort to the timeout method to resolve a deadlock.

7.5.10 Performance Tuning Tips

1. If the Unix '`top`' or the Windows '`Task Manager`' shows that the CPU usage percentage with your workload is less than 70%, your workload is probably disk-bound. Maybe you are making too many transaction commits, or the buffer pool is too small. Making the buffer pool bigger can help, but do not set it bigger than 80% of physical memory.
2. Wrap several modifications into one transaction. `InnoDB` must flush the log to disk at each transaction commit, if that transaction made modifications to the database. Since the rotation speed of a disk is typically at most 167 revolutions/second, that constrains the number of commits to the same 167/second if the disk does not fool the operating system.
3. If you can afford the loss of some latest committed transactions, you can set the '`my.cnf`' parameter `innodb_flush_log_at_trx_commit` to 0. `InnoDB` tries to flush the log once per second anyway, though the flush is not guaranteed.
4. Make your log files big, even as big as the buffer pool. When `InnoDB` has written the log files full, it has to write the modified contents of the buffer pool to disk in a checkpoint. Small log files will cause many unnecessary disk writes. The drawback in big log files is that recovery time will be longer.
5. Also the log buffer should be quite big, say 8 MB.
6. (Relevant from 3.23.39 up.) In some versions of Linux and Unix, flushing files to disk with the Unix `fdatasync` and other similar methods is surprisingly slow. The default method `InnoDB` uses is the `fdatasync` function. If you are not satisfied with the database write performance, you may try setting `innodb_flush_method` in '`my.cnf`' to `O_DSYNC`, though `O_DSYNC` seems to be slower on most systems.
7. In importing data to `InnoDB`, make sure that MySQL does not have `autocommit=1` on. Then every insert requires a log flush to disk. Put before your plain SQL import file line

   ```
   SET AUTOCOMMIT=0;
   ```

   and after it

```
COMMIT;
```

If you use the '`mysqldump`' option `--opt`, you will get dump files which are fast to import also to an `InnoDB` table, even without wrapping them to the above `SET AUTOCOMMIT=0; ... COMMIT;` wrappers.

8. Beware of big rollbacks of mass inserts: `InnoDB` uses the insert buffer to save disk I/O in inserts, but in a corresponding rollback no such mechanism is used. A disk-bound rollback can take 30 times the time of the corresponding insert. Killing the database process will not help because the rollback will start again at the database startup. The only way to get rid of a runaway rollback is to increase the buffer pool so that the rollback becomes CPU-bound and runs fast, or delete the whole `InnoDB` database.
9. Beware also of other big disk-bound operations. Use `DROP TABLE` or `TRUNCATE` (from MySQL-4.0 up) to empty a table, not `DELETE FROM yourtable`.
10. Use the multi-line `INSERT` to reduce communication overhead between the client and the server if you need to insert many rows:

    ```
    INSERT INTO yourtable VALUES (1, 2), (5, 5);
    ```

    This tip is of course valid for inserts into any table type, not just `InnoDB`.

7.5.10.1 `SHOW INNODB STATUS` and the `InnoDB` Monitors

Starting from version 3.23.42, `InnoDB` includes InnoDB Monitors that print information about the `InnoDB` internal state. Starting from versions 3.23.52 and 4.0.3 you can use the SQL command `SHOW INNODB STATUS` to fetch the output of the standard InnoDB Monitor to the SQL client. The data is useful in performance tuning. If you are using the '`mysql`' interactive SQL client, the output is more readable if you replace the usual semicolon statement terminator by `\G`:

```
SHOW INNODB STATUS\G
```

Another way to use InnoDB Monitors is to let them continuosly write data to the standard output of the server '`mysqld`' (note: the MySQL client will not print anything). When switched on, `InnoDB` Monitors print data about once every 15 seconds. If you run '`mysqld`' as a daemon then this output is usually directed to the '`.err`' log in the MySQL `datadir`. This data is useful in performance tuning. On Windows you must start `mysqld-max` from an MS-DOS prompt with the `--console` option if you want to direct the output to the MS-DOS prompt window.

There is a separate `innodb_lock_monitor` which prints the same information as `innodb_monitor` plus information on locks set by each transaction.

The printed information includes data on:

- lock waits of a transactions,
- semaphore waits of threads,
- pending file I/O requests,
- buffer pool statistics, and
- purge and insert buffer merge activity of the main thread of `InnoDB`.

You can start InnoDB Monitor through the following SQL command:

```
CREATE TABLE innodb_monitor(a INT) type = innodb;
```

and stop it by

```
DROP TABLE innodb_monitor;
```

The `CREATE TABLE` syntax is just a way to pass a command to the `InnoDB` engine through the MySQL SQL parser: the created table is not relevant at all for InnoDB Monitor. If you shut down the database when the monitor is running, and you want to start the monitor again, you have to drop the table before you can issue a new `CREATE TABLE` to start the monitor. This syntax may change in a future release.

A sample output of the InnoDB Monitor:

```
================================
010809 18:45:06 INNODB MONITOR OUTPUT
================================
--------------------------
LOCKS HELD BY TRANSACTIONS
--------------------------
LOCK INFO:
Number of locks in the record hash table 1294
LOCKS FOR TRANSACTION ID 0 579342744
TABLE LOCK table test/mytable trx id 0 582333343 lock_mode IX

RECORD LOCKS space id 0 page no 12758 n bits 104 table test/mytable index
PRIMARY trx id 0 582333343 lock_mode X
Record lock, heap no 2 PHYSICAL RECORD: n_fields 74; 1-byte offs FALSE;
info bits 0
 0: len 4; hex 0001a801; asc ;; 1: len 6; hex 000022b5b39f; asc ";;
 2: len 7; hex 000002001e03ec; asc ;; 3: len 4; hex 00000001;
...
-----------------------------------------
CURRENT SEMAPHORES RESERVED AND SEMAPHORE WAITS
-----------------------------------------
SYNC INFO:
Sorry, cannot give mutex list info in non-debug version!
Sorry, cannot give rw-lock list info in non-debug version!
-----------------------------------------------------
SYNC ARRAY INFO: reservation count 6041054, signal count 2913432
4a239430 waited for by thread 49627477 op. S-LOCK file NOT KNOWN line 0
Mut ex 0 sp 5530989 r 62038708 sys 2155035;
rws 0 8257574 8025336; rwx 0 1121090 1848344
-----------------------------------------------------
CURRENT PENDING FILE I/O'S
--------------------------
Pending normal aio reads:
Reserved slot, messages 40157658 4a4a40b8
Reserved slot, messages 40157658 4a477e28
...
Reserved slot, messages 40157658 4a4424a8
```

```
Reserved slot, messages 40157658 4a39ea38
Total of 36 reserved aio slots
Pending aio writes:
Total of 0 reserved aio slots
Pending insert buffer aio reads:
Total of 0 reserved aio slots
Pending log writes or reads:
Reserved slot, messages 40158c98 40157f98
Total of 1 reserved aio slots
Pending synchronous reads or writes:
Total of 0 reserved aio slots
-----------
BUFFER POOL
-----------
LRU list length 8034
Free list length 0
Flush list length 999
Buffer pool size in pages 8192
Pending reads 39
Pending writes: LRU 0, flush list 0, single page 0
Pages read 31383918, created 51310, written 2985115
----------------------------
END OF INNODB MONITOR OUTPUT
============================
010809 18:45:22 InnoDB starts purge
010809 18:45:22 InnoDB purged 0 pages
```

Some notes on the output:

- If the section LOCKS HELD BY TRANSACTIONS reports lock waits, then your application may have lock contention. The output can also help to trace reasons for transaction deadlocks.

- Section SYNC INFO will report reserved semaphores if you compile InnoDB with `UNIV_SYNC_DEBUG` defined in '`univ.i`'.

- Section SYNC ARRAY INFO reports threads waiting for a semaphore and statistics on how many times threads have needed a spin or a wait on a mutex or a rw-lock semaphore. A big number of threads waiting for semaphores may be a result of disk I/O, or contention problems inside InnoDB. Contention can be due to heavy parallelism of queries, or problems in operating system thread scheduling.

- Section CURRENT PENDING FILE I/O'S lists pending file I/O requests. A large number of these indicates that the workload is disk I/O-bound.

- Section BUFFER POOL gives you statistics on pages read and written. You can calculate from these numbers how many datafile I/Os your queries are currently doing.

7.5.11 Implementation of Multi-versioning

Since InnoDB is a multi-versioned database, it must keep information of old versions of rows in the tablespace. This information is stored in a data structure we call a rollback segment after an analogous data structure in Oracle.

InnoDB internally adds two fields to each row stored in the database. A 6-byte field tells the transaction identifier for the last transaction which inserted or updated the row. Also a deletion is internally treated as an update where a special bit in the row is set to mark it as deleted. Each row also contains a 7-byte field called the roll pointer. The roll pointer points to an undo log record written to the rollback segment. If the row was updated, then the undo log record contains the information necessary to rebuild the content of the row before it was updated.

InnoDB uses the information in the rollback segment to perform the undo operations needed in a transaction rollback. It also uses the information to build earlier versions of a row for a consistent read.

Undo logs in the rollback segment are divided into insert and update undo logs. Insert undo logs are only needed in transaction rollback and can be discarded as soon as the transaction commits. Update undo logs are used also in consistent reads, and they can be discarded only after there is no transaction present for which InnoDB has assigned a snapshot that in a consistent read could need the information in the update undo log to build an earlier version of a database row.

You must remember to commit your transactions regularly, also those transactions which only issue consistent reads. Otherwise InnoDB cannot discard data from the update undo logs, and the rollback segment may grow too big, filling up your tablespace.

The physical size of an undo log record in the rollback segment is typically smaller than the corresponding inserted or updated row. You can use this information to calculate the space need for your rollback segment.

In our multi-versioning scheme a row is not physically removed from the database immediately when you delete it with an SQL statement. Only when InnoDB can discard the update undo log record written for the deletion, it can also physically remove the corresponding row and its index records from the database. This removal operation is called a purge, and it is quite fast, usually taking the same order of time as the SQL statement which did the deletion.

7.5.12 Table and Index Structures

MySQL stores its data dictionary information of tables in '`.frm`' files in database directories. But every InnoDB type table also has its own entry in InnoDB internal data dictionaries inside the tablespace. When MySQL drops a table or a database, it has to delete both a '`.frm`' file or files, and the corresponding entries inside the InnoDB data dictionary. This is the reason why you cannot move InnoDB tables between databases simply by moving the '`.frm`' files, and why `DROP DATABASE` did not work for InnoDB type tables in MySQL versions <= 3.23.43.

Every InnoDB table has a special index called the clustered index where the data of the rows is stored. If you define a `PRIMARY KEY` on your table, then the index of the primary key will be the clustered index.

If you do not define a primary key for your table, InnoDB will internally generate a clustered index where the rows are ordered by the row ID that InnoDB assigns to the rows in such a table. The row ID is a 6-byte field which monotonically increases as new rows are inserted. Thus the rows ordered by the row ID will be physically in the insertion order.

Accessing a row through the clustered index is fast, because the row data will be on the same page where the index search leads us. In many databases the data is traditionally stored on a different page from the index record. If a table is large, the clustered index architecture often saves a disk I/O when compared to the traditional solution.

The records in non-clustered indexes (we also call them secondary indexes), in InnoDB contain the primary key value for the row. InnoDB uses this primary key value to search for the row from the clustered index. Note that if the primary key is long, the secondary indexes will use more space.

7.5.12.1 Physical Structure of an Index

All indexes in InnoDB are B-trees where the index records are stored in the leaf pages of the tree. The default size of an index page is 16 KB. When new records are inserted, InnoDB tries to leave 1 / 16 of the page free for future insertions and updates of the index records.

If index records are inserted in a sequential (ascending or descending) order, the resulting index pages will be about 15/16 full. If records are inserted in a random order, then the pages will be 1/2 - 15/16 full. If the fillfactor of an index page drops below 1/2, InnoDB will try to contract the index tree to free the page.

7.5.12.2 Insert Buffering

It is a common situation in a database application that the primary key is a unique identifier and new rows are inserted in the ascending order of the primary key. Thus the insertions to the clustered index do not require random reads from a disk.

On the other hand, secondary indexes are usually non-unique and insertions happen in a relatively random order into secondary indexes. This would cause a lot of random disk I/Os without a special mechanism used in InnoDB.

If an index record should be inserted to a non-unique secondary index, InnoDB checks if the secondary index page is already in the buffer pool. If that is the case, InnoDB will do the insertion directly to the index page. But, if the index page is not found from the buffer pool, InnoDB inserts the record to a special insert buffer structure. The insert buffer is kept so small that it entirely fits in the buffer pool, and insertions can be made to it very fast.

The insert buffer is periodically merged to the secondary index trees in the database. Often we can merge several insertions on the same page in of the index tree, and hence save disk I/Os. It has been measured that the insert buffer can speed up insertions to a table up to 15 times.

7.5.12.3 Adaptive Hash Indexes

If a database fits almost entirely in main memory, then the fastest way to perform queries on it is to use hash indexes. InnoDB has an automatic mechanism which monitors index searches made to the indexes defined for a table, and if InnoDB notices that queries could benefit from building of a hash index, such an index is automatically built.

But note that the hash index is always built based on an existing B-tree index on the table. InnoDB can build a hash index on a prefix of any length of the key defined for the B-tree, depending on what search pattern InnoDB observes on the B-tree index. A hash index can be partial: it is not required that the whole B-tree index is cached in the buffer pool. InnoDB will build hash indexes on demand to those pages of the index which are often accessed.

In a sense, through the adaptive hash index mechanism InnoDB adapts itself to ample main memory, coming closer to the architecture of main memory databases.

7.5.12.4 Physical Record Structure

- Each index record in InnoDB contains a header of 6 bytes. The header is used to link consecutive records together, and also in the row level locking.
- Records in the clustered index contain fields for all user-defined columns. In addition, there is a 6-byte field for the transaction id and a 7-byte field for the roll pointer.
- If the user has not defined a primary key for a table, then each clustered index record contains also a 6-byte row ID field.
- Each secondary index record contains also all the fields defined for the clustered index key.
- A record contains also a pointer to each field of the record. If the total length of the fields in a record is < 128 bytes, then the pointer is 1 byte, else 2 bytes.

7.5.12.5 How an `AUTO_INCREMENT` Column Works in InnoDB

After a database startup, when a user first does an insert to a table `T` where an auto-increment column has been defined, and the user does not provide an explicit value for the column, then InnoDB executes `SELECT MAX(auto-inc-column) FROM T`, and assigns that value incremented by one to the column and the auto-increment counter of the table. We say that the auto-increment counter for table `T` has been initialised.

InnoDB follows the same procedure in initialising the auto-increment counter for a freshly created table.

Note that if the user specifies in an insert the value 0 to the auto-increment column, then InnoDB treats the row like the value would not have been specified.

After the auto-increment counter has been initialised, if a user inserts a row where he explicitly specifies the column value, and the value is bigger than the current counter value, then the counter is set to the specified column value. If the user does not explicitly specify a value, then InnoDB increments the counter by one and assigns its new value to the column.

The auto-increment mechanism, when assigning values from the counter, bypasses locking and transaction handling. Therefore you may also get gaps in the number sequence if you roll back transactions which have got numbers from the counter.

The behaviour of auto-increment is not defined if a user gives a negative value to the column or if the value becomes bigger than the maximum integer that can be stored in the specified integer type.

7.5.13 File Space Management and Disk I/O

7.5.13.1 Disk I/O

In disk I/O InnoDB uses asynchronous I/O. On Windows NT it uses the native asynchronous I/O provided by the operating system. On Unix, InnoDB uses simulated asynchronous I/O built into InnoDB: InnoDB creates a number of I/O threads to take care of I/O operations, such as read-ahead. In a future version we will add support for simulated aio on Windows NT and native aio on those versions of Unix which have one.

On Windows NT InnoDB uses non-buffered I/O. That means that the disk pages InnoDB reads or writes are not buffered in the operating system file cache. This saves some memory bandwidth.

Starting from 3.23.41 InnoDB uses a novel file flush technique called doublewrite. It adds safety to crash recovery after an operating system crash or a power outage, and improves performance on most Unix flavors by reducing the need for fsync operations.

Doublewrite means that InnoDB before writing pages to a datafile first writes them to a contiguous tablespace area called the doublewrite buffer. Only after the write and the flush to the doublewrite buffer has completed, InnoDB writes the pages to their proper positions in the datafile. If the operating system crashes in the middle of a page write, InnoDB will in recovery find a good copy of the page from the doublewrite buffer.

Starting from 3.23.41 you can also use a raw disk partition as a datafile, though this has not been tested yet. When you create a new datafile you have to put the keyword `newraw` immediately after the datafile size in `innodb_data_file_path`. The partition must be at least as large as the size that you specify. Note that 1M in InnoDB is 1024 x 1024 bytes, while in disk specifications 1 MB usually means 1000 000 bytes.

```
innodb_data_file_path=/dev/hdd1:5Gnewraw;/dev/hdd2:2Gnewraw
```

When you start the database again you **must** change the keyword to `raw`. Otherwise, InnoDB will write over your partition!

```
innodb_data_file_path=/dev/hdd1:5Graw;/dev/hdd2:2Graw
```

By using a raw disk you can on some versions of Unix perform unbuffered I/O.

When you use raw disk partitions, make sure they have permissions that allow read and write access to the account used for running the MySQL server.

There are two read-ahead heuristics in InnoDB: sequential read-ahead and random read-ahead. In sequential read-ahead InnoDB notices that the access pattern to a segment in the tablespace is sequential. Then InnoDB will post in advance a batch of reads of database pages to the I/O system. In random read-ahead InnoDB notices that some area in a

tablespace seems to be in the process of being fully read into the buffer pool. Then InnoDB posts the remaining reads to the I/O system.

7.5.13.2 File Space Management

The datafiles you define in the configuration file form the tablespace of InnoDB. The files are simply catenated to form the tablespace, there is no striping in use. Currently you cannot define where in the tablespace your tables will be allocated. However, in a newly created tablespace, InnoDB will allocate space starting from the low end.

The tablespace consists of database pages whose default size is 16 KB. The pages are grouped into extents of 64 consecutive pages. The 'files' inside a tablespace are called segments in InnoDB. The name of the rollback segment is somewhat misleading because it actually contains many segments in the tablespace.

For each index in InnoDB we allocate two segments: one is for non-leaf nodes of the B-tree, the other is for the leaf nodes. The idea here is to achieve better sequentiality for the leaf nodes, which contain the data.

When a segment grows inside the tablespace, InnoDB allocates the first 32 pages to it individually. After that InnoDB starts to allocate whole extents to the segment. InnoDB can add to a large segment up to 4 extents at a time to ensure good sequentiality of data.

Some pages in the tablespace contain bitmaps of other pages, and therefore a few extents in an InnoDB tablespace cannot be allocated to segments as a whole, but only as individual pages.

When you issue a query `SHOW TABLE STATUS FROM ... LIKE ...` to ask for available free space in the tablespace, InnoDB will report the extents which are definitely free in the tablespace. InnoDB always reserves some extents for clean-up and other internal purposes; these reserved extents are not included in the free space.

When you delete data from a table, InnoDB will contract the corresponding B-tree indexes. It depends on the pattern of deletes if that frees individual pages or extents to the tablespace, so that the freed space is available for other users. Dropping a table or deleting all rows from it is guaranteed to release the space to other users, but remember that deleted rows can be physically removed only in a purge operation after they are no longer needed in transaction rollback or consistent read.

7.5.13.3 Defragmenting a Table

If there are random insertions or deletions in the indexes of a table, the indexes may become fragmented. By fragmentation we mean that the physical ordering of the index pages on the disk is not close to the alphabetical ordering of the records on the pages, or that there are many unused pages in the 64-page blocks which were allocated to the index.

It can speed up index scans if you periodically use `mysqldump` to dump the table to a text file, drop the table, and reload it from the dump. Another way to do the defragmenting is to perform a 'null' alter table operation `ALTER TABLE tablename TYPE=InnoDB`. That makes `MySQL` to rebuild the table.

If the insertions to an index are always ascending and records are deleted only from the end, then the file space management algorithm of InnoDB guarantees that fragmentation in the index will not occur.

7.5.14 Error Handling

The error handling in InnoDB is not always the same as specified in the SQL standard. According to SQL-99, any error during an SQL statement should cause the rollback of that statement. InnoDB sometimes rolls back only part of the statement, or the whole transaction. The following list specifies the error handling of InnoDB.

- If you run out of file space in the tablespace, you will get the MySQL `'Table is full'` error and InnoDB rolls back the SQL statement.
- A transaction deadlock or a timeout in a lock wait make InnoDB to roll back the whole transaction.
- A duplicate key error only rolls back the insert of that particular row, even in a statement like `INSERT INTO ... SELECT ...`. This will probably change so that the SQL statement will be rolled back if you have not specified the `IGNORE` option in your statement.
- A 'row too long' error rolls back the SQL statement.
- Other errors are mostly detected by the MySQL layer of code, and they roll back the corresponding SQL statement.

7.5.15 Restrictions on InnoDB Tables

- InnoDB tables do not support fulltext indexes.
- In Windows InnoDB stores the database names and table names internally always in lower case. To move databases in a binary format from Unix to Windows or from Windows to Unix you should have all table and database names in lower case.
- **Warning**: do **NOT** convert MySQL system tables from MyISAM TO InnoDB tables! This is not supported; if you do this MySQL will not restart until you restore the old system tables from a backup or re-generate them with the `mysql_install_db` script.
- `SHOW TABLE STATUS` does not give accurate statistics on InnoDB tables, except for the physical size reserved by the table. The row count is only a rough estimate used in SQL optimisation.
- If you try to create a unique index on a prefix of a column you will get an error:

  ```
  CREATE TABLE T (A CHAR(20), B INT, UNIQUE (A(5))) TYPE = InnoDB;
  ```

  If you create a non-unique index on a prefix of a column, InnoDB will create an index over the whole column.
- `INSERT DELAYED` is not supported for InnoDB tables.
- The MySQL `LOCK TABLES` operation does not know of InnoDB row level locks set in already completed SQL statements: this means that you can get a table lock on a table even if there still exist transactions of other users which have row level locks on the same table. Thus your operations on the table may have to wait if they collide with these locks of other users. Also a deadlock is possible. However, this does not endanger

transaction integrity, because the row level locks set by InnoDB will always take care of the integrity. Also, a table lock prevents other transactions from acquiring more row level locks (in a conflicting lock mode) on the table.

- A table cannot contain more than 1000 columns.
- `DELETE FROM TABLE` does not regenerate the table but instead deletes all rows, one by one, which is not that fast. In future versions of MySQL you can use `TRUNCATE` which is fast.
- The default database page size in InnoDB is 16 KB. By recompiling the code one can set it from 8 KB to 64 KB. The maximun row length is slightly less than half of a database page in versions <= 3.23.40 of InnoDB. Starting from source release 3.23.41 BLOB and TEXT columns are allowed to be < 4 GB, the total row length must also be < 4 GB. InnoDB does not store fields whose size is <= 128 bytes on separate pages. After InnoDB has modified the row by storing long fields on separate pages, the remaining length of the row must be less than half a database page. The maximun key length is 7000 bytes.
- On some operating systems datafiles must be < 2 GB. The combined size of log files must be < 4 GB.
- The maximum tablespace size is 4 billion database pages. This is also the maximum size for a table. The minimum tablespace size is 10 MB.
- When you restart the MySQL server, InnoDB may reuse an old value for an `AUTO_INCREMENT` column.
- You cannot set the first `AUTO_INCREMENT` column value in InnoDB with `CREATE TABLE ... AUTO_INCREMENT=...` (or `ALTER TABLE ...`). To set the value insert a dummy row with a value one less, and delete that dummy row.

7.5.16 InnoDB Change History

7.5.16.1 MySQL/InnoDB-4.0.14, July 22, 2003

bullet InnoDB now supports the `SAVEPOINT` and `ROLLBACK TO SAVEPOINT` SQL statements. See http://www.innodb.com/ibman.html#Savepoints for the syntax.

bullet You can now create column prefix keys like in `CREATE TABLE t (a BLOB, INDEX (a(10)))`.

bullet You can also use `O_DIRECT` as the `innodb_flush_method` on the latest versions of Linux and FreeBSD. Beware of possible bugs in those operating systems, though.

bullet Fixed the checksum calculation of data pages. Previously most OS file system corruption went unnoticed. Note that if you downgrade from version >= 4.0.14 to an earlier version < 4.0.14 then in the first startup(s) InnoDB will print warnings:

```
InnoDB: Warning: an inconsistent page in the doublewrite buffer
InnoDB: space id 2552202359 page number 8245, 127'th page in dblwr buf.
```

but that is not dangerous and can be ignored.

bullet Modified the buffer pool replacement algorithm so that it tries to flush modified pages if there are no replaceable pages in the last 10 % of the LRU list. This can reduce disk i/o if the workload is a mixture of reads and writes.

bullet The buffer pool checkpoint flush algorithm now tries to flush also close neighbors of the page at the end of the flush list. This can speed up database shutdown, and can also speed up disk writes if InnoDB log files are very small compared to the buffer pool size.

bullet In 4.0.13 we made `SHOW INNODB STATUS` to print detailed info on the latest `UNIQUE KEY` error, but storing that info could slow down `REPLACE` significantly. We no longer store or print the info.

bullet Fixed a bug: `SET FOREIGN_KEY_CHECKS=0` was not replicated properly in the MySQL replication. The fix will not be backported to 3.23.

bullet Fixed a bug: the parameter `innodb_max_dirty_pages_pct` forgot to take into account the free pages in the buffer pool. This could lead to excessive flushing even though there were lots of free pages in the buffer pool. Workaround: `SET GLOBAL innodb_max_dirty_pages_pct = 100`.

bullet Fixed a bug: if there were big index scans then a file read request could starve and InnoDB could assert because of a very long semaphore wait.

bullet Fixed a bug: if `AUTOCOMMIT=1` then inside `LOCK TABLES` MySQL failed to do the commit after an updating SQL statement if binlogging was not on, and for `SELECT`s did not commit regardless of binlogging state.

bullet Fixed a bug: InnoDB could make the index page directory corrupt in the first B-tree page splits after a mysqld startup. A symptom would be an assertion in page0page.c, in function page_dir_find_slot().

bullet Fixed a bug: if in a `FOREIGN KEY` with an `UPDATE CASCADE` clause the parent column was of a different internal storage length than the child column, then a cascaded update would make the column length wrong in the child table and corrupt the child table. Because of MySQL's 'silent column specification changes' a fixed-length `CHAR` column can change internally to a `VARCHAR` and cause this error.

bullet Fixed a bug: if a non-`latin1` character set was used and if in a `FOREIGN KEY` the parent column was of a different internal storage length than the child column, then all inserts to the child table would fail in a foreign key error.

bullet Fixed a bug: InnoDB could complain that it cannot find the clustered index record, or in rare cases return an extraneous row if a rollback, purge, and a `SELECT` coincided.

bullet Fixed a possible hang over the btr0sea.c latch if `SELECT` was used inside `LOCK TABLES`.

bullet Fixed a bug: contrary to what the release note of 4.0.13 said, the group commit still did not work if the MySQL binlogging was on.

bullet Fixed a bug: os_event_wait() did not work properly in Unix, which might have caused starvation in various log operations.

bullet Fixed a bug: if a single `DELETE` statement first managed to delete some rows and then failed in a `FOREIGN KEY` error or a 'Table is full error', MySQL did not roll back the whole SQL statement as it should, and also wrote the failed statement to the binlog, reporting there a non-zero error_code.

bullet Fixed a bug: the maximum allowed number of columns in a table is 1000, but InnoDB did not check that limit in `CREATE TABLE`, and a subsequent `INSERT` or `SELECT` from that table could cause an assertion.

7.5.16.2 MySQL/InnoDB-3.23.57, June 20, 2003

- Changed the default value of `innodb_flush_log_at_trx_commit` from 0 to 1. If you have not specified it explicitly in your '`my.cnf`', and your application runs much slower with this new release, it is because the value 1 causes a log flush to disk at each transaction commit.
- Fixed a bug: InnoDB forgot to call pthread_mutex_destroy() when a table was dropped. That could cause memory leakage on FreeBSD and other non-Linux Unixes.
- Fixed a bug: MySQL could erroneously return 'Empty set' if InnoDB estimated an index range size to 0 records though the range was not empty; MySQL also failed to do the next-key locking in the case of an empty index range.
- Fixed a bug: `GROUP BY` and `DISTINCT` could treat NULL values inequal.

7.5.16.3 MySQL/InnoDB-4.0.13, May 20, 2003

- `InnoDB` now supports `ALTER TABLE DROP FOREIGN KEY`. You have to use `SHOW CREATE TABLE` to find the internally generated foreign key ID when you want to drop a foreign key.
- `SHOW INNODB STATUS` now prints detailed information of the latest detected `FOREIGN KEY` and `UNIQUE KEY` errors. If you do not understand why `InnoDB` gives the error 150 from a `CREATE TABLE`, you can use this statement to study the reason.
- `ANALYZE TABLE` now works also for `InnoDB` type tables. It makes 10 random dives to each of the index trees and updates index cardinality estimates accordingly. Note that since it is only an estimate, repeated runs of `ANALYZE TABLE` may produce different numbers. MySQL uses index cardinality estimates only in join optimisation. If some join is not optimised in the right way, you may try using `ANALYZE TABLE`.
- `InnoDB` group commit capability now works also when MySQL binlogging is switched on. There have to be `>` 2 client threads for the group commit to become active.
- Changed the default value of `innodb_flush_log_at_trx_commit` from 0 to 1. If you have not specified it explicitly in your '`my.cnf`', and your application runs much slower with this new release, it is because the value 1 causes a log flush to disk at each transaction commit.
- Added a new global settable MySQL system variable `innodb_max_dirty_pages_pct`. It is an integer in the range 0 - 100. The default is 90. The main thread in `InnoDB` tries to flush pages from the buffer pool so that at most this many percents are not yet flushed at any time.
- If `innodb_force_recovery=6`, do not let `InnoDB` do repair of corrupt pages based on the doublewrite buffer.
- `InnoDB` start-up now happens faster because it does not set the memory in the buffer pool to zero.
- Fixed a bug: The `InnoDB` parser for `FOREIGN KEY` definitions was confused by the keywords 'foreign key' inside MySQL comments.
- Fixed a bug: If you dropped a table to which there was a `FOREIGN KEY` reference, and later created the same table with non-matching column types, `InnoDB` could assert in '`dict0load.c`', in function `dict_load_table()`.

bullet Fixed a bug: `GROUP BY` and `DISTINCT` could treat `NULL` values as not equal. MySQL also failed to do the next-key locking in the case of an empty index range.

bullet Fixed a bug: Do not commit the current transaction when a MyISAM table is updated; this also makes `CREATE TABLE` not to commit an `InnoDB` transaction, even when binlogging is enabled.

bullet Fixed a bug: We did not allow `ON DELETE SET NULL` to modify the same table where the delete was made; we can allow it because that cannot produce infinite loops in cascaded operations.

bullet Fixed a bug: Allow `HANDLER PREV` and `NEXT` also after positioning the cursor with a unique search on the primary key.

bullet Fixed a bug: If `MIN()` or `MAX()` resulted in a deadlock or a lock wait timeout, MySQL did not return an error, but returned `NULL` as the function value.

bullet Fixed a bug: `InnoDB` forgot to call `pthread_mutex_destroy()` when a table was dropped. That could cause memory leakage on FreeBSD and other non-Linux Unix systems.

7.5.16.4 MySQL/InnoDB-4.1.0, April 3, 2003

- `InnoDB` now supports up to 64 GB of buffer pool memory in a Windows 32-bit Intel computer. This is possible because `InnoDB` can use the AWE extension of Windows to address memory over the 4 GB limit of a 32-bit process. A new startup variable `innodb_buffer_pool_awe_mem_mb` enables AWE and sets the size of the buffer pool in megabytes.
- Reduced the size of buffer headers and the lock table. `InnoDB` uses 2 % less memory.

7.5.16.5 MySQL/InnoDB-3.23.56, March 17, 2003

- Fixed a major bug in InnoDB query optimisation: queries of type SELECT ... WHERE indexcolumn < x and SELECT ... WHERE indexcolumn > x could cause a table scan even if the selectivity would have been very good.
- Fixed a potential bug if MySQL calls store_lock with TL_IGNORE in the middle of a query.

7.5.16.6 MySQL/InnoDB-4.0.12, March 18, 2003

- In crash recovery InnoDB now prints the progress in percents of a transaction rollback.
- Fixed a bug/feature: if your application program used mysql_use_result(), and used >= 2 connections to send SQL queries, it could deadlock on the adaptive hash S-latch in btr0sea.c. Now mysqld releases the S-latch whenever it passes data from a SELECT to the client.
- Fixed a bug: MySQL could erroneously return 'Empty set' if InnoDB estimated an index range size to 0 records though the range was not empty; MySQL also failed to do the next-key locking in the case of an empty index range.

7.5.16.7 MySQL/InnoDB-4.0.11, February 25, 2003

- Fixed a bug introduced in 4.0.10: SELECT ... FROM ... ORDER BY ... DESC could hang in an infinite loop.
- An outstanding bug: SET FOREIGN_KEY_CHECKS=0 is not replicated properly in the MySQL replication.

7.5.16.8 MySQL/InnoDB-4.0.10, February 4, 2003

- In INSERT INTO t1 SELECT ... FROM t2 WHERE ... MySQL previously set a table level read lock on t2. This lock is now removed.
- Increased SHOW INNODB STATUS max printed length to 200 KB.
- Fixed a major bug in InnoDB query optimisation: queries of type SELECT ... WHERE indexcolumn < x and SELECT ... WHERE indexcolumn > x could cause a table scan even if the selectivity would have been very good.
- Fixed a bug: purge could cause a hang in a BLOB table where the primary key index tree was of height 1. Symptom: semaphore waits caused by an X-latch set in btr_free_externally_stored_field().
- Fixed a bug: using InnoDB HANDLER commands on a fresh handle crashed mysqld in ha_innobase::change_active_index().
- Fixed a bug: if MySQL estimated a query in the middle of a SELECT statement, InnoDB could hang on the adaptive hash index latch in btr0sea.c.
- Fixed a bug: InnoDB could report table corruption and assert in page_dir_find_owner_slot() if an adaptive hash index search coincided with purge or an insert.
- Fixed a bug: some file system snapshot tool in Windows 2000 could cause an InnoDB file write to fail with error 33 ERROR_LOCK_VIOLATION. In synchronous writes InnoDB now retries the write 100 times at 1 second intervals.
- Fixed a bug: REPLACE INTO t1 SELECT ... did not work if t1 has an auto-inc column.
- An outstanding bug: SET FOREIGN_KEY_CHECKS=0 is not replicated properly in the MySQL replication.

7.5.16.9 MySQL/InnoDB-3.23.55, January 24, 2003

- In INSERT INTO t1 SELECT ... FROM t2 WHERE ... MySQL previously set a table level read lock on t2. This lock is now removed.
- Fixed a bug: if the combined size of InnoDB log files was >= 2 GB in a 32-bit computer, InnoDB would write log in a wrong position. That could make crash recovery and InnoDB Hot Backup to fail in log scan.
- Fixed a bug: index cursor restoration could theoretically fail.
- Fixed a bug: an assertion in btr0sea.c, in function btr_search_info_update_slow could theoretically fail in a race of 3 threads.

- Fixed a bug: purge could cause a hang in a BLOB table where the primary key index tree was of height 1. Symptom: semaphore waits caused by an X-latch set in btr_free_externally_stored_field().
- Fixed a bug: if MySQL estimated a query in the middle of a SELECT statement, InnoDB could hang on the adaptive hash index latch in btr0sea.c.
- Fixed a bug: InnoDB could report table corruption and assert in page_dir_find_owner_slot() if an adaptive hash index search coincided with purge or an insert.
- Fixed a bug: some file system snapshot tool in Windows 2000 could cause an InnoDB file write to fail with error 33 ERROR_LOCK_VIOLATION. In synchronous writes InnoDB now retries the write 100 times at 1 second intervals.
- An outstanding bug: SET FOREIGN_KEY_CHECKS=0 is not replicated properly in the MySQL replication. The fix will appear in 4.0.11 and will probably not be backported to 3.23.
- Fixed bug in InnoDB page0cur.c in function page_cur_search_with_match which caused InnoDB to remain on the same page forever. This bug is evident only in tables with more than one page.

7.5.16.10 MySQL/InnoDB-4.0.9, January 14, 2003

- Removed the warning message: 'InnoDB: Out of memory in additional memory pool.'
- Fixed a bug: if the combined size of InnoDB log files was >= 2 GB in a 32-bit computer, InnoDB would write log in a wrong position. That could make crash recovery and InnoDB Hot Backup to fail.
- Fixed a bug: index cursor restoration could theoretically fail.

7.5.16.11 MySQL/InnoDB-4.0.8, January 7, 2003

- InnoDB now supports also FOREIGN KEY (...) REFERENCES ...(...) [ON UPDATE CASCADE | ON UPDATE SET NULL | ON UPDATE RESTRICT | ON UPDATE NO ACTION].
- Tables and indexes now reserve 4 % less space in the tablespace. Also existing tables reserve less space. By upgrading to 4.0.8 you will see more free space in "InnoDB free" in SHOW TABLE STATUS.
- Fixed bugs: updating the PRIMARY KEY of a row would generate a foreign key error on all FOREIGN KEYs which referenced secondary keys of the row to be updated. Also, if a referencing FOREIGN KEY constraint only referenced the first columns in an index, and there were more columns in that index, updating the additional columns generated a foreign key error.
- Fixed a bug: if an index contains some column twice, and that column is updated, the table will become corrupt. From now on InnoDB prevents creation of such indexes.
- Fixed a bug: removed superfluous error 149 and 150 printouts from the .err log when a locking SELECT caused a deadlock or a lock wait timeout.
- Fixed a bug: an assertion in btr0sea.c, in function btr_search_info_update_slow could theoretically fail in a race of 3 threads.

- Fixed a bug: one could not switch a session transaction isolation level back to REPEATABLE READ after setting it to something else.

7.5.16.12 MySQL/InnoDB-4.0.7, December 26, 2002

- InnoDB in 4.0.7 is essentially the same as in 4.0.6.

7.5.16.13 MySQL/InnoDB-4.0.6, December 19, 2002

- Since innodb_log_arch_dir has no relevance under MySQL, there is no need to specify it any more in my.cnf.
- LOAD DATA INFILE in AUTOCOMMIT=1 mode no longer does implicit commits for each 1 MB of written binlog.
- Fixed a bug introduced in 4.0.4: LOCK TABLES ... READ LOCAL should not set row locks on the rows read. This caused deadlocks and lock wait timeouts in mysqldump.
- Fixed two bugs introduced in 4.0.4: in AUTO_INCREMENT, REPLACE could cause the counter to be left 1 too low. A deadlock or a lock wait timeout could cause the same problem.
- Fixed a bug: TRUNCATE on a TEMPORARY table crashed InnoDB.
- Fixed a bug introduced in 4.0.5: if binlogging was not switched on, INSERT INTO ... SELECT ... or CREATE TABLE ... SELECT ... could cause InnoDB to hang on a semaphore created in btr0sea.c, line 128. Workaround: switch binlogging on.
- Fixed a bug: in replication issuing SLAVE STOP in the middle of a multi-statement transaction could cause that SLAVE START would only perform a part of the transaction. A similar error could occur if the slave crashed and was restarted.

7.5.16.14 MySQL/InnoDB-3.23.54, December 12, 2002

- Fixed a bug: the InnoDB range estimator greatly exaggerated the size of a short index range if the paths to the endpoints of the range in the index tree happened to branch already in the root. This could cause unnecessary table scans in SQL queries.
- Fixed a bug: ORDER BY could fail if you had not created a primary key to a table, but had defined several indexes of which at least one was a UNIQUE index with all its columns declared as NOT NULL.
- Fixed a bug: a lock wait timeout in connection with ON DELETE CASCADE could cause corruption in indexes.
- Fixed a bug: if a SELECT was done with a unique key from a primary index, and the search matched to a delete-marked record, InnoDB could erroneously return the NEXT record.
- Fixed a bug introduced in 3.23.53: LOCK TABLES ... READ LOCAL should not set row locks on the rows read. This caused deadlocks and lock wait timeouts in mysqldump.
- Fixed a bug: if an index contains some column twice, and that column is updated, the table will become corrupt. From now on InnoDB prevents creation of such indexes.

7.5.16.15 MySQL/InnoDB-4.0.5, November 18, 2002

- InnoDB now supports also transaction isolation levels READ COMMITTED and READ UNCOMMITTED. READ COMMITTED more closely emulates Oracle and makes porting of applications from Oracle to MySQL easier.
- Deadlock resolution is now selective: we try to pick as victims transactions with less modified or inserted rows.
- FOREIGN KEY definitions are now aware of the lower_case_table_names setting in my.cnf.
- SHOW CREATE TABLE does not output the database name to a FOREIGN KEY definition if the referred table is in the same database as the table.
- InnoDB does a consistency check to most index pages before writing them to a datafile.
- If you set innodb_force_recovery > 0, InnoDB tries to jump over corrupt index records and pages when doing SELECT * FROM table. This helps in dumping.
- InnoDB now again uses asynchronous unbuffered I/O in Windows 2000 and XP; only unbuffered simulated async I/O in NT, 95/98/ME.
- Fixed a bug: the InnoDB range estimator greatly exaggerated the size of a short index range if the paths to the endpoints of the range in the index tree happened to branch already in the root. This could cause unnecessary table scans in SQL queries. The fix will also be backported to 3.23.54.
- Fixed a bug present in 3.23.52, 4.0.3, 4.0.4: InnoDB startup could take very long or even crash on some Windows 95/98/ME computers.
- Fixed a bug: the AUTO-INC lock was held to the end of the transaction if it was granted after a lock wait. This could cause unnecessary deadlocks.
- Fixed a bug: if SHOW INNODB STATUS, innodb_monitor, or innodb_lock_monitor had to print several hundred transactions in one report, and the output became truncated, InnoDB would hang, printing to the error log many waits for a mutex created at srv0srv.c, line 1621.
- Fixed a bug: SHOW INNODB STATUS on Unix always reported average file read size as 0 bytes.
- Fixed a potential bug in 4.0.4: InnoDB now does ORDER BY ... DESC like MyISAM.
- Fixed a bug: DROP TABLE could cause crash or a hang if there was a rollback concurrently running on the table. The fix will only be backported to 3.23 if this appears a real problem for users.
- Fixed a bug: ORDER BY could fail if you had not created a primary key to a table, but had defined several indexes of which at least one was a UNIQUE index with all its columns declared as NOT NULL.
- Fixed a bug: a lock wait timeout in connection with ON DELETE CASCADE could cause corruption in indexes.
- Fixed a bug: if a SELECT was done with a unique key from a primary index, and the search matched to a delete-marked record, InnoDB could return the NEXT record.
- Outstanding bugs: in 4.0.4 two bugs were introduced to AUTO_INCREMENT. REPLACE can cause the counter to be left 1 too low. A deadlock or a lock wait timeout can cause the same problem. These will be fixed in 4.0.6.

7.5.16.16 MySQL/InnoDB-3.23.53, October 9, 2002

- We again use unbuffered disk I/O to datafiles in Windows. Windows XP and Windows 2000 read performance seems to be very poor with normal I/O.
- Tuned range estimator so that index range scans are preferred over full index scans.
- Allow dropping and creating a table even if innodb_force_recovery is set. One can use this to drop a table which would cause a crash in rollback or purge, or if a failed table import causes a runaway rollback in recovery.
- Fixed a bug present in 3.23.52, 4.0.3, 4.0.4: InnoDB startup could take very long or even crash on some Windows 95/98/ME computers.
- Fixed a bug: fast shutdown (which is the default) sometimes was slowed down by purge and insert buffer merge.
- Fixed a bug: doing a big SELECT from a table where no rows were visible in a consistent read could cause a very long (> 600 seconds) semaphore wait in btr0cur.c line 310.
- Fixed a bug: the AUTO-INC lock was held to the end of the transaction if it was granted after a lock wait. This could cause unnecessary deadlocks.
- Fixed a bug: if you created a temporary table inside LOCK TABLES, and used that temporary table, that caused an assertion failure in ha_innobase.cc.
- Fixed a bug: if SHOW INNODB STATUS, innodb_monitor, or innodb_lock_monitor had to print several hundred transactions in one report, and the output became truncated, InnoDB would hang, printing to the error log many waits for a mutex created at srv0srv.c, line 1621.
- Fixed a bug: SHOW INNODB STATUS on Unix always reported average file read size as 0 bytes.

7.5.16.17 MySQL/InnoDB-4.0.4, October 2, 2002

- We again use unbuffered disk I/O in Windows. Windows XP and Windows 2000 read performance seems to be very poor with normal I/O.
- Increased the max key length of InnoDB tables from 500 to 1024 bytes.
- Increased the table comment field in SHOW TABLE STATUS so that up to 16000 characters of foreign key definitions can be printed there.
- The auto-increment counter is no longer incremented if an insert of a row immediately fails in an error.
- Allow dropping and creating a table even if innodb_force_recovery is set. One can use this to drop a table which would cause a crash in rollback or purge, or if a failed table import causes a runaway rollback in recovery.
- Fixed a bug: Using ORDER BY primarykey DESC in 4.0.3 causes an assertion failure in btr0pcur.c, line 203.
- Fixed a bug: fast shutdown (which is the default) sometimes was slowed down by purge and insert buffer merge.

- Fixed a bug: doing a big SELECT from a table where no rows were visible in a consistent read could cause a very long (> 600 seconds) semaphore wait in btr0cur.c line 310.
- Fixed a bug: if the MySQL query cache was used, it did not get invalidated by a modification done by ON DELETE CASCADE or ...SET NULL.
- Fixed a bug: if you created a temporary table inside LOCK TABLES, and used that temporary table, that caused an assertion failure in ha_innodb.cc.
- Fixed a bug: if you set innodb_flush_log_at_trx_commit to 1, SHOW VARIABLES would show its value as 16 million.

7.5.16.18 MySQL/InnoDB-4.0.3, August 28, 2002

- Removed unnecessary deadlocks when inserts have to wait for a locking read, update, or delete to release its next-key lock.
- The MySQL `HANDLER` SQL commands now work also for `InnoDB` type tables. `InnoDB` does the `HANDLER` reads always as consistent reads. `HANDLER` is a direct access path to read individual indexes of tables. In some cases `HANDLER` can be used as a substitute of server-side cursors.
- Fixed a bug in 4.0.2: even a simple insert could crash the AIX version.
- Fixed a bug: if you used in a table name characters whose code is > 127, in DROP TABLE InnoDB could assert on line 155 of pars0sym.c.
- Compilation from source now provides a working version both on HP-UX-11 and HP-UX-10.20. The source of 4.0.2 worked only on 11, and the source of 3.23.52 only on 10.20.
- Fixed a bug: if compiled on 64-bit Solaris, InnoDB produced a bus error at startup.

7.5.16.19 MySQL/InnoDB-3.23.52, August 16, 2002

- The feature set of 3.23 will be frozen from this version on. New features will go the 4.0 branch, and only bug fixes will be made to the 3.23 branch.
- Many CPU-bound join queries now run faster. On Windows also many other CPU-bound queries run faster.
- A new SQL command SHOW INNODB STATUS returns the output of the InnoDB Monitor to the client. The InnoDB Monitor now prints detailed information on the latest detected deadlock.
- InnoDB made the SQL query optimiser to avoid too much index-only range scans and choose full table scans instead. This is now fixed.
- `BEGIN` and `COMMIT` are now added in the binlog around transactions. The MySQL replication now respects transaction borders: a user will no longer see half transactions in replication slaves.
- A replication slave now prints in crash recovery the last master binlog position it was able to recover to.
- A new setting innodb_flush_log_at_trx_commit=2 makes InnoDB to write the log to the operating system file cache at each commit. This is almost as fast as the setting

innodb_flush_log_at_trx_commit=0, and the setting 2 also has the nice feature that in a crash where the operating system does not crash, no committed transaction is lost. If the operating system crashes or there is a power outage, then the setting 2 is no safer than the setting 0.

- Added checksum fields to log blocks.
- SET FOREIGN_KEY_CHECKS=0 helps in importing tables in an arbitrary order which does not respect the foreign key rules.
- SET UNIQUE_CHECKS=0 speeds up table imports into InnoDB if you have UNIQUE constraints on secondary indexes. This flag should be used only if you are certain that the input records contain no UNIQUE constraint violations.
- SHOW TABLE STATUS now lists also possible ON DELETE CASCADE or ON DELETE SET NULL in the comment field of the table.
- When CHECK TABLE is run on any InnoDB type table, it now checks also the adaptive hash index for all tables.
- If you defined ON DELETE CASCADE or SET NULL and updated the referenced key in the parent row, InnoDB deleted or updated the child row. This is now changed to conform to SQL-92: you get the error 'Cannot delete parent row'.
- Improved the auto-increment algorithm: now the first insert or SHOW TABLE STATUS initialises the auto-increment counter for the table. This removes almost all surprising deadlocks caused by SHOW TABLE STATUS.
- Aligned some buffers used in reading and writing to datafiles. This allows using unbuffered raw devices as datafiles in Linux.
- Fixed a bug: If you updated the primary key of a table so that only the case of characters changed, that could cause assertion failures, mostly in page0page.ic line 515.
- Fixed a bug: If you delete or update a row referenced in a foreign key constraint and the foreign key check has to wait for a lock, then the check may report an erroneous result. This affects also the ON DELETE... operation.
- Fixed a bug: A deadlock or a lock wait timeout error in InnoDB causes InnoDB to roll back the whole transaction, but MySQL could still write the earlier SQL statements to the binlog, even though InnoDB rolled them back. This could, for example, cause replicated databases to get out-of-sync.
- Fixed a bug: If the database happened to crash in the middle of a commit, then the recovery might leak tablespace pages.
- Fixed a bug: If you specified a non-latin1 character set in my.cnf, then, in contrary to what is stated in the manual, in a foreign key constraint a string type column had to have the same length specification in the referencing table and the referenced table.
- Fixed a bug: DROP TABLE or DROP DATABASE could fail if there simultaneously was a CREATE TABLE running.
- Fixed a bug: If you configured the buffer pool bigger than 2 GB in a 32-bit computer, InnoDB would assert in buf0buf.ic line 214.
- Fixed a bug: on 64-bit computers updating rows which contained the SQL NULL in some column could cause the undo log and the ordinary log to become corrupt.

- Fixed a bug: innodb_log_monitor caused a hang if it suppressed lock prints for a page.
- Fixed a bug: in the HP-UX-10.20 version mutexes would leak and cause race conditions and crashes in any part of InnoDB code.
- Fixed a bug: if you ran in the AUTOCOMMIT mode, executed a SELECT, and immediately after that a RENAME TABLE, then RENAME would fail and MySQL would complain about error 1192.
- Fixed a bug: if compiled on 64-bit Solaris, InnoDB produced a bus error at startup.

7.5.16.20 MySQL/InnoDB-4.0.2, July 10, 2002

- InnoDB is essentially the same as InnoDB-3.23.51.
- If no innodb_data_file_path is specified, InnoDB at the database creation now creates a 10 MB auto-extending datafile ibdata1 to the datadir of MySQL. In 4.0.1 the file was 64 MB and not auto-extending.

7.5.16.21 MySQL/InnoDB-3.23.51, June 12, 2002

- Fixed a bug: a join could result in a seg fault in copying of a BLOB or TEXT column if some of the BLOB or TEXT columns in the table contained SQL NULL values.
- Fixed a bug: if you added self-referential foreign key constraints with ON DELETE CASCADE to tables and a row deletion caused InnoDB to attempt the deletion of the same row twice because of a cascading delete, then you got an assertion failure.
- Fixed a bug: if you use MySQL 'user level locks' and close a connection, then InnoDB may assert in ha_innobase.cc, line 302.

7.5.16.22 MySQL/InnoDB-3.23.50, April 23, 2002

- InnoDB now supports an auto-extending last datafile. You do not need to preallocate the whole datafile at the database startup.
- Made several changes to facilitate the use of the InnoDB Hot Backup tool. It is a separate non-free tool you can use to take online backups of your database without shutting down the server or setting any locks.
- If you want to run the InnoDB Hot Backup tool on an auto-extending datafile you have to upgrade it to version ibbackup-0.35.
- The log scan phase in crash recovery will now run much faster.
- Starting from this server version, the hot backup tool truncates unused ends in the backup InnoDB datafiles.
- To allow the hot backup tool to work, on Windows we no longer use unbuffered I/O or native async I/O; instead we use the same simulated async I/O as on Unix.
- You can now define the ON DELETE CASCADE or ON DELETE SET NULL clause on foreign keys.
- FOREIGN KEY constraints now survive ALTER TABLE and CREATE INDEX.
- We suppress the FOREIGN KEY check if any of the column values in the foreign key or referenced key to be checked is the SQL NULL. This is compatible with Oracle, for example.

- SHOW CREATE TABLE now lists also foreign key constraints. Also mysqldump no longer forgets about foreign keys in table definitions.
- You can now add a new foreign key constraint with ALTER TABLE ... ADD CONSTRAINT FOREIGN KEY (...) REFERENCES ... (...).
- FOREIGN KEY definitions now allow backquotes around table and column names.
- MySQL command SET TRANSACTION ISOLATION LEVEL ... has now the following effect on InnoDB tables: if a transaction is defined as SERIALIZABLE then InnoDB conceptually adds LOCK IN SHARE MODE to all consistent reads. If a transaction is defined to have any other isolation level, then InnoDB obeys its default locking strategy which is REPEATABLE READ.
- SHOW TABLE STATUS no longer sets an x-lock at the end of an auto-increment index if the auto-increment counter has already been initialised. This removes in almost all cases the surprising deadlocks caused by SHOW TABLE STATUS.
- Fixed a bug: in a CREATE TABLE statement the string 'foreign' followed by a non-space character confused the FOREIGN KEY parser and caused table creation to fail with errno 150.

7.5.16.23 MySQL/InnoDB-3.23.49, February 17, 2002

- Fixed a bug: if you called DROP DATABASE for a database on which there simultaneously were running queries, the MySQL server could crash or hang. Crashes fixed, but a full fix has to wait some changes in the MySQL layer of code.
- Fixed a bug: on Windows one had to put the database name in lower case for DROP DATABASE to work. Fixed in 3.23.49: case no longer matters on Windows. On Unix the database name remains case-sensitive.
- Fixed a bug: if one defined a non-latin1 character set as the default character set, then definition of foreign key constraints could fail in an assertion failure in dict0crea.c, reporting an internal error 17.

7.5.16.24 MySQL/InnoDB-3.23.48, February 9, 2002

- Tuned the SQL optimiser to favor more often index searches over table scans.
- Fixed a performance problem when several large SELECT queries are run concurrently on a multiprocessor Linux computer. Large CPU-bound SELECT queries will now also generally run faster on all platforms.
- If MySQL binlogging is used, InnoDB now prints after crash recovery the latest MySQL binlog file name and the position in that file (= byte offset) InnoDB was able to recover to. This is useful, for example, when resynchronizing a master and a slave database in replication.
- Added better error messages to help in installation problems.
- One can now recover also MySQL temporary tables which have become orphaned inside the InnoDB tablespace.
- InnoDB now prevents a FOREIGN KEY declaration where the signedness is not the same in the referencing and referenced integer columns.

- Fixed a bug: calling SHOW CREATE TABLE or SHOW TABLE STATUS could cause memory corruption and make mysqld to crash. Especially at risk was mysqldump, because it calls frequently SHOW CREATE TABLE.
- Fixed a bug: if on Unix you did an ALTER TABLE to an InnoDB table and simultaneously did queries to it, mysqld could crash with an assertion failure in row0row.c, line 474.
- Fixed a bug: if inserts to several tables containing an auto-inc column were wrapped inside one LOCK TABLES, InnoDB asserted in lock0lock.c.
- In 3.23.47 we allowed several NULLS in a UNIQUE secondary index. But CHECK TABLE was not relaxed: it reports the table as corrupt. CHECK TABLE no longer complains in this situation.
- Fixed a bug: on Sparc and other high-endian processors SHOW VARIABLES showed innodb_flush_log_at_trx_commit and other boolean-valued startup parameters always OFF even if they were switched on.
- Fixed a bug: if you ran mysqld-max-nt as a service on Windows NT/2000, the service shutdown did not always wait long enough for the InnoDB shutdown to finish.

7.5.16.25 MySQL/InnoDB-3.23.47, December 28, 2001

- Recovery happens now faster, especially in a lightly loaded system, because background checkpointing has been made more frequent.
- InnoDB allows now several similar key values in a UNIQUE secondary index if those values contain SQL NULLs. Thus the convention is now the same as in MyISAM tables.
- InnoDB gives a better row count estimate for a table which contains BLOBs.
- In a FOREIGN KEY constraint InnoDB is now case-insensitive to column names, and in Windows also to table names.
- InnoDB allows a FOREIGN KEY column of CHAR type to refer to a column of VARCHAR type, and vice versa. MySQL silently changes the type of some columns between CHAR and VARCHAR, and these silent changes do not hinder FOREIGN KEY declaration any more.
- Recovery has been made more resilient to corruption of log files.
- Unnecessary statistics calculation has been removed from queries which generate a temporary table. Some ORDER BY and DISTINCT queries will now run much faster.
- MySQL now knows that the table scan of an InnoDB table is done through the primary key. This will save a sort in some ORDER BY queries.
- The maximum key length of InnoDB tables is again restricted to 500 bytes. The MySQL interpreter is not able to handle longer keys.
- The default value of innodb_lock_wait_timeout was changed from infinite to 50 seconds, the default value of innodb_file_io_threads from 9 to 4.

7.5.16.26 MySQL/InnoDB-4.0.1, December 23, 2001

- InnoDB is the same as in 3.23.47.

- In 4.0.0 the MySQL interpreter did not know the syntax LOCK IN SHARE MODE. This has been fixed.
- In 4.0.0 multi-table delete did not work for transactional tables. This has been fixed.

7.5.16.27 MySQL/InnoDB-3.23.46, November 30, 2001

- This is the same as 3.23.45.

7.5.16.28 MySQL/InnoDB-3.23.45, November 23, 2001

- This is a bugfix release.
- In versions 3.23.42-.44 when creating a table on Windows you have to use lower case letters in the database name to be able to access the table. Fixed in 3.23.45.
- InnoDB now flushes stdout and stderr every 10 seconds: if these are redirected to files, the file contents can be better viewed with an editor.
- Fixed an assertion failure in .44, in trx0trx.c, line 178 when you drop a table which has the .frm file but does not exist inside InnoDB.
- Fixed a bug in the insert buffer. The insert buffer tree could get into an inconsistent state, causing a crash, and also crashing the recovery. This bug could appear especially in large table imports or alterations.
- Fixed a bug in recovery: InnoDB could go into an infinite loop constantly printing a warning message that it cannot find free blocks from the buffer pool.
- Fixed a bug: when you created a temporary table of the InnoDB type, and then used ALTER TABLE to it, the MySQL server could crash.
- Prevented creation of MySQL system tables 'mysql.user', 'mysql.host', or 'mysql.db', in the InnoDB type.
- Fixed a bug which can cause an assertion failure in 3.23.44 in srv0srv.c, line 1728.

7.5.16.29 MySQL/InnoDB-3.23.44, November 2, 2001

- You can define foreign key constraints on InnoDB tables. An example: FOREIGN KEY (col1) REFERENCES table2(col2).
- You can create > 4 GB datafiles in those file systems that allow it.
- Improved InnoDB monitors, including a new innodb_table_monitor which allows you to print the contents of the InnoDB internal data dictionary.
- DROP DATABASE will now work also for InnoDB tables.
- Accent characters in the default character set latin1 will be ordered according to the MySQL ordering.
 NOTE: if you are using latin1 and have inserted characters whose code is > 127 to an indexed CHAR column, you should run CHECK TABLE on your table when you upgrade to 3.23.43, and drop and reimport the table if CHECK TABLE reports an error!
- InnoDB will calculate better table cardinality estimates.
- Change in deadlock resolution: in .43 a deadlock rolls back only the SQL statement, in .44 it will roll back the whole transaction.

- Deadlock, lock wait timeout, and foreign key constraint violations (no parent row, child rows exist) now return native MySQL error codes 1213, 1205, 1216, 1217, respectively.
- A new my.cnf parameter innodb_thread_concurrency helps in performance tuning in high concurrency environments.
- A new my.cnf option innodb_force_recovery will help you in dumping tables from a corrupted database.
- A new my.cnf option innodb_fast_shutdown will speed up shutdown. Normally InnoDB does a full purge and an insert buffer merge at shutdown.
- Raised maximum key length to 7000 bytes from a previous limit of 500 bytes.
- Fixed a bug in replication of auto-inc columns with multiline inserts.
- Fixed a bug when the case of letters changes in an update of an indexed secondary column.
- Fixed a hang when there are > 24 datafiles.
- Fixed a crash when MAX(col) is selected from an empty table, and col is a not the first column in a multi-column index.
- Fixed a bug in purge which could cause crashes.

7.5.16.30 MySQL/InnoDB-3.23.43, October 4, 2001

- This is essentially the same as InnoDB-3.23.42.

7.5.16.31 MySQL/InnoDB-3.23.42, September 9, 2001

- Fixed a bug which corrupted the table if the primary key of a > 8000-byte row was updated.
- There are now 3 types of InnoDB Monitors: innodb_monitor, innodb_lock_monitor, and innodb_tablespace_monitor. innodb_monitor now prints also buffer pool hit rate and the total number of rows inserted, updated, deleted, read.
- Fixed a bug in RENAME TABLE.
- Fixed a bug in replication with an auto-increment column.

7.5.16.32 MySQL/InnoDB-3.23.41, August 13, 2001

- Support for < 4 GB rows. The previous limit was 8000 bytes.
- Use the doublewrite file flush method.
- Raw disk partitions supported as datafiles.
- InnoDB Monitor.
- Several hang bugs fixed and an `ORDER BY` bug ('Sort aborted') fixed.

7.5.16.33 MySQL/InnoDB-3.23.40, July 16, 2001

- Only a few rare bugs fixed.

7.5.16.34 MySQL/InnoDB-3.23.39, June 13, 2001

- `CHECK TABLE` now works for `InnoDB` tables.
- A new '`my.cnf`' parameter `innodb_unix_file_flush_method` introduced. It can be used to tune disk write performance.
- An auto-increment column now gets new values past the transaction mechanism. This saves CPU time and eliminates transaction deadlocks in new value assignment.
- Several bug fixes, most notably the rollback bug in 3.23.38.

7.5.16.35 MySQL/InnoDB-3.23.38, May 12, 2001

- The new syntax `SELECT ... LOCK IN SHARE MODE` is introduced.
- `InnoDB` now calls `fsync()` after every disk write and calculates a checksum for every database page it writes or reads, which will reveal disk defects.
- Several bug fixes.

7.5.17 `InnoDB` Contact Information

Contact information of Innobase Oy, producer of the `InnoDB` engine. Web site: `http://www.innodb.com/`. E-mail: `sales@innodb.com`

```
phone: 358-9-6969 3250 (office) 358-40-5617367 (mobile)
Innobase Oy Inc.
World Trade Center Helsinki
Aleksanterinkatu 17
P.O.Box 800
00101 Helsinki
Finland
```

7.6 `BDB` or `BerkeleyDB` Tables

7.6.1 Overview of `BDB` Tables

BerkeleyDB, available at `http://www.sleepycat.com/` has provided MySQL with a transactional storage engine. Support for this storage engine is included in the MySQL source distribution starting from version 3.23.34 and is activated in the MySQL-Max binary. This storage engine is typically called `BDB` for short.

`BDB` tables may have a greater chance of surviving crashes and are also capable of `COMMIT` and `ROLLBACK` operations on transactions. The MySQL source distribution comes with a `BDB` distribution that has a couple of small patches to make it work more smoothly with MySQL. You can't use a non-patched `BDB` version with MySQL.

We at MySQL AB are working in close cooperation with Sleepycat to keep the quality of the MySQL/BDB interface high.

When it comes to supporting BDB tables, we are committed to help our users to locate the problem and help creating a reproducible test case for any problems involving BDB tables. Any such test case will be forwarded to Sleepycat who in turn will help us find and fix the problem. As this is a two-stage operation, any problems with BDB tables may take a little longer for us to fix than for other storage engines. However, as the BerkeleyDB code itself has been used by many other applications than MySQL, we don't envision any big problems with this. See Section 1.4.1 [Support], page 16.

7.6.2 Installing BDB

If you have downloaded a binary version of MySQL that includes support for BerkeleyDB, simply follow the instructions for installing a binary version of MySQL. See Section 2.2.9 [Installing binary], page 85. See Section 4.8.5 [mysqld-max], page 323.

To compile MySQL with Berkeley DB support, download MySQL Version 3.23.34 or newer and configure MySQL with the `--with-berkeley-db` option. See Section 2.3 [Installing source], page 88.

```
cd /path/to/source/of/mysql-3.23.34
./configure --with-berkeley-db
```

Please refer to the manual provided with the BDB distribution for more updated information.

Even though Berkeley DB is in itself very tested and reliable, the MySQL interface is still considered gamma quality. We are actively improving and optimising it to get it stable very soon.

7.6.3 BDB Startup Options

If you are running with AUTOCOMMIT=0 then your changes in BDB tables will not be updated until you execute COMMIT. Instead of commit you can execute ROLLBACK to forget your changes. See Section 6.7.1 [COMMIT], page 580.

If you are running with AUTOCOMMIT=1 (the default), your changes will be committed immediately. You can start an extended transaction with the BEGIN WORK SQL command, after which your changes will not be committed until you execute COMMIT (or decide to ROLLBACK the changes).

The following options to mysqld can be used to change the behaviour of BDB tables:

Option	Description
`--bdb-home=directory`	Base directory for BDB tables. This should be the same directory you use for `--datadir`.
`--bdb-lock-detect=#`	Berkeley lock detect. One of (DEFAULT, OLDEST, RANDOM, or YOUNGEST).
`--bdb-logdir=directory`	Berkeley DB log file directory.
`--bdb-no-sync`	Don't synchronously flush logs.
`--bdb-no-recover`	Don't start Berkeley DB in recover mode.
`--bdb-shared-data`	Start Berkeley DB in multi-process mode (Don't use DB_PRIVATE when initialising Berkeley DB)
`--bdb-tmpdir=directory`	Berkeley DB temporary file directory.

`--skip-bdb`	Disable usage of `BDB` tables.
`-O bdb_max_`	Set the maximum number of locks possible. See
`lock=1000`	Section 4.6.8.4 [`bdb_max_lock`], page 290.

If you use `--skip-bdb`, MySQL will not initialise the Berkeley DB library and this will save a lot of memory. Of course, you cannot use `BDB` tables if you are using this option. If you try to create a `BDB` table, MySQL will instead create a `MyISAM` table.

Normally you should start `mysqld` without `--bdb-no-recover` if you intend to use `BDB` tables. This may, however, give you problems when you try to start `mysqld` if the `BDB` log files are corrupted. See Section 2.4.2 [Starting server], page 107.

With `bdb_max_lock` you can specify the maximum number of locks (10000 by default) you can have active on a `BDB` table. You should increase this if you get errors of type `bdb: Lock table is out of available locks` or `Got error 12 from ...` when you have do long transactions or when `mysqld` has to examine a lot of rows to calculate the query.

You may also want to change `binlog_cache_size` and `max_binlog_cache_size` if you are using big multi-line transactions. See Section 6.7.1 [`COMMIT`], page 580.

7.6.4 Characteristics of `BDB` Tables

- To be able to rollback transactions, the `BDB` storage engine maintains log files. For maximum performance you should place these on another disk than your databases by using the `--bdb-logdir` option.
- MySQL performs a checkpoint each time a new `BDB` log file is started, and removes any log files that are not needed for current transactions. One can also run `FLUSH LOGS` at any time to checkpoint the Berkeley DB tables.

  For disaster recovery, one should use table backups plus MySQL's binary log. See Section 4.5.1 [Backup], page 259.

  Warning: If you delete old log files that are in use, `BDB` will not be able to do recovery at all and you may lose data if something goes wrong.
- MySQL requires a `PRIMARY KEY` in each `BDB` table to be able to refer to previously read rows. If you don't create one, MySQL will create an maintain a hidden `PRIMARY KEY` for you. The hidden key has a length of 5 bytes and is incremented for each insert attempt.
- If all columns you access in a `BDB` table are part of the same index or part of the primary key, then MySQL can execute the query without having to access the actual row. In a `MyISAM` table the above holds only if the columns are part of the same index.
- The `PRIMARY KEY` will be faster than any other key, as the `PRIMARY KEY` is stored together with the row data. As the other keys are stored as the key data `+` the `PRIMARY KEY`, it's important to keep the `PRIMARY KEY` as short as possible to save disk and get better speed.
- `LOCK TABLES` works on `BDB` tables as with other tables. If you don't use `LOCK TABLE`, MySQL will issue an internal multiple-write lock on the table to ensure that the table will be properly locked if another thread issues a table lock.
- Internal locking in `BDB` tables is done on page level.
- `SELECT COUNT(*) FROM table_name` is slow as `BDB` tables doesn't maintain a count of the number of rows in the table.

- Sequential scanning is slower than with `MyISAM` tables as the data in `BDB` tables stored in B-trees and not in a separate datafile.
- The application must always be prepared to handle cases where any change of a `BDB` table may make an automatic rollback and any read may fail with a deadlock error.
- Keys are not prefix or suffix-compressed like keys in `MyISAM` tables. In other words, the key information will take a little more space in `BDB` tables compared to `MyISAM` tables.
- There are often holes in the `BDB` table to allow you to insert new rows in the middle of the key tree. This makes `BDB` tables somewhat larger than `MyISAM` tables.
- The optimiser needs to know an approximation of the number of rows in the table. MySQL solves this by counting inserts and maintaining this in a separate segment in each `BDB` table. If you don't issue a lot of `DELETE` or `ROLLBACK` statements, this number should be accurate enough for the MySQL optimiser, but as MySQL only stores the number on close, it may be incorrect if MySQL dies unexpectedly. It should not be fatal even if this number is not 100% correct. One can update the number of rows by executing `ANALYZE TABLE` or `OPTIMIZE TABLE`. See Section 4.6.2 [ANALYZE TABLE], page 281 . See Section 4.6.1 [OPTIMIZE TABLE], page 281.
- If you get full disk with a `BDB` table, you will get an error (probably error 28) and the transaction should roll back. This is in contrast with `MyISAM` and `ISAM` tables where `mysqld` will wait for enough free disk before continuing.

7.6.5 Things We Need to Fix for `BDB` in the Near Future

- It's very slow to open many `BDB` tables at the same time. If you are going to use `BDB` tables, you should not have a very big table cache (like `>256`) and you should use `--no-auto-rehash` with the `mysql` client. We plan to partly fix this in 4.0.
- `SHOW TABLE STATUS` doesn't yet provide that much information for `BDB` tables.
- Optimise performance.
- Change to not use page locks at all when we are scanning tables.

7.6.6 Operating Systems Supported by `BDB`

Currently we know that the `BDB` storage engine works with the following operating systems:

- Linux 2.x Intel
- Sun Solaris (sparc and x86)
- FreeBSD 4.x/5.x (x86, sparc64)
- IBM AIX 4.3.x
- SCO OpenServer
- SCO UnixWare 7.1.x

It doesn't work with the following operating systems:

- Linux 2.x Alpha
- Linux 2.x AMD64
- Linux 2.x IA64

- Linux 2.x s390
- Max OS X

Note: The above list is not complete; we will update it as we receive more information.

If you build MySQL with support for `BDB` tables and get the following error in the log file when you start `mysqld`:

```
bdb: architecture lacks fast mutexes: applications cannot be threaded
Can't init databases
```

This means that `BDB` tables are not supported for your architecture. In this case you must rebuild MySQL without `BDB` table support.

7.6.7 Restrictions on `BDB` Tables

Here follows the restrictions you have when using `BDB` tables:

- `BDB` tables store in the '`.db`' file the path to the file as it was created. (This was done to be able to detect locks in a multi-user environment that supports symlinks).

  The effect of this is that `BDB` tables are not movable between directories!
- When taking backups of `BDB` tables, you have to either use `mysqldump` or take a backup of all `table_name.db` files and the `BDB` log files. The `BDB` log files are the files in the base data directory named `log.XXXXXXXXXX` (ten digits); The `BDB` storage engine stores unfinished transactions in the log files and requires these logs to be present when `mysqld` starts.

7.6.8 Errors That May Occur When Using `BDB` Tables

- If you get the following error in the `hostname.err` `log` when starting `mysqld`:

  ```
  bdb:  Ignoring log file: .../log.XXXXXXXXXX: unsupported log version #
  ```

  it means that the new `BDB` version doesn't support the old log file format. In this case you have to delete all `BDB` logs from your database directory (the files with names that have the format `log.XXXXXXXXXX`) and restart `mysqld`. We would also recommend you to do a `mysqldump --opt` of your old `BDB` tables, delete the old tables, and restore the dump.
- If you are not running in auto-commit mode and delete a table that is referenced in another transaction, you may get the following error messages in your MySQL error log:

  ```
  001119 23:43:56  bdb:  Missing log fileid entry
  001119 23:43:56  bdb:  txn_abort: Log undo failed for LSN:
                        1 3644744: Invalid
  ```

  This is not fatal but we don't recommend that you delete tables if you are not in auto-commit mode, until this problem is fixed (the fix is not trivial).

8 Introduction to MaxDB

MaxDB is an enterprise level database. MaxDB is the new name of a database management system formerly called SAP DB.

8.1 History of MaxDB

The history of SAP DB goes back to the early 1980s when it was developed as a commercial product (Adabas). The database has changed names several times since then. When SAP AG, a Walldorf, Germany, based company, took over the development of that database system, it was called SAP DB.

SAP developed that database system to serve as a storage system for all heavy-duty SAP applications, namely R/3. SAP DB was meant to provide an alternative to third-party database systems like Oracle, Microsoft SQL Server, or DB2 by IBM. In October 2000, SAP AG released SAP DB under the GNU GPL license (see Appendix H [GPL license], page 1023), thus making it open source software. In October 2003, more than 2,000 customers of SAP AG were using SAP DB as their main database system, and more than another 2,000 customers were using it as a separate database system besides their main database, as part of the APO/LiveCache solution.

In May 2003, a technology partnership was formed between MySQL AB and SAP AG. That partnership entitles MySQL AB to further develop SAP DB, rename it, and sell commercial licenses of the renamed SAP DB to customers who do not want to be bound to the restrictions imposed to them when using that database system under the GNU GPL (see Appendix H [GPL license], page 1023). In August 2003, SAP DB was renamed to MaxDB by MySQL AB.

8.2 Licensing and Support

MaxDB can be used under the same licenses available for the other products distributed by MySQL AB (Section 1.4.3 [MySQL licenses], page 17). Thus, MaxDB will be available under the GNU General Public License (Appendix H [GPL license], page 1023), and a commercial license (Section 1.4 [Licensing and Support], page 15).

MySQL will offer MaxDB support to non-SAP customers.

The first rebranded version will be MaxDB 7.5.00 that will be released in late 2003.

8.3 Basic Concepts of MaxDB

MaxDB operates as a client/server product. It was developed to meet the demands of installations processing a high volume of online transactions. Both online backup and expansion of the database are supported. Microsoft Clustered Server is supported directly for multiple server implementations; other failover solutions must be scripted manually. Database management tools are provided in both Windows and browser-based implementations.

8.4 Feature Differences between MaxDB and MySQL

The following list provides a short summary of the main differences between MaxDB and MySQL; it is not complete.

- MaxDB runs as a client/server system. MySQL can run as a client/server system or as an embedded system.
- MaxDB might not run on all platforms supported by MySQL. For example, MaxDB does not run on IBM's OS/2.
- MaxDB uses a proprietary network protocol for client/server communication, while MySQL uses either TCP/IP (with or without SSL encryption), sockets (under Unix-like systems), or named pipes (under Windows NT-family systems).
- MaxDB supports stored procedures. For MySQL, stored procedures are not scheduled for implementation until version 5.0. MaxDB also supports programming of triggers through an SQL extension, which is scheduled for MySQL 5.1. MaxDB contains a debugger for stored procedure languages, can cascade nested triggers, and supports multiple triggers per action and row.
- MaxDB is distributed containing user interfaces that are text-based, graphical, or web-based. MySQL is distributed with text-based user interfaces only; a graphical user interface (MySQL Control Center) is shipped separately from the main distributions. Web-based user interfaces for MySQL are offered by third parties.
- MaxDB supports a number of programming interfaces also supported by MySQL. However, MaxDB does not support RDO, ADO, or .NET, all of which are supported by MySQL. MaxDB supports embedded SQL only with C/C++.
- MaxDB contains administrative features that MySQL does not have: Job scheduling by time, event, and alert, and sending messages to a database administrator on alert thresholds.

8.5 Interoperability Features between MaxDB and MySQL

The following features will be included in MaxDB versions to be released shortly after the first 7.5.00 version. These features will allow interoperation between MaxDB and MySQL:

- There will be a MySQL proxy enabling one to connect to MaxDB using the MySQL protocol. This makes it possible to use MySQL client programs for MaxDB, like the `mysql` command-line user interface, the `mysqldump` dump utility, or the `mysqlimport` import program. Using `mysqldump`, one can easily dump data from one database system and export (or even pipe) those data to the other database system.
- Replication between MySQL and MaxDB will be supported in both directions. That is, either MySQL or MaxDB can be used as the master replication server. The long-range plan is to converge and extend the replication syntax so that both database systems understand the same syntax. See Section 4.11.1 [Replication Intro], page 355.

8.6 MaxDB-related Links

The main page for information about MaxDB is `http://www.mysql.com/maxdb`. Eventually, all information available at `http://www.sapdb.org` will be moved there.

8.7 Reserved Words in MaxDB

Like MySQL, MaxDB has a number of reserved words that have special meanings. Normally, they cannot be used as names of identifiers, such as database or table names. The following table lists reserved words in MaxDB, indicates the context in which those words are used, and indicates whether or not they have counterparts in MySQL. If such a counterpart exists, the meaning in MySQL might be identical, or differing in some aspects. The main purpose is to list in which respects MaxDB differs from MySQL; therefore, this list is not complete.

For the list of reserved words in MySQL, see See Section 6.1.7 [Reserved words], page 451.

Reserved in MaxDB	Context of usage in MaxDB	MySQL counterpart
`@`	May prefix identifier, like "`@table`"	Not allowed
`ADDDATE()`	SQL function	`ADDDATE()`; new in MySQL version 4.1.1
`ADDTIME()`	SQL function	`ADDTIME()`; new in MySQL version 4.1.1
`ALPHA`	SQL function	Nothing comparable
`ARRAY`	Data type	Not implemented
`ASCII()`	SQL function	`ASCII()`, but implemented with a different meaning
`AUTOCOMMIT`	Transactions; `ON` by default	Transactions; `OFF` by default
`BOOLEAN`	Column types; `BOOLEAN` accepts as values only `TRUE`, `FALSE`, and `NULL`	`BOOLEAN` was added in MySQL version 4.1.0; it is a synonym for `BOOL` which is mapped to `TINYINT(1)`. It accepts integer values in the same range as `TINYINT` as well as `NULL`. `TRUE` and `FALSE` can be used as aliases for `1` and `0`.
`CHECK`	`CHECK TABLE`	`CHECK TABLE`; similar, but not identical usage
`COLUMN`	Column types	`COLUMN`; noise word
`CHAR()`	SQL function	`CHAR()`; identical syntax; similar, not identical usage
`COMMIT`	Implicit commits of transactions happen when data definition queries are being issued	Implicit commits of transactions happen when data definition queries are being issued, but also with a number of other queries
`COSH()`	SQL function	Nothing comparable
`COT()`	SQL function	`COT()`; identical syntax and implementation
`CREATE`	SQL, data definition language	`CREATE`
`DATABASE`	SQL function	`DATABASE()`; `DATABASE` is used in a different context, for example `CREATE DATABASE`

DATE()	SQL function	CURRENT_DATE
DATEDIFF()	SQL function	DATEDIFF(); new in MySQL version 4.1.1
DAY()	SQL function	Nothing comparable
DAYOFWEEK()	SQL function	DAYOFWEEK(); the first day (1) by default is Monday in MaxDB, and Sunday in MySQL
DISTINCT	SQL functions AVG, MAX, MIN, SUM	DISTINCT; but used in a different context: SELECT DISTINCT
DROP	inter alia in DROP INDEX	DROP INDEX; similar, but not identical usage
EBCDIC()	SQL function	Nothing comparable
EXPAND()	SQL function	Nothing comparable
EXPLAIN	Optimisation	EXPLAIN; similar, but not identical usage
FIXED()	SQL function	Nothing comparable
FLOAT()	SQL function	Nothing comparable
HEX()	SQL function	HEX(); similar, but not identical usage
INDEX()	SQL function	INSTR() or LOCATE(); similar, but not identical syntaxes and meanings
INDEX	USE INDEX, IGNORE INDEX and similar hints are being used right after SELECT, like SELECT ... USE INDEX	USE INDEX, IGNORE INDEX and similar hints are being used in the FROM clause of a SELECT query, like in SELECT ... FROM ... USE INDEX
INITCAP()	SQL function	Nothing comparable
LENGTH()	SQL function	LENGTH(); identical syntax, but slightly different implementation
LFILL()	SQL function	Nothing comparable
LIKE	Comparisons	LIKE; but the extended LIKE MaxDB provides rather resembles the MySQL REGEX
LIKE wildcards	MaxDB supports "%", "_", "ctrl+underline", "ctrl+up arrow", "*", and "?" as wildcards in a LIKE comparison	MySQL supports "%", and "_" as wildcards in a LIKE comparison
LPAD()	SQL function	LPAD(); slightly different implementation
LTRIM()	SQL function	LTRIM(); slightly different implementation
MAKEDATE()	SQL function	MAKEDATE(); new in MySQL version 4.1.1
MAKETIME()	SQL function	MAKETIME(); new in MySQL version 4.1.1
MAPCHAR()	SQL function	Nothing comparable
MICROSECOND()	SQL function	MICROSECOND(); new in MySQL version 4.1.1
NOROUND()	SQL function	Nothing comparable
NULL	Column types; comparisons	NULL; MaxDB supports special NULL values that are returned by arithmetic operations that lead to an overflow or a division by zero; MySQL does not support such special values
PI	SQL function	PI(); identical syntax and implementation, but parantheses are mandatory
REF	Data type	Nothing comparable

RFILL()	SQL function	Nothing comparable
ROWNO	Predicate in WHERE clause	Similar to LIMIT clause
RPAD()	SQL function	RPAD(); slightly different implementation
RTRIM()	SQL function	RTRIM(); slightly different implementation
SEQUENCE	CREATE SEQUENCE, DROP SEQUENCE	AUTO_INCREMENT; similar concept, but differing implementation
SINH()	SQL function	Nothing comparable
SOUNDS()	SQL function	SOUNDEX(); slightly different syntax
STATISTICS	UPDATE STATISTICS	ANALYZE; similar concept, but differing implementation
SUBSTR()	SQL function	SUBSTRING(); slightly different implementation
SUBTIME()	SQL function	SUBTIME(); new in MySQL version 4.1.1
SYNONYM	Data definition language: CREATE [PUBLIC] SYNONYM, RENAME SYNONYM, DROP SYNONYM	Nothing comparable
TANH()	SQL function	Nothing comparable
TIME()	SQL function	CURRENT_TIME
TIMEDIFF()	SQL function	TIMEDIFF(); new in MySQL version 4.1.1
TIMESTAMP()	SQL function	TIMESTAMP(); new in MySQL version 4.1.1
TIMESTAMP() as argument to DAYOFMONTH() and DAYOFYEAR()	SQL function	Nothing comparable
TIMEZONE()	SQL function	Nothing comparable
TRANSACTION()	Returns the ID of the current transaction	Nothing comparable
TRANSLATE()	SQL function	REPLACE(); identical syntax and implementation
TRIM()	SQL function	TRIM(); slightly different implementation
TRUNC()	SQL function	TRUNCATE(); slightly different syntax and implementation
USE	mysql commandline user interface command	USE
USER	SQL function	USER(); identical syntax, but slightly different implementation, and parantheses are mandatory
UTC_DIFF()	SQL function	UTC_DATE(); provides a means to calculate the result of UTC_DIFF()
VALUE()	SQL function, alias for COALESCE()	COALESCE(); identical syntax and implementation
VARIANCE()	SQL function	Nothing comparable
WEEKOFYEAR()	SQL function	WEEKOFYEAR(); new in MySQL version 4.1.1

8.8 Functions

8.9 Column Types

9 National Character Sets and Unicode

Improved handling of character sets is one of the features added to MySQL in Version 4.1. This chapter explains:

- What are character sets and collations
- The multi-level default system
- New syntax in MySQL 4.1
- Affected functions and operations
- The meaning of each individual character set and collation

The features described here are as implemented in MySQL 4.1.1. (MySQL 4.1.0 has some but not all of these features, and some of them are implemented differently.)

9.1 Character Sets and Collations in General

A **character set** is a set of symbols and encodings. A **collation** is a set of rules for comparing characters in a character set. Let's make the distinction clear with an example of an imaginary character set.

Suppose we had an alphabet with four letters: 'A', 'B', 'a', 'b'. We give each letter a number: 'A' = 0, 'B' = 1, 'a' = 2, 'c' = 3. The letter 'A' is a symbol, the number 0 is the **encoding** for 'A', and the combination of all four letters and their encodings is a **character set**.

Now, suppose we want to compare two string values, 'A' and 'B'. The simplest way to do this is to look at the encodings — 0 for 'A' and 1 for 'B' — and because 0 is less than 1, we say 'A' is less than 'B'. Now, what we've just done is apply a collation to our character set. The collation is a set of rules (only one rule in this case): "compare the encodings". We call this simplest of all possible collations a **binary** collation.

But what if we want to say that the lowercase and uppercase letters are equivalent? Then we would have at least two rules: (1) treat the lowercase letters 'a' and 'b' as equivalent to 'A' and 'B'; (2) then compare the encodings. We call this a **case insensitive** collation. It's a little more complex than a binary collation.

In real life, most character sets have many characters: not just 'A' and 'B' but whole alphabets, sometimes multiple alphabets or eastern writing systems with thousands of characters, along with many special symbols and punctuation marks. Also in real life, most collations have many rules: not just case insensitivity but also accent insensitivity (an "accent" is a mark attached to a character as in German 'Ö') and multiple-character mappings (such as the rule that 'Ö' = 'OE' in one of the two German collations).

MySQL 4.1 can do these things for you:

- Store strings using a variety of character sets
- Compare strings using a variety of collations
- Mix strings with different character sets or collations in the same server, the same database, or even the same table
- Allow specification of character set and collation at any level

In these respects, not only is MySQL 4.1 far more flexible than MySQL 4.0, it also is far ahead of other DBMSs. However, to use the new features effectively, you will need to learn what character sets and collations are available, how to change their defaults, and what the various string operators do with them.

9.2 Character Sets and Collations in MySQL

A character set always has at least one collation. It may have several collations.

For example, character set `latin1` ("ISO-8859-1 West European") has the following collations:

Collation	Meaning
`latin1_bin`	Binary according to `latin1` encoding
`latin1_danish_ci`	Danish/Norwegian
`latin1_german1_ci`	German DIN-1
`latin1_german2_ci`	German DIN-2
`latin1_swedish_ci`	Swedish/Finnish
`latin1_general_ci`	Multilingual

Notes:

- Two different character sets can't have the same collation.
- Each character set has one collation that is the *default collation*. For example, the default collation for `latin1` is `latin1_swedish_ci`.

Notice that there is a convention for collation names: They start with the name of the character set they are associated with, they usually include a language name, and they end with `_ci` (case insensitive), `_cs` (case sensitive), or `_bin` (binary).

9.3 Determining the Default Character Set and Collation

There are default settings for character sets and collations at four levels: server, database, table, connection. The following description may appear complex, but it's been found in practice that multi-level defaulting leads to natural and obvious results.

9.3.1 Server Character Set and Collation

The MySQL Server has a server character set and a server collation, which may not be null.

MySQL determines the server character set and server collation thus:

- According to the option settings in effect when the server starts up.

At this level, the decision is simple. The server character set and collation depend on the options that you use when you start `mysqld`. You can use `--default-character-set=character_set_name` for the character set, and along with it you can add `--default-collation=collation_name` for the collation. If you don't specify a character set, that

is the same as saying `--default-character-set=latin1`. If you specify only a character set (for instance, `latin1`) but not a collation, that is the same as saying `--default-charset=latin1 --collation=latin1_swedish_ci` because `latin1_swedish_ci` is the default collation for `latin1`. Therefore the following three commands all have the same effect:

```
shell> mysqld
shell> mysqld --default-character-set=latin1
shell> mysqld --default-character-set=latin1
           --default-collation=latin1_swedish_ci
```

One way to change the settings is by recompiling. If you want to change the default server character set and collation when building from sources, use: `--with-character-set` and `--with-collation` as arguments for `configure`. For example:

```
shell> ./configure --with-character-set=latin1
```

or

```
shell> ./configure --with-character-set=latin1
           --with-collation=latin1_german1_ci
```

Both `mysqld` and `configure` check that the character set/collation combination is valid. Each program displays an error message and terminates if the combination is not valid.

9.3.2 Database Character Set and Collation

Every database has a database character set and a database collation, which may not be null. The `CREATE DATABASE` and `ALTER DATABASE` commands now have optional clauses for specifying the database character set and collation:

```
CREATE DATABASE db_name
   [DEFAULT CHARACTER SET character_set_name [COLLATE collation_name]]

ALTER DATABASE db_name
    [DEFAULT CHARACTER SET character_set_name [COLLATE collation_name]]
```

Example:

```
CREATE DATABASE db_name
   DEFAULT CHARACTER SET latin1 COLLATE latin1_swedish_ci;
```

MySQL chooses the database character set and database collation thus:

- If both `CHARACTER SET X` and `COLLATE Y` were specified, then character set `X` and collation `Y`.
- If `CHARACTER SET X` was specified without `COLLATE`, then character set `X` and its default collation.
- Otherwise, the server character set and server collation.

MySQL's `CREATE DATABASE ... DEFAULT CHARACTER SET ...` syntax is analogous to the standard-SQL `CREATE SCHEMA ... CHARACTER SET ...` syntax. Because of this, it is possible to create databases with different character sets and collations, on the same MySQL server.

The database character set and collation are used as default values if the table character set and collation are not specified in `CREATE TABLE` statements. They have no other purpose.

9.3.3 Table Character Set and Collation

Every table has a table character set and a table collation, which may not be null. The `CREATE TABLE` and `ALTER TABLE` statements now have optional clauses for specifying the table character set and collation:

```
CREATE TABLE table_name ( column_list )
   [DEFAULT CHARACTER SET character_set_name [COLLATE collation_name]]

ALTER TABLE table_name
   [DEFAULT CHARACTER SET character_set_name] [COLLATE collation_name]
```

Example:

```
CREATE TABLE t1 ( ... ) DEFAULT CHARACTER SET latin1 COLLATE latin1_danish_ci;
```

MySQL chooses the table character set and collation thus:

- If both `CHARACTER SET X` and `COLLATE Y` were specified, then character set `X` and collation `Y`.
- If `CHARACTER SET X` was specified without `COLLATE`, then character set `X` and its default collation.
- Otherwise, the database character set and collation.

The table character set and collation are used as default values, if the column character set and collation are not specified in individual column definitions. The table character set and collation are MySQL extensions; there are no such things in standard SQL.

9.3.4 Column Character Set and Collation

Every "character" column (that is, a column of type `CHAR`, `VARCHAR`, or `TEXT`) has a column character set and a column collation, which may not be null. Column definition syntax now has optional clauses for specifying the column character set and collation:

```
column_name {CHAR | VARCHAR | TEXT} (column_length)
    [CHARACTER SET character_set_name [COLLATE collation_name]]
```

Example:

```
CREATE TABLE Table1
(
   column1 VARCHAR(5) CHARACTER SET latin1 COLLATE latin1_german1_ci
);
```

MySQL chooses the column character set and collation thus:

- If both `CHARACTER SET X` and `COLLATE Y` were specified, then character set `X` and collation `Y`.
- If `CHARACTER SET X` was specified without `COLLATE`, then character set `X` and its default collation.
- Otherwise, the table character set and collation.

The `CHARACTER SET` and `COLLATE` clauses are standard SQL.

9.3.5 Examples of Character Set and Collation Assignment

The following examples show how MySQL determines default character set and collation values.

Example 1: Table + Column Definition

```
CREATE TABLE t1
(
  c1 CHAR(10) CHARACTER SET latin1 COLLATE latin1_german1_ci
) DEFAULT CHARACTER SET latin2 COLLATE latin2_bin;
```

Here you have a column with a `latin1` character set and a `latin1_german1_ci` collation. The definition is explicit, so that's straightforward. Notice that there's no problem storing a `latin1` column in a `latin2` table.

Example 2: Table + Column Definition

```
CREATE TABLE t1
(
   c1 CHAR(10) CHARACTER SET latin1
) DEFAULT CHARACTER SET latin1 COLLATE latin1_danish_ci;
```

This time we have a column with a `latin1` character set and a default collation. Now, although it might seem natural, the default collation is not taken from the table level. Instead, because the default collation for `latin1` is always `latin1_swedish_ci`, column `c1` will have a collation of `latin1_swedish_ci` (not `latin1_danish_ci`).

Example 3: Table + Column Definition

```
CREATE TABLE t1
(
   c1 CHAR(10)
) DEFAULT CHARACTER SET latin1 COLLATE latin1_danish_ci;
```

We have a column with a default character set and a default collation. In this circumstance, MySQL looks up to the table level for inspiration in determining the column character set and collation. So the character set for column `c1` is `latin1` and its collation is `latin1_danish_ci`.

Example 4: Database + Table + Column Definition

```
CREATE DATABASE d1 DEFAULT CHARACTER SET latin2 COLLATE latin2_czech_ci;
USE d1;
CREATE TABLE t1
(
   c1 CHAR(10)
);
```

We create a column without specifying its character set and collation. We're also not specifying a character set and a collation at the table level. In this circumstance, MySQL looks up to the database level for inspiration. (The database's settings become the table's settings, and thereafter become the column's setting.) So the character set for column `c1` is `latin2` and its collation is `latin2_czech_ci`.

9.3.6 Connection Character Sets and Collations

Every connection has connection character sets and connection collations, which may not be null. There are actually two connection character sets, which we will call "connection/literals" and "connection/results" when it is necessary to distinguish them.

Consider what a "connection" is: It's what you make when you connect to the server. The client sends SQL statements, such as queries, over the connection to the server. The server sends responses, such as result sets, over the connection back to the client. This leads to several questions, such as: (a) what character set is the query in when it leaves the client? (b) what character set should the server translate a query to after receiving it? (c) what character set should the server translate to before shipping result sets or error messages back to the client? You can fine-tune the setting for these things, or you can depend on the defaults (in which case, you can skip this section).

There are two statements that affect the connection character sets:

```
SET NAMES character_set_name
SET CHARACTER SET character_set_name
```

`SET NAMES` indicates what is in the SQL statement that the client sends. Thus, `SET NAMES cp1251` tells the server "future incoming messages from this client will be in character set `cp1251`" and the server is free to translate to its own character set, if appropriate.

`SET CHARACTER SET` indicates what is in the SQL statement that the client sends, and also what is in the result set that the server sends back to the client. Thus, `SET CHARACTER SET` includes `SET NAMES`, and also specifies what character set the column values will have if, for example, you use a `SELECT` statement.

EXAMPLE: Suppose that `column1` is defined as `CHAR(5) CHARACTER SET latin2`. If you do not say `SET CHARACTER SET`, then for `SELECT column1 FROM t` the server will send back all the values for `column1` using character set `latin2`. If on the other hand you say `SET CHARACTER SET latin1` then the server will, just before sending back, convert the `latin2` values to `latin1`. Such conversion is slow and may be lossy.

When you execute `SET NAMES` or `SET CHARACTER SET`, you are also changing the "connection collation". However, the connection collation exists for consistency only. Usually its value doesn't matter.

With the `mysql` client, it is not necessary to execute `SET NAMES` every time you start up. You can add the `--default-character-set-name` option setting to your `mysql` statement line, or in your option file. For example, the following option file setting will change the connection character set each time you run `mysql`:

```
[mysql]
default-character-set-name=character_set_name
```

9.3.7 Character String Literal Character Set and Collation

Every character string literal has a character set and a collation, which may not be null.

A character string literal may have an optional character set introducer and `COLLATE` clause:

```
[_character_set_name]'string' [COLLATE collation_name]
```

Examples:

```
SELECT 'string';
SELECT _latin1'string';
SELECT _latin1'string' COLLATE latin1_danish_ci;
```

The simple statement `SELECT 'string'` uses the connection/literal character set.

The `_character_set_name` expression is formally called an *introducer*. It tells the parser, "the string that is about to follow is in character set `X`." Because this has confused people in the past, we emphasize that an introducer does not cause any conversion, it is strictly a signal that does not change the string's value. An introducer is also legal before standard hex literal and numeric hex literal notation (`x'literal'` and `0xnnnn`), and before `?` (parameter substitution when using prepared statements within a programming language interface).

Examples:

```
SELECT _latin1 x'AABBCC';
SELECT _latin1 0xAABBCC;
SELECT _latin1 ?;
```

MySQL determines a literal's character set and collation thus:

- If both `_X` and `COLLATE Y` were specified then the literal character set is `X` and the literal collation is `Y`
- If `_X` is specified but `COLLATE` is not specified, then the literal character set is `X` and the literal collation is `X`'s default collation
- Otherwise, the connection/literals character set and collation.

Examples:

- A string with `latin1` character set and `latin1_german1_ci` collation:

  ```
  SELECT _latin1'Müller' COLLATE latin1_german1_ci;
  ```

- A string with `latin1` character set and its default collation, that is, `latin1_swedish_ci`:

  ```
  SELECT _latin1'Müller';
  ```

- A string with the connection/literals character set and collation:

  ```
  SELECT 'Müller';
  ```

Character set introducers and the `COLLATE` clause are implemented according to standard-SQL specifications.

9.3.8 `COLLATE` Clause in Various Parts of an SQL Query

With the `COLLATE` clause you can override whatever the default collation is for a comparison. `COLLATE` may be used in various parts of SQL queries. Here are some examples:

- With ORDER BY:

```
SELECT k
FROM t1
ORDER BY k COLLATE latin1_german2_ci;
```

- With AS:

```
SELECT k COLLATE latin1_german2_ci AS k1
FROM t1
ORDER BY k1;
```

- With GROUP BY:

```
SELECT k
FROM t1
GROUP BY k COLLATE latin1_german2_ci;
```

- With aggregate functions:

```
SELECT MAX(k COLLATE latin1_german2_ci)
FROM t1;
```

- With DISTINCT:

```
SELECT DISTINCT k COLLATE latin1_german2_ci
FROM t1;
```

- With WHERE:

```
SELECT *
FROM t1
WHERE _latin1 'Müller' COLLATE latin1_german2_ci = k;
```

- With HAVING:

```
SELECT k
FROM t1
GROUP BY k
HAVING k = _latin1 'Müller' COLLATE latin1_german2_ci;
```

9.3.9 COLLATE Clause Precedence

The COLLATE clause has high precedence (higher than ||), so the expression

```
x || y COLLATE z
```

is equivalent to:

```
x || (y COLLATE z)
```

9.3.10 BINARY Operator

The BINARY operator is a shorthand for a COLLATE clause. For example, BINARY 'x' is equivalent to 'x' COLLATE y, where y is the name of an appropriate binary collation. For example, assuming that column a is of character set latin1, these two queries have the same effect:

```
SELECT * FROM t1 ORDER BY BINARY a;
SELECT * FROM t1 ORDER BY a COLLATE latin1_bin;
```

Note: Every character set has a binary collation.

9.3.11 Some Special Cases Where the Collation Determination is Tricky

In the great majority of queries, it is obvious what collation MySQL uses to resolve a comparison operation. For example, in the following cases it should be clear that the collation will be "the column collation of column `x`":

```
SELECT x FROM T ORDER BY x;
SELECT x FROM T WHERE x = x;
SELECT DISTINCT x FROM T;
```

However, when multiple operands are involved, there can be ambiguity. For example:

```
SELECT x FROM T WHERE x = 'Y';
```

Should this query use the collation of the column `x`, or of the string literal `'Y'`?

Standard SQL resolves such questions using what used to be called "coercibility" rules. The essence is: Because `x` and `'Y'` both have collations, whose collation takes precedence? It's complex, but these rules would take care of most situations:

- An explicit `COLLATE` clause has precedence 4.
- A concatenation of two strings with different collations has precedence 3.
- A column's collation has precedence 2.
- A literal's collation has precedence 1.

Those rules resolve ambiguities thus:

- Use the collation with the highest precedence.
- If both sides have the same precedence, then it's an error if the collations aren't the same.

Examples:

`column1 = 'A'`	Use collation of `column1`
`column1 = 'A' COLLATE x`	Use collation of `'A'`
`column1 COLLATE x = 'A' COLLATE y`	Error

9.3.12 Collations Must Be for the Right Character Set

Recall that each character set has one or more collations, and each collation is associated with one and only one character set. Therefore, the following statement causes an error message because the `latin2_bin` collation is not legal with the `latin1` character set:

```
mysql> SELECT _latin1 'x' COLLATE latin2_bin;
ERROR 1251: COLLATION 'latin2_bin' is not valid
for CHARACTER SET 'latin1'
```

9.3.13 An example of the Effect of Collation

Suppose column `X` in table `T` has these `latin1` column values:

```
Muffler
Müller
MX Systems
MySQL
```

And suppose that the column values are retrieved using the following statement:

```
SELECT X FROM T ORDER BY X COLLATE collation_name;
```

The resulting order of the values for different collations is shown in this table:

latin1_swedish_ci	latin1_german1_ci	latin1_german2_ci
Muffler	Muffler	Müller
MX Systems	Müller	Muffler
Müller	MX Systems	MX Systems
MySQL	MySQL	MySQL

The table is an example that shows what the effect would be if we used different collations in an `ORDER BY` clause. The character that's causing the trouble in this example is the U with two dots over it, which the Germans call U-umlaut, but we'll call it U-diaeresis.

The first column shows the result of the `SELECT` using the Swedish/Finnish collating rule, which says that U-diaeresis sorts with Y.

The second column shows the result of the `SELECT` using the German DIN-1 rule, which says that U-diaeresis sorts with U.

The third column shows the result of the `SELECT` using the German DIN-2 rule, which says that U-diaeresis sorts with UE.

Three different collations, three different results. That's what MySQL is here to handle. By using the appropriate collation, you can choose the sort order you want.

9.4 Operations Affected by Character Set Support

This section describes operations that take character set information into account now.

9.4.1 Result Strings

MySQL has many operators and functions that return a string. This section answers the question: What is the character set and collation of such a string?

For simple functions that take a string input and return a string result as output, the output's character set and collation are the same as the principal input's. For example, `UPPER(X)` returns a string whose character string and collation are the same as that of `X`. The same applies for: `INSTR()`, `LCASE()`, `LOWER()`, `LTRIM()`, `MID()`, `REPEAT()`, `REPLACE()`, `REVERSE()`, `RIGHT()`, `RPAD()`, `RTRIM()`, `SOUNDEX()`, `SUBSTRING()`, `TRIM()`, `UCASE()`, `UPPER()`. (Also note: the `REPLACE()` function, unlike all other functions, ignores the collation of the string input and performs a case-insensitive comparison every time.)

For operations that combine multiple string inputs and return a single string output, SQL-99's "aggregation rules" apply. They are:

- If explicit `COLLATE X` occurs, then use `X`
- If explicit `COLLATE X` and `COLLATE Y` occur, then error

- Otherwise, if all collations are `X`, then use `X`
- Otherwise, the result has no collation

For example, with `CASE ... WHEN a THEN b WHEN b THEN c COLLATE X END`, the resultant collation is `X`. The same applies for: `CONCAT()`, `GREATEST()`, `IF()`, `LEAST()`, `CASE`, `UNION`, `||`, `ELT()`.

For operations that convert to character data, the result string's character set and collation are in the *connection/literals character set* and have the *connection/literals collation*. This applies for: `CHAR()`, `CAST()`, `CONV()`, `FORMAT()`. `HEX()`, `SPACE()`.

9.4.2 CONVERT()

`CONVERT()` provides a way to convert data between different character sets. The syntax is:

```
CONVERT(expr USING transcoding_name)
```

In MySQL, transcoding names are the same as the corresponding character set names.

Examples:

```
SELECT CONVERT(_latin1'Müller' USING utf8);
INSERT INTO utf8table (utf8column)
   SELECT CONVERT(latin1field USING utf8) FROM latin1table;
```

`CONVERT(... USING ...)` is implemented according to the SQL-99 specification.

9.4.3 CAST()

You may also use `CAST()` to convert a string to a different character set. The new format is:

```
CAST ( character_string AS character_data_type
    CHARACTER SET character_set_name )
```

Example:

```
SELECT CAST(_latin1'test' AS CHAR CHARACTER SET utf8);
```

You may not use a `COLLATE` clause inside a `CAST()`, but you may use it outside, that is, `CAST(... COLLATE ...)` is illegal but `CAST(...) COLLATE ...` is legal.

Example:

```
SELECT CAST(_latin1'test' AS CHAR CHARACTER SET utf8) COLLATE utf8_bin;
```

If you use `CAST()` without specifying `CHARACTER SET`, then the resulting character set and collation are the connection/literal character set and its default collation. If you use `CAST()` with `CHARACTER SET X`, then the resulting character set is `X` and the resulting collation is `X`'s default collation.

9.4.4 SHOW CHARACTER SET

The `SHOW CHARACTER SET` command shows all available character sets. It takes an optional `LIKE` clause that indicates which character set names to match.

For example:

```
mysql> SHOW CHARACTER SET LIKE 'latin%';
+---------+-----------------------------+-------------------+--------+
| Charset | Description                 | Default collation | Maxlen |
+---------+-----------------------------+-------------------+--------+
| latin1  | ISO 8859-1 West European    | latin1_swedish_ci |      1 |
| latin2  | ISO 8859-2 Central European | latin2_general_ci |      1 |
| latin5  | ISO 8859-9 Turkish          | latin5_turkish_ci |      1 |
| latin7  | ISO 8859-13 Baltic          | latin7_general_ci |      1 |
+---------+-----------------------------+-------------------+--------+
4 rows in set (0.00 sec)
```

Notes about the preceding listing:

- The `Maxlen` column shows the maximum number of bytes used to store one character.

9.4.5 SHOW COLLATION

The output from `SHOW COLLATION` includes all available character sets. It takes an optional `LIKE` clause that indicates which collation names to match.

```
mysql> SHOW COLLATION LIKE 'latin1%';
+-------------------+---------+----+---------+----------+---------+
| Collation         | Charset | Id | Default | Compiled | Sortlen |
+-------------------+---------+----+---------+----------+---------+
| latin1_german1_ci | latin1  |  5 |         |          |       0 |
| latin1_swedish_ci | latin1  |  8 | Yes     | Yes      |       0 |
| latin1_danish_ci  | latin1  | 15 |         |          |       0 |
| latin1_german2_ci | latin1  | 31 |         | Yes      |       2 |
| latin1_bin        | latin1  | 47 |         | Yes      |       0 |
| latin1_general_ci | latin1  | 48 |         |          |       0 |
| latin1_general_cs | latin1  | 49 |         |          |       0 |
+-------------------+---------+----+---------+----------+---------+
7 rows in set (0.00 sec)
```

The `Default` column indicates whether a collation is the default for its character set. `Compiled` indicates whether or not the character set is compiled into the server. `Sortlen` is related to the amount of memory required to sort strings expressed in the character set.

9.4.6 SHOW CREATE DATABASE

The following query shows a `CREATE DATABASE` statement that will create the given database. The result includes all database options. `DEFAULT CHARACTER SET` and `COLLATE` are supported. All database options are stored in a text file that can be found in the database directory.

```
mysql> SHOW CREATE DATABASE a;
+----------+-----------------------------------------------------------------------------
| Database | Create Database
|
+----------+-----------------------------------------------------------------------------
```

```
| a        | CREATE DATABASE `a` /*!40100 DEFAULT CHARACTER SET macce
COLLATE macce_ci_ai */ |
+----------+-------------------------------------------------------------------------------
1 row in set (0.00 sec)
```

9.4.7 SHOW FULL COLUMNS

The `SHOW COLUMNS` statement now displays the collations of a table's columns, when invoked as `SHOW FULL COLUMNS`. Columns with `CHAR`, `VARCHAR`, or `TEXT` datatypes have non-`NULL` collations. Numeric and other non-character types have `NULL` collations. For example:

```
mysql> SHOW FULL COLUMNS FROM a;
+-------+---------+-------------------+------+-----+---------+-------+
| Field | Type    | Collation         | Null | Key | Default | Extra |
+-------+---------+-------------------+------+-----+---------+-------+
| a     | char(1) | latin1_swedish_ci | YES  |     | NULL    |       |
| b     | int(11) | NULL              | YES  |     | NULL    |       |
+-------+---------+-------------------+------+-----+---------+-------+
2 rows in set (0.02 sec)
```

The character set is not part of the display.

9.5 Unicode Support

There are two new (as of MySQL version 4.1) character sets for storing Unicode data: `ucs2` (the UCS-2 Unicode character set) and `utf8` (the UTF-8 encoding of the Unicode character set).

- In UCS-2 (binary Unicode representation) every character is represented by a two-byte Unicode code with the most significant byte first. For example: "LATIN CAPITAL LETTER A" has the code 0x0041 and it's stored as a two byte sequence: 0x00 0x41. "CYRILLIC SMALL LETTER YERU" (Unicode 0x044B) is stored as a two byte sequence: 0x04 0x4B. For Unicode characters and their codes please refer to the Unicode Home Page (`http://www.unicode.org/`).

  Temporary restriction: UCS-2 can't (yet) be used as a client character set. That means that `SET NAMES ucs2` will not work.
- The UTF8 character set (transform Unicode representation) is an alternative way to store Unicode data. It is implemented according to RFC2279. The idea of the UTF8 character set is that various Unicode characters fit into byte sequences of different lengths.
  - Basic Latin letters, digits, and punctuation signs use one byte.
  - Most European and Middle East script letters fit into a two-byte sequence: extended Latin letters (with tilde, macron, acute, grave and other accents), Cyrillic, Greek, Armenian, Hebrew, Arabic, Syriac, and others.
  - Korean, Chinese and Japanese ideographs use three-byte sequences.
  - Currently, MySQL UTF8 support does not include four-byte sequences.

Tip: To save space with UTF8, use `VARCHAR` instead of `CHAR`. Otherwise, MySQL has to reserve 30 bytes for a `CHAR(10) CHARACTER SET utf8` column, because that's the maximum possible length.

9.6 UTF8 for Metadata

The metadata is the data about the data. Anything that describes the database, as opposed to being the contents of the database, is metadata. Thus column names, database names, user names, version names, and most of the string results from `SHOW`, are metadata.

All metadata must be in the same character set. (Otherwise, `SHOW` wouldn't work properly because different rows in the same column would be in different character sets.) On the other hand, metadata must include all characters in all languages. (Otherwise, users wouldn't be able to name columns and tables in their own languages.) In order to allow for both of these objectives, MySQL stores metadata in a Unicode character set, namely UTF8. This will not cause any disruption if you never use accented characters. But if you do, you should be aware that metadata is in UTF8.

This means that `USER()` (and its synonyms, `SESSION_USER()` and `SYSTEM_USER()`), `CURRENT_USER()`, and `VERSION()` functions will have the UTF8 character set by default.

This does NOT mean that the headers of columns and the results of `DESCRIBE` functions will be in the UTF8 character set by default. (When you say `SELECT column1 FROM t` the name `column1` itself will be returned from the server to the client in the client's character set as determined by the `SET NAMES` statement.)

If you want the server to pass metadata results back in a non-UTF8 character set, then use `SET CHARACTER SET` to force the server to convert (see Section 9.3.6 [Charset-connection], page 670), or set the client to do the conversion. It is always more efficient to set the client to do the conversion, but this option will not be available for many clients until late in the MySQL 4.x product cycle.

If you are just using, for example, the `USER()` function for comparison or assignment within a single statement ... don't worry. MySQL will do some automatic conversion for you.

```
SELECT * FROM Table1 WHERE USER() = latin1_column;
```

This will work, because the contents of `latin1_column` are automatically converted to UTF8 before the comparison.

```
INSERT INTO Table1 (latin1_column) SELECT USER();
```

This will work, becaues the contents of `USER()` are automatically converted to `latin1` before the assignment. Automatic conversion is not fully implemented yet, but should work correctly in a later version.

Although automatic conversion is not in the SQL standard, the SQL standard document does say that every character set is (in terms of supported characters) a "subset" of Unicode. Since it is a well-known principle that "what applies to a superset can apply to a subset," we believe that a collation for Unicode can apply for comparisons with non-Unicode strings.

VERSION 4.1.1 NOTE: The '`errmsg.txt`' files will all be in UTF8 after this point. Conversion to the client character set will be automatic, as for metadata. Also: We may change the default behaviour for passing back result set metadata in the near future.

9.7 Compatibility with Other DBMSs

For SAP DB compatibility these two statements are the same:

```
CREATE TABLE t1 (f1 CHAR(n) UNICODE);
CREATE TABLE t1 (f1 CHAR(n) CHARACTER SET ucs2);
```

9.8 New Character Set Configuration File format

In MySQL 4.1, character set configuration is stored in XML files, one file per character set. (In previous versions, this information was stored in '`.conf`' files.)

9.9 National Character Set

In MySQL-4.x and earlier, `NCHAR` and `CHAR` were synonymous. ANSI defines `NCHAR` or `NATIONAL CHAR` as a way to define that a `CHAR` column should use some predefined character set. MySQL uses `utf8` as that predefined character set. For example, these column type declarations are equivalent:

```
CHAR(10) CHARACTER SET utf8
NATIONAL CHARACTER(10)
NCHAR(10)
```

As are these:

```
VARCHAR(10) CHARACTER SET utf8
NATIONAL VARCHAR(10)
NCHAR VARCHAR(10)
NATIONAL CHARACTER VARYING(10)
NATIONAL CHAR VARYING(10)
```

You can use `N'literal'` to create a string in national character set.

These two statements are equivalent:

```
SELECT N'some text';
SELECT _utf8'some text';
```

9.10 Upgrading from MySQL 4.0

Now, what about upgrading from older versions of MySQL? MySQL 4.1 is almost upward compatible with MySQL 4.0 and earlier for the simple reason that almost all of the features are new, so there's nothing in earlier versions to conflict with. However, there are some differences and a few things to be aware of.

Most important: The "MySQL 4.0 character set" has the properties of both "MySQL 4.1 character sets" and "MySQL 4.1 collations." You will have to unlearn this. Henceforth we will not bundle character set / collation properties in the same conglomerate object.

There is a special treatment of national character sets in MySQL 4.1. `NCHAR` is not the same as `CHAR`, and `N'...'` literals are not the same as `'...'` literals.

Finally, there is a different file format for storing information about character sets and collations. Make sure you have reinstalled the '`/share/mysql/charsets/`' directory containing the new configuration files.

If you want to start `mysqld` from a 4.1.x distribution with data created by MySQL 4.0, you should start the server with the same character set and collation. In this case you won't need to reindex your data.

There are two ways to do so:

```
shell> ./configure --with-character-set=... --with-collation=...
shell> ./mysqld --default-character-set=... --default-collation=...
```

If you used `mysql` with, for example, the MySQL 4.0 `danish` character set, you should now use the `latin1` character set and the `latin1_danish_ci` collation:

```
shell> ./configure --with-character-set=latin1
           --with-collation=latin1_danish_ci
shell> ./mysqld --default-character-set=latin1
           --default-collation=latin1_danish_ci
```

Use the table shown in the next section to find old 4.0 character set names and their 4.1 character set/collation pair equivalents.

9.10.1 4.0 Character Sets and Corresponding 4.1 Character Set/Collation Pairs

ID	4.0 Character Set	4.1 Character Set	4.1 Collation
1	big5	big5	big5_chinese_ci
2	czech	latin2	latin2_czech_ci
3	dec8	dec8	dec8_swedish_ci
4	dos	cp850	cp850_general_ci
5	german1	latin1	latin1_german1_ci
6	hp8	hp8	hp8_english_ci
7	koi8_ru	koi8r	koi8r_general_ci
8	latin1	latin1	latin1_swedish_ci
9	latin2	latin2	latin2_general_ci
10	swe7	swe7	swe7_swedish_ci
11	usa7	ascii	ascii_general_ci
12	ujis	ujis	ujis_japanese_ci
13	sjis	sjis	sjis_japanese_ci
14	cp1251	cp1251	cp1251_bulgarian_ci
15	danish	latin1	latin1_danish_ci
16	hebrew	hebrew	hebrew_general_ci
17	win1251	(removed)	(removed)
18	tis620	tis620	tis620_thai_ci
19	euc_kr	euckr	euckr_korean_ci
20	estonia	latin7	latin7_estonian_ci
21	hungarian	latin2	latin2_hungarian_ci
22	koi8_ukr	koi8u	koi8u_ukrainian_ci
23	win1251ukr	cp1251	cp1251_ukrainian_ci

```
24        gb2312            gb2312            gb2312_chinese_ci
25        greek             greek             greek_general_ci
26        win1250           cp1250            cp1250_general_ci
27        croat             latin2            latin2_croatian_ci
28        gbk               gbk               gbk_chinese_ci
29        cp1257            cp1257            cp1257_lithuanian_ci
30        latin5            latin5            latin5_turkish_ci
31        latin1_de         latin1            latin1_german2_ci
```

9.11 The Character Sets and Collations that MySQL Supports

Here is an annotated list of character sets and collations that MySQL supports. Because options and installation settings differ, some sites will not have all items in the list, and some sites will have items that are not on the list because defining new character sets or collations is straightforward.

MySQL supports 70+ collations for 30+ character sets.

```
mysql> SHOW CHARACTER SET;
+----------+-----------------------------+---------------------+--------+
| Charset  | Description                 | Default collation   | Maxlen |
+----------+-----------------------------+---------------------+--------+
| big5     | Big5 Traditional Chinese    | big5_chinese_ci     |      2 |
| dec8     | DEC West European           | dec8_swedish_ci     |      1 |
| cp850    | DOS West European           | cp850_general_ci    |      1 |
| hp8      | HP West European            | hp8_english_ci      |      1 |
| koi8r    | KOI8-R Relcom Russian       | koi8r_general_ci    |      1 |
| latin1   | ISO 8859-1 West European    | latin1_swedish_ci   |      1 |
| latin2   | ISO 8859-2 Central European | latin2_general_ci   |      1 |
| swe7     | 7bit Swedish                | swe7_swedish_ci     |      1 |
| ascii    | US ASCII                    | ascii_general_ci    |      1 |
| ujis     | EUC-JP Japanese             | ujis_japanese_ci    |      3 |
| sjis     | Shift-JIS Japanese          | sjis_japanese_ci    |      2 |
| cp1251   | Windows Cyrillic            | cp1251_bulgarian_ci |      1 |
| hebrew   | ISO 8859-8 Hebrew           | hebrew_general_ci   |      1 |
| tis620   | TIS620 Thai                 | tis620_thai_ci      |      1 |
| euckr    | EUC-KR Korean               | euckr_korean_ci     |      2 |
| koi8u    | KOI8-U Ukrainian            | koi8u_general_ci    |      1 |
| gb2312   | GB2312 Simplified Chinese   | gb2312_chinese_ci   |      2 |
| greek    | ISO 8859-7 Greek            | greek_general_ci    |      1 |
| cp1250   | Windows Central European    | cp1250_general_ci   |      1 |
| gbk      | GBK Simplified Chinese      | gbk_chinese_ci      |      2 |
| latin5   | ISO 8859-9 Turkish          | latin5_turkish_ci   |      1 |
| armscii8 | ARMSCII-8 Armenian          | armscii8_general_ci |      1 |
| utf8     | UTF-8 Unicode               | utf8_general_ci     |      3 |
| ucs2     | UCS-2 Unicode               | ucs2_general_ci     |      2 |
| cp866    | DOS Russian                 | cp866_general_ci    |      1 |
```

```
| keybcs2  | DOS Kamenicky Czech-Slovak  | keybcs2_general_ci  |      1 |
| macce    | Mac Central European        | macce_general_ci    |      1 |
| macroman | Mac West European           | macroman_general_ci |      1 |
| cp852    | DOS Central European        | cp852_general_ci    |      1 |
| latin7   | ISO 8859-13 Baltic          | latin7_general_ci   |      1 |
| cp1256   | Windows Arabic              | cp1256_general_ci   |      1 |
| cp1257   | Windows Baltic              | cp1257_general_ci   |      1 |
| binary   | Binary pseudo charset       | binary              |      1 |
+----------+-----------------------------+---------------------+--------+
33 rows in set (0.01 sec)
```

NB: ALL CHARACTER SETS HAVE A BINARY COLLATION. WE HAVE NOT INCLUDED THE BINARY COLLATION IN ALL THE DESCRIPTIONS THAT FOLLOW.

9.11.1 The Unicode Character Sets

Of course there are our two Unicode character sets. You can store texts in about 650 languages using these character sets. We have not added a large number of collations for these two new sets yet, but that will be happening soon. Now they have default case-insensitive accent-insensitive collations, plus the binary collation.

```
+---------+----------------+-------------------+--------+
| Charset | Description    | Default collation | Maxlen |
+---------+----------------+-------------------+--------+
| utf8    | UTF-8 Unicode  | utf8_general_ci   |      3 |
| ucs2    | UCS-2 Unicode  | ucs2_general_ci   |      2 |
+---------+----------------+-------------------+--------+
```

9.11.2 Platform Specific Character Sets

```
+----------+-----------------------------+---------------------+--------+
| Charset  | Description                 | Default collation   | Maxlen |
+----------+-----------------------------+---------------------+--------+
| dec8     | DEC West European           | dec8_swedish_ci     |      1 |
| hp8      | HP West European            | hp8_english_ci      |      1 |
+----------+-----------------------------+---------------------+--------+
```

9.11.3 Character Sets for South Europe and Middle East

```
+----------+-----------------------------+---------------------+--------+
| Charset  | Description                 | Default collation   | Maxlen |
+----------+-----------------------------+---------------------+--------+
| armscii8 | ARMSCII-8 Armenian          | armscii8_general_ci |      1 |
| cp1256   | Windows Arabic              | cp1256_general_ci   |      1 |
| hebrew   | ISO 8859-8 Hebrew           | hebrew_general_ci   |      1 |
| greek    | ISO 8859-7 Greek            | greek_general_ci    |      1 |
| latin5   | ISO 8859-9 Turkish          | latin5_turkish_ci   |      1 |
| geostd8  | Georgian                    | geostd8_general_ci  |      1 |
+----------+-----------------------------+---------------------+--------+
```

9.11.4 The Asian Character Sets

The Asian character sets that we support include Chinese, Japanese, Korean, and Thai. These can be complicated. For example, the Chinese sets have to allow for thousands of different characters.

Charset	Description	Default collation	Maxlen
big5	Big5 Traditional Chinese	big5_chinese_ci	2
gb2312	GB2312 Simplified Chinese	gb2312_chinese_ci	2
gbk	GBK Simplified Chinese	gbk_chinese_ci	2
euckr	EUC-KR Korean	euckr_korean_ci	2
ujis	EUC-JP Japanese	ujis_japanese_ci	3
sjis	Shift-JIS Japanese	sjis_japanese_ci	2
tis620	TIS620 Thai	tis620_thai_ci	1

9.11.5 The Baltic Character Sets

The Baltic character sets cover Estonian, Latvian, and Lithuanian languages. There are two Baltic character sets currently supported:

- `latin7` (ISO 8859-13 Baltic):

Collation	Charset	Id	Default	Compiled	Sortlen
latin7_estonian_cs	latin7	20			0
latin7_general_ci	latin7	41	Yes		0
latin7_general_cs	latin7	42			0
latin7_bin	latin7	79			0

- `cp1257` (Windows Baltic):

Collation	Charset	Id	Default	Compiled	Sortlen
cp1257_lithuanian_ci	cp1257	29			0
cp1257_bin	cp1257	58			0
cp1257_general_ci	cp1257	59	Yes		0

9.11.6 The Cyrillic Character Sets

Here are the Cyrillic character sets and collations for use with Belarusian, Bulgarian, Russian, Ukrainian languages.

- `cp1251` (Windows Cyrillic):

```
+----------------------+----------+----+---------+----------+---------+
| Collation            | Charset  | Id | Default | Compiled | Sortlen |
+----------------------+----------+----+---------+----------+---------+
| cp1251_bulgarian_ci  | cp1251   | 14 |         |          |       0 |
| cp1251_ukrainian_ci  | cp1251   | 23 |         |          |       0 |
| cp1251_bin           | cp1251   | 50 |         |          |       0 |
| cp1251_general_ci    | cp1251   | 51 | Yes     |          |       0 |
| cp1251_general_cs    | cp1251   | 52 |         |          |       0 |
+----------------------+----------+----+---------+----------+---------+
```

- `cp866` (DOS Russian):

```
+----------------------+----------+----+---------+----------+---------+
| Collation            | Charset  | Id | Default | Compiled | Sortlen |
+----------------------+----------+----+---------+----------+---------+
| cp866_general_ci     | cp866    | 36 | Yes     |          |       0 |
| cp866_bin            | cp866    | 68 |         |          |       0 |
+----------------------+----------+----+---------+----------+---------+
```

- `koi8r` (KOI8-R Relcom Russian, primarily used in Russia on Unix):

```
+----------------------+----------+----+---------+----------+---------+
| Collation            | Charset  | Id | Default | Compiled | Sortlen |
+----------------------+----------+----+---------+----------+---------+
| koi8r_general_ci     | koi8r    |  7 | Yes     |          |       0 |
| koi8r_bin            | koi8r    | 74 |         |          |       0 |
+----------------------+----------+----+---------+----------+---------+
```

- `koi8u` (KOI8-U Ukrainian, primarily used in Ukraine on Unix):

```
+----------------------+----------+----+---------+----------+---------+
| Collation            | Charset  | Id | Default | Compiled | Sortlen |
+----------------------+----------+----+---------+----------+---------+
| koi8u_general_ci     | koi8u    | 22 | Yes     |          |       0 |
| koi8u_bin            | koi8u    | 75 |         |          |       0 |
+----------------------+----------+----+---------+----------+---------+
```

9.11.7 The Central European Character Sets

We have some support for character sets used in The Czech Republic, Slovakia, Hungary, Romania, Slovenia, Croatia, and Poland.

- `cp1250` (Windows Central European):

```
+----------------------+----------+----+---------+----------+---------+
| Collation            | Charset  | Id | Default | Compiled | Sortlen |
+----------------------+----------+----+---------+----------+---------+
| cp1250_general_ci    | cp1250   | 26 | Yes     |          |       0 |
| cp1250_czech_ci      | cp1250   | 34 |         | Yes      |       2 |
| cp1250_bin           | cp1250   | 66 |         |          |       0 |
+----------------------+----------+----+---------+----------+---------+
```

- `cp852` (DOS Central European):

```
+----------------------+----------+----+---------+----------+---------+
| Collation            | Charset  | Id | Default | Compiled | Sortlen |
+----------------------+----------+----+---------+----------+---------+
| cp852_general_ci     | cp852    | 40 | Yes     |          |       0 |
| cp852_bin            | cp852    | 81 |         |          |       0 |
+----------------------+----------+----+---------+----------+---------+
```

- `macce` (Mac Central European):

```
+----------------------+----------+----+---------+----------+---------+
| Collation            | Charset  | Id | Default | Compiled | Sortlen |
+----------------------+----------+----+---------+----------+---------+
| macce_general_ci     | macce    | 38 | Yes     |          |       0 |
| macce_bin            | macce    | 43 |         |          |       0 |
+----------------------+----------+----+---------+----------+---------+
```

- `latin2` (ISO 8859-2 Central European):

```
+----------------------+----------+----+---------+----------+---------+
| Collation            | Charset  | Id | Default | Compiled | Sortlen |
+----------------------+----------+----+---------+----------+---------+
| latin2_czech_ci      | latin2   |  2 |         | Yes      |       4 |
| latin2_general_ci    | latin2   |  9 | Yes     |          |       0 |
| latin2_hungarian_ci  | latin2   | 21 |         |          |       0 |
| latin2_croatian_ci   | latin2   | 27 |         |          |       0 |
| latin2_bin           | latin2   | 77 |         |          |       0 |
+----------------------+----------+----+---------+----------+---------+
```

- `keybcs2` (DOS Kamenicky Czech-Slovak):

```
+----------------------+----------+----+---------+----------+---------+
| Collation            | Charset  | Id | Default | Compiled | Sortlen |
+----------------------+----------+----+---------+----------+---------+
| keybcs2_general_ci   | keybcs2  | 37 | Yes     |          |       0 |
| keybcs2_bin          | keybcs2  | 73 |         |          |       0 |
+----------------------+----------+----+---------+----------+---------+
```

9.11.8 The West European Character Sets

West European Character Sets cover most West European languages, such as French, Spanish, Catalan, Basque, Portuguese, Italian, Albanian, Dutch, German, Danish, Swedish, Norwegian, Finnish, Faroese, Icelandic, Irish, Scottish, and English.

- `latin1` (ISO 8859-1 West European):

```
+----------------------+----------+----+---------+----------+---------+
| Collation            | Charset  | Id | Default | Compiled | Sortlen |
+----------------------+----------+----+---------+----------+---------+
| latin1_german1_ci    | latin1   |  5 |         |          |       0 |
| latin1_swedish_ci    | latin1   |  8 | Yes     | Yes      |       0 |
| latin1_danish_ci     | latin1   | 15 |         |          |       0 |
| latin1_german2_ci    | latin1   | 31 |         | Yes      |       2 |
| latin1_bin           | latin1   | 47 |         | Yes      |       0 |
```

```
| latin1_general_ci    | latin1   | 48 |         |          |       0 |
| latin1_general_cs    | latin1   | 49 |         |          |       0 |
+----------------------+----------+----+---------+----------+---------+
```

The `latin1_swedish_ci` collation is the default that probably is used by the majority of MySQL customers. It is constantly stated that this is based on the Swedish/Finnish collation rules, but you will find Swedes and Finns who disagree with that statement.

The `latin1_german1_ci` and `latin1_german2_ci` collations are based on the DIN-1 and DIN-2 standards, where DIN stands for Deutsches Institut für Normung (that is, the German answer to ANSI). DIN-1 is called the dictionary collation and DIN-2 is called the phone-book collation.

- `latin1_german1_ci` (dictionary) rules:

  'Ä' = 'A', 'Ö' = 'O', 'Ü' = 'U', 'ß' = 's'

- `latin1_german2_ci` (phone-book) rules:

  'Ä' = 'AE', 'Ö' = 'OE', 'Ü' = 'UE', 'ß' = 'ss'

- `macroman` (Mac West European):

```
+----------------------+----------+----+---------+----------+---------+
| Collation            | Charset  | Id | Default | Compiled | Sortlen |
+----------------------+----------+----+---------+----------+---------+
| macroman_general_ci  | macroman | 39 | Yes     |          |       0 |
| macroman_bin         | macroman | 53 |         |          |       0 |
+----------------------+----------+----+---------+----------+---------+
```

- `cp850` (DOS West European):

```
+----------------------+----------+----+---------+----------+---------+
| Collation            | Charset  | Id | Default | Compiled | Sortlen |
+----------------------+----------+----+---------+----------+---------+
| cp850_general_ci     | cp850    |  4 | Yes     |          |       0 |
| cp850_bin            | cp850    | 80 |         |          |       0 |
+----------------------+----------+----+---------+----------+---------+
```

10 Spatial Extensions in MySQL

MySQL 4.1 introduces spatial extensions to allow the generation, storage, and analysis of geographic features. Currently, these features are available for MyISAM tables only.

This chapter covers the following topics:

- The basis of these spatial extensions in the OpenGIS geometry model
- Data formats for representing spatial data
- How to use spatial data in MySQL
- Use of indexing for spatial data
- MySQL differences from the OpenGIS specification

10.1 Introduction

MySQL implements spatial extensions following the specification of the `Open GIS Consortium` (OGC). This is an international consortium of more than 250 companies, agencies, and universities participating in the development of publicly available conceptual solutions that can be useful with all kinds of applications that manage spatial data. The OGC maintains a web site at `http://www.opengis.org/`.

In 1997, the Open GIS Consortium published the *OpenGIS ® Simple Features Specifications For SQL*, a document that proposes several conceptual ways for extending an SQL RDBMS to support spatial data. This specification is available from the Open GIS web site at `http://www.opengis.org/techno/implementation.htm`. It contains additional information relevant to this chapter.

MySQL implements a subset of the **SQL with Geometry Types** environment proposed by OGC. This term refers to an SQL environment that has been extended with a set of geometry types. A geometry-valued SQL column is implemented as a column that has a geometry type. The specifications describe a set of SQL geometry types, as well as functions on those types to create and analyse geometry values.

A **geographic feature** is anything in the world that has a location. A feature can be:

- An entity. For example, a mountain, a pond, a city.
- A space. For example, a postcode area, the tropics.
- A definable location. For example, a crossroad, as a particular place where two streets intersect.

You can also find documents that use term **geospatial feature** to refer to geographic features.

Geometry is another word that denotes a geographic feature. The original meaning of the word **geometry** denotes a branch of mathematics. Another meaning comes from cartography, referring to the geometric features that cartographers use to map the world.

This chapter uses all of these terms synonymously: **geographic feature**, **geospatial feature**, **feature**, or **geometry**. The term most commonly used here is **geometry**.

Let's define a **geometry** as *a point or an aggregate of points representing anything in the world that has a location.*

10.2 The OpenGIS Geometry Model

The set of geometry types proposed by OGC's **SQL with Geometry Types** environment is based on the **OpenGIS Geometry Model**. In this model, each geometric object has the following general properties:

- It is associated with a Spatial Reference System, which describes the coordinate space in which the object is defined.
- It belongs to some geometry class.

10.2.1 The Geometry Class Hierarchy

The geometry classes define a hierarchy as follows:

- `Geometry` (non-instantiable)
  - `Point` (instantiable)
  - `Curve` (non-instantiable)
    - `LineString` (instantiable)
      - `Line`
      - `LinearRing`
  - `Surface` (non-instantiable)
    - `Polygon` (instantiable)
  - `GeometryCollection` (instantiable)
    - `MultiPoint` (instantiable)
    - `MultiCurve` (non-instantiable)
      - `MultiLineString` (instantiable)
    - `MultiSurface` (non-instantiable)
      - `MultiPolygon` (instantiable)

Some of these classes are abstract (non-instantiable). That is, it is not possible to create an object of these classes. Other classes are instantiable and objects may be created of them. Each class has properties and instantiable classes may have assertions (rules that define valid class instances).

`Geometry` is the base class. It's an abstract class. The instantiable subclasses of `Geometry` are restricted to zero-, one-, and two-dimensional geometric objects that exist in two-dimensional coordinate space. All instantiable geometry classes are defined so that valid instances of a geometry class are topologically closed (that is, all defined geometries include their boundary).

The base `Geometry` class has subclasses for `Point`, `Curve`, `Surface` and `GeometryCollection`:

- `Point` represents zero-dimensional objects.
- `Curve` represents one-dimensional objects, and has subclass `LineString`, with sub-subclasses `Line` and `LinearRing`.
- `Surface` is designed for two-dimensional objects and has subclass `Polygon`.

- `GeometryCollection` has specialised zero-, one-, and two-dimensional collection classes named `MultiPoint`, `MultiLineString`, and `MultiPolygon` for modelling geometries corresponding to collections of `Points`, `LineStrings`, and `Polygons`, respectively. `MultiCurve` and `MultiSurface` are introduced as abstract superclasses that generalise the collection interfaces to handle `Curves` and `Surfaces`.

`Geometry`, `Curve`, `Surface`, `MultiCurve`, and `MultiSurface` are defined as non-instantiable classes. They define a common set of methods for their subclasses and are included for the reason of extensibility.

`Point`, `LineString`, `Polygon`, `GeometryCollection`, `MultiPoint`, `MultiLineString`, and `MultiPolygon` are instantiable classes.

10.2.2 Class `Geometry`

`Geometry` is the root class of the hierarchy. It is a non-instantiable class but has a number of properties that are common to all geometry values created from any of the `Geometry` subclasses. These properties are described in the following list. (Particular subclasses have their own specific properties, described later.)

Geometry properties

A geometry value has the following properties:

- Its **type**. Each geometry belongs to one of the instantiable classes in the hierarchy.
- Its **SRID**, or Spatial Reference Identifier. This value identifies the geometry's associated Spatial Reference System that describes the coordinate space in which the geometry object is defined.
- Its **coordinates** in its Spatial Reference System, represented as double-precision (8-byte) numbers. All non-empty geometries include at least one pair of (X,Y) coordinates. Empty geometries contain no coordinates.

  Coordinates are related to the SRID. For example, in different coordinate systems, the distance between two objects may differ even when objects have the same coordinates, because the distance on the **planar** coordinate system and the distance on the **geocentric** system (coordinates on the Earth's surface) are different things.
- Its **interior**, **boundary**, and **exterior**. All geometries occupy some position in space. The exterior of a geometry is all space not occupied by the geometry. The interior is the space occupied by the geometry. The boundary is the interface between geometry's interior and exterior.
- Its **MBR** (Minimum Bounding Rectangle), or Envelope. This is the bounding geometry, formed by the minimum and maximum (X,Y) coordinates:

  ```
  ((MINX MINY, MAXX MINY, MAXX MAXY, MINX MAXY, MINX MINY))
  ```
- The quality of being **simple** or **non-simple**. Geometry values of some types (`LineString`, `MultiPoint`, `MultiLineString`) are either simple or non-simple. Each type determines its own assertions for being simple or non-simple.
- The quality of being **closed** or **not closed**. Geometry values of some types (`LineString`, `MultiString`) are either closed or not closed. Each type determines its own assertions for being closed or not closed.

- The quality of being **empty** or **not empty** A geometry is empty if it does not have any points. Exterior, interior and boundary of an empty geometry are not defined (that is, they are represented by a `NULL` value). An empty geometry is defined to be always simple and has an area of 0.
- Its **dimension**. A geometry can have a dimension of −1, 0, 1, or 2:
  - −1 stands for empty geometries.
  - 0 stands for geometries with no length and no area.
  - 1 stands for geometries with non-zero length and zero area.
  - 2 stands for geometries with non-zero area.

  `Point` objects have a dimension of zero. `LineString` objects have a dimension of 1. `Polygon` objects have a dimension of 2. The dimensions of `MultiPoint`, `MultiLineString`, and `MultiPolygon` objects are the same as the dimensions of the elements they consist of.

10.2.3 Class `Point`

A `Point` is a geometry that represents a single location in coordinate space.

`Point` Examples

- Imagine a large-scale map of the world with many cities. A point could represent each city.
- On a city map, a Point could represent a bus stop.

`Point` Properties

- X-coordinate value.
- Y-coordinate value.
- `Point` is defined as a zero-dimensional geometry.
- The boundary of a `Point` is the empty set.

10.2.4 Class `Curve`

A `Curve` is a one-dimensional geometry, usually represented by a sequence of points. Particular subclasses of `Curve` define the type of interpolation between points. `Curve` is a non-instantiable class.

`Curve` Properties

- The coordinates of its points.
- `Curve` is defined as one-dimensional geometry.
- A `Curve` is simple if it does not pass through the same point twice.
- A `Curve` is closed if its start point is equal to its end point.

- The boundary of a closed `Curve` is empty.
- The boundary of a non-closed `Curve` consists of its two end points.
- A `Curve` that is simple and closed is a `LinearRing`.

10.2.5 Class `LineString`

A `LineString` is a `Curve` with linear interpolation between points.

`LineString` Examples

- On a world map, `LineString` objects could represent rivers.
- In a city map, `LineString` objects could represent streets.

`LineString` Properties

- Coordinates of `LineString` segments, defined by each consecutive pair of points.
- A `LineString` is a `Line` if it consists of exactly two points.
- A `LineString` is a `LinearRing` if it's both closed and simple.

10.2.6 Class `Surface`

A `Surface` is a two-dimensional geometry. It is a non-instantiable class. Its only instantiable subclass is `Polygon`.

`Surface` Properties

- A `Surface` is defined as a two-dimensional geometry.
- The OpenGIS specification defines a simple `Surface` as a geometry that consists of a single "patch" that is associated with a single exterior boundary and zero or more interior boundaries.
- The boundary of a simple `Surface` is the set of closed curves corresponding to its exterior and interior boundaries.

10.2.7 Class `Polygon`

A `Polygon` is a planar `Surface` representing a multisided geometry. It is defined by a single exterior boundary and zero or more interior boundaries, where each interior boundary defines a hole in the `Polygon`.

`Polygon` Examples

- On a region map, `Polygon` objects could represent forests, districts, etc.

`Polygon` Assertions

- The boundary of a `Polygon` consists of a set of `LinearRing`s (that is, `LineString`s that are both simple and closed) that make up its exterior and interior boundaries.
- No two rings in the boundary cross. The rings in the boundary of a `Polygon` may intersect at a `Point`, but only as a tangent.
- A `Polygon` may not have cut lines, spikes, or punctures.
- The interior of every `Polygon` is a connected point set.
- The exterior of a `Polygon` with one or more holes is not connected. Each hole defines a connected component of the exterior.

In the above assertions, polygons are simple geometries. These assertions make a `Polygon` a simple geometry.

10.2.8 Class `GeometryCollection`

A `GeometryCollection` is a geometry that is a collection of one or more geometries of any class.

All the elements in a `GeometryCollection` must be in the same Spatial Reference System (that is, in the same coordinate system). `GeometryCollection` places no other constraints on its elements, although the subclasses of `GeometryCollection` described in the following sections may restrict membership. Retrictions may be based on:

- Element type (for example, a `MultiPoint` may contain only `Point` elements)
- Dimension
- Constraints on the degree of spatial overlap between elements

10.2.9 Class `MultiPoint`

A `MultiPoint` is a geometry collection composed of `Point` elements. The points are not connected or ordered in any way.

`MultiPoint` Examples

- On a world map, a `Multipoint` could represent a chain of small islands.
- On a city map, a `Multipoint` could represent the outlets for a ticket office.

`MultiPoint` Properties

- `MultiPoint` is defined as a zero-dimensional geometry.
- A `MultiPoint` is simple if no two of its `Point` values are equal (have identical coordinate values).
- The boundary of a `MultiPoint` is the empty set.

10.2.10 Class `MultiCurve`

A `MultiCurve` is a geometry collection composed of `Curve` elements. `MultiCurve` is a non-instantiable class.

`MultiCurve` Properties

- `MultiCurve` is defined as a one-dimensional geometry.
- A `MultiCurve` is simple if and only if all of its elements are simple, the only intersections between any two elements occur at points that are on the boundaries of both elements.
- The boundary of a `MultiCurve` is obtained by applying the "mod 2 union rule" (also known as the odd-even rule): A point is in the boundary of a `MultiCurve` if it is in the boundaries of an odd number of `MultiCurve` elements.
- A `MultiCurve` is closed if all of its elements are closed.
- The boundary of a closed `MultiCurve` is always empty.

10.2.11 Class `MultiLineString`

A `MultiLineString` is a `MultiCurve` geometry collection composed of `LineString` elements.

`MultiLineString` Examples

- On a region map, a `MultiLineString` could represent a river system or a highway system.

10.2.12 Class `MultiSurface`

A `MultiSurface` is a geometry collection composed of surface elements. `MultiSurface` is a non-instantiable class. Its only instantiable subclass is `MultiPolygon`.

`MultiSurface` Assertions

- The interiors of any two surfaces in a `MultiSurface` may not intersect.
- The boundaries of any two elements in a `MultiSurface` may intersect at most at a finite number of points.

10.2.13 Class `MultiPolygon`

A `MultiPolygon` is a `MultiSurface` object composed of `Polygon` elements.

`MultiPolygon` Examples

- On a region map, a `MultiPolygon` could represent a system of lakes.

`MultiPolygon` Assertions

- The interiors of two `Polygon` values that are elements of a `MultiPolygon` may not intersect.
- The boundaries of any two `Polygon` values that are elements of a `MultiPolygon` may not cross and may touch at only a finite number of points. (Crossing is also forbidden by the preceding assertion.)
- A `MultiPolygon` may not have cut lines, spikes or punctures. A `MultiPolygon` is a regular, closed point set.
- The interior of a `MultiPolygon` composed of more than one `Polygon` is not connected. The number of connected components of the interior of a `MultiPolygon` is equal to the number of `Polygon` values in the `MultiPolygon`.

`MultiPolygon` Properties

- A `MultiPolygon` is defined as a two-dimensional geometry.
- The boundary of a `MultiPolygon` is a set of closed curves (`LineString` values) corresponding to the boundaries of its `Polygon` elements.
- Each `Curve` in the boundary of the `MultiPolygon` is in the boundary of exactly one element `Polygon`.
- Every `Curve` in the boundary of an element `Polygon` is in the boundary of the `MultiPolygon`.

10.3 Supported Spatial Data Formats

This section describes the standard spatial data formats that are used to represent geometry objects in queries. They are:

- Well-Known Text (WKT) format
- Well-Known Binary (WKB) format

Internally, MySQL stores geometry values in a format that is not identical to either WKT or WKB format.

10.3.1 Well-Known Text (WKT) Format

The Well-Known Text (WKT) representation of Geometry is designed to exchange geometry data in ASCII form.

Examples of WKT representations of geometry objects are:

- A `Point`:

  ```
  POINT(15 20)
  ```

  Note that point coordinates are specified with no separating comma.
- A `LineString` with four points:

  ```
  LINESTRING(0 0, 10 10, 20 25, 50 60)
  ```

- A `Polygon` with one exterior ring and one interior ring:

  ```
  POLYGON((0 0,10 0,10 10,0 10,0 0),(5 5,7 5,7 7,5 7, 5 5))
  ```

- A `MultiPoint` with three `Point` values:

  ```
  MULTIPOINT(0 0, 20 20, 60 60)
  ```

- A `MultiLineString` with two `LineString` values:

  ```
  MULTILINESTRING((10 10, 20 20), (15 15, 30 15))
  ```

- A `MultiPolygon` with two `Polygon` values:

  ```
  MULTIPOLYGON(((0 0,10 0,10 10,0 10,0 0)),((5 5,7 5,7 7,5 7, 5 5)))
  ```

- A `GeometryCollection` consisting of two `Point` values and one `LineString`:

  ```
  GEOMETRYCOLLECTION(POINT(10 10), POINT(30 30), LINESTRING(15 15, 20 20))
  ```

A Backus-Naur grammar that specifies the formal production rules for writing WKT values may be found in the OGC specification document referenced near the beginning of this chapter.

10.3.2 Well-Known Binary (WKB) Format

The Well-Known Binary (WKB) representation for geometric values is defined by the OpenGIS specifications. It is also defined in the ISO "SQL/MM Part 3: Spatial" standard.

WKB is used to exchange geometry data as binary streams represented by `BLOB` values containing geometric WKB information.

WKB uses 1-byte unsigned integers, 4-byte unsigned integers, and 8-byte double-precision numbers (IEEE 754 format). A byte is 8 bits.

For example, a WKB value that corresponds to `POINT(1 1)` consists of this sequence of 21 bytes (each represented here by two hex digits):

```
0101000000000000000000F03F000000000000F03F
```

The sequence may be broken down into these components:

```
Byte order : 01
WKB type   : 01000000
X          : 000000000000F03F
Y          : 000000000000F03F
```

Component representation is as follows:

- The byte order may be either 0 or 1 to indicate little-endian or big-endian storage. The little-endian and big-endian byte orders are also known as Network Data Representation (NDR) and External Data Representation (XDR), respectively.
- The WKB type is a code that indicates the geometry type. Values from 1 through 7 indicate `Point`, `LineString`, `Polygon`, `MultiPoint`, `MultiLineString`, `MultiPolygon`, and `GeometryCollection`.
- A `Point` value has X and Y coordinates, each represented as a double-precision value.

WKB values for more complex geometry values are represented by more complex data structures, as detailed in the OpenGIS specification.

10.4 Creating a Spatially Enabled MySQL Database

This section describes the datatypes you can use for representing spatial data in MySQL, and the functions available for creating and retrieving spatial values.

10.4.1 MySQL Spatial Datatypes

MySQL provides a set of datatypes that correspond to classes in the class hierarchy of the OpenGIS Geometry Model. Some of these types hold single geometry values:

- `GEOMETRY`
- `POINT`
- `LINESTRING`
- `POLYGON`

`GEOMETRY` is the most general of these single-value types; it can store geometry values of any type. The others restrict their values to a particular geometry type.

The other datatypes hold collections of values:

- `MULTIPOINT`
- `MULTILINESTRING`
- `MULTIPOLYGON`
- `GEOMETRYCOLLECTION`

`GEOMETRYCOLLECTION` can store a collection of objects of any type. The other collection types restrict collection members to those having a particular geometry type.

10.4.2 Creating Spatial Values

This section describes how to create spatial values using Well-Known Text and Well-Known Binary functions that are defined in the OpenGIS standard, and using MySQL-specific functions.

10.4.2.1 Creating Geometry Values Using WKT Functions

MySQL provides a number of functions that take as input parameters a Well-Known Text representation (and, optionally, a spatial reference system identifier (SRID)), and return the corresponding geometry.

`GeomFromText()` accepts a WKT of any geometry type as its first argument. An implementation also provides type-specific construction functions for construction of geometry values of each geometry type.

`GeomFromText(wkt[,srid])`
`GeometryFromText(wkt[,srid])`

Constructs a geometry value of any type using its WKT representation and SRID.

`PointFromText(wkt[,srid])`
: Constructs a `POINT` value using its WKT representation and SRID.

`LineFromText(wkt[,srid])`
`LineStringFromText(wkt[,srid])`
: Constructs a `LINESTRING` value using its WKT representation and SRID.

`PolyFromText(wkt[,srid])`
`PolygonFromText(wkt[,srid])`
: Constructs a `POLYGON` value using its WKT representation and SRID.

`MPointFromText(wkt[,srid])`
`MultiPointFromText(wkt[,srid])`
: Constructs a `MULTIPOINT` value using its WKT representation and SRID.

`MLineFromText(wkt[,srid])`
`MultiLineStringFromText(wkt[,srid])`
: Constructs a `MULTILINESTRING` value using its WKT representation and SRID.

`MPolyFromText(wkt[,srid])`
`MultiPolygonFromText(wkt[,srid])`
: Constructs a `MULTIPOLYGON` value using its WKT representation and SRID.

`GeomCollFromText(wkt[,srid])`
`GeometryCollectionFromText(wkt[,srid])`
: Constructs a `GEOMETRYCOLLECTION` value using its WKT representation and SRID.

The OpenGIS specification also describes optional functions for constructing `Polygon` or `MultiPolygon` values based on the WKT representation of a collection of rings or closed `LineString` values. These values may intersect. MySQL does not yet implement these functions:

`BdPolyFromText(wkt,srid)`
: Constructs a `Polygon` value from a `MultiLineString` value in WKT format containing an arbitrary collection of closed `LineString` values.

`BdMPolyFromText(wkt,srid)`
: Constructs a `MultiPolygon` value from a `MultiLineString` value in WKT format containing an arbitrary collection of closed `LineString` values.

10.4.2.2 Creating Geometry Values Using WKB Functions

MySQL provides a number of functions that take as input parameters a `BLOB` containing a Well-Known Binary representation (and, optionally, a spatial reference system identifier (SRID)), and return the corresponding geometry.

`GeomFromWKT()` accepts a WKB of any geometry type as its first argument. An implementation also provides type-specific construction functions for construction of geometry values of each geometry type.

`GeomFromWKB(wkb[,srid])`
`GeometryFromWKB(wkt[,srid])`
: Constructs a geometry value of any type using its WKB representation and SRID.

`PointFromWKB(wkb[,srid])`
: Constructs a `POINT` value using its WKB representation and SRID.

`LineFromWKB(wkb[,srid])`
`LineStringFromWKB(wkb[,srid])`
: Constructs a `LINESTRING` value using its WKB representation and SRID.

`PolyFromWKB(wkb[,srid])`
`PolygonFromWKB(wkb[,srid])`
: Constructs a `POLYGON` value using its WKB representation and SRID.

`MPointFromWKB(wkb[,srid])`
`MultiPointFromWKB(wkb[,srid])`
: Constructs a `MULTIPOINT` value using its WKB representation and SRID.

`MLineFromWKB(wkb[,srid])`
`MultiLineStringFromWKB(wkb[,srid])`
: Constructs a `MULTILINESTRING` value using its WKB representation and SRID.

`MPolyFromWKB(wkb[,srid])`
`MultiPolygonFromWKB(wkb[,srid])`
: Constructs a `MULTIPOLYGON` value using its WKB representation and SRID.

`GeomCollFromWKB(wkb[,srid])`
`GeometryCollectionFromWKB(wkt[,srid])`
: Constructs a `GEOMETRYCOLLECTION` value using its WKB representation and SRID.

The OpenGIS specification also describes optional functions for constructing `Polygon` or `MultiPolygon` values based on the WKB representation of a collection of rings or closed `LineString` values. These values may intersect. MySQL does not yet implement these functions:

`BdPolyFromWKB(wkb,srid)`
: Constructs a `Polygon` value from a `MultiLineString` value in WKB format containing an arbitrary collection of closed `LineString` values.

`BdMPolyFromWKB(wkb,srid)`
: Constructs a `MultiPolygon` value from a `MultiLineString` value in WKB format containing an arbitrary collection of closed `LineString` values.

10.4.2.3 Creating Geometry Values Using MySQL-Specific Functions

Note: MySQL does not yet implement the functions listed in this section.

MySQL provides a set of useful functions for creating geometry WKB representations. The functions described in this section are MySQL extensions to the OpenGIS specifications.

The results of these functions are `BLOB` values containing WKB representations of geometry values with no SRID. The results of these functions can be substituted as the first argument for any function in the `GeomFromWKB()` function family.

`Point(x,y)`
: Constructs a WKB `Point` using its coordinates.

`MultiPoint(pt1,pt2,...)`
: Constructs a WKB `MultiPoint` value using WKB `Point` arguments. If any argument is not a `WKBPoint`, the return value is `NULL`.

`LineString(pt1,pt2,...)`
: Constructs a WKB `LineString` value from a number of WKB `Point` arguments. If any argument is not a WKB `Point`, the return value is `NULL`. If the number of `Point` arguments is less than two, the return value is `NULL`.

`MultiLineString(ls1,ls2,...)`
: Constructs a WKB `MultiLineString` value using using WBK `LineString` arguments. If any argument is not a `LineString`, the return value is `NULL`.

`Polygon(ls1,ls2,...)`
: Constructs a WKB `Polygon` value from a number of WKB `LineString` arguments. If any argument does not represent the WKB of a `LinearRing` (that is, not a closed and simple `LineString`) the return value is `NULL`.

`MultiPolygon(poly1,poly2,...)`
: Constructs a WKB `MultiPolygon` value from a set of WKB `Polygon` arguments. If any argument is not a WKB `Polygon`, the rerurn value is `NULL`.

`GeometryCollection(g1,g2,...)`
: Constucts a WKB `GeometryCollection`. If any argument is not a well-formed WKB representation of a geometry, the return value is `NULL`.

10.4.3 Creating Spatial Columns

MySQL provides a standard way of creating spatial columns for geometry types, for example, with `CREATE TABLE` or `ALTER TABLE`. Currently, spatial columns are supported only for `MyISAM` tables.

- Use the `CREATE TABLE` statement to create a table with a spatial column:

```
mysql> CREATE TABLE geom (g GEOMETRY);
Query OK, 0 rows affected (0.02 sec)
```

- Use the `ALTER TABLE` statement to add or drop a spatial column to or from an existing table:

```
mysql> ALTER TABLE geom ADD pt POINT;
Query OK, 0 rows affected (0.00 sec)
Records: 0  Duplicates: 0  Warnings: 0
mysql> ALTER TABLE geom DROP pt;
Query OK, 0 rows affected (0.00 sec)
Records: 0  Duplicates: 0  Warnings: 0
```

10.4.4 Populating Spatial Columns

After you have created spatial columns, you can populate them with spatial data.

Values should be stored in internal geometry format, but you can convert them to that format from either Well-Known Text (WKT) or Well-Known Binary (WKB) format. The following examples demonstrate how to insert geometry values into a table by converting WKT values into internal geometry format.

You can perform the conversion directly in the `INSERT` statement:

```
INSERT INTO geom VALUES (GeomFromText('POINT(1 1)'));

SET @g = 'POINT(1 1)';
INSERT INTO geom VALUES (GeomFromText(@g));
```

Or conversion can take place prior to the `INSERT`:

```
SET @g = GeomFromText('POINT(1 1)');
INSERT INTO geom VALUES (@g);
```

The following examples insert more complex geometries into the table:

```
SET @g = 'LINESTRING(0 0,1 1,2 2)';
INSERT INTO geom VALUES (GeomFromText(@g));

SET @g = 'POLYGON((0 0,10 0,10 10,0 10,0 0),(5 5,7 5,7 7,5 7, 5 5))';
INSERT INTO geom VALUES (GeomFromText(@g));

SET @g = 'GEOMETRYCOLLECTION(POINT(1 1),LINESTRING(0 0,1 1,2 2,3 3,4 4))';
INSERT INTO geom VALUES (GeomFromText(@g));
```

The preceding examples all use `GeomFromText()` to create geometry values. You can also use type-specific functions:

```
SET @g = 'POINT(1 1)';
INSERT INTO geom VALUES (PointFromText(@g));

SET @g = 'LINESTRING(0 0,1 1,2 2)';
INSERT INTO geom VALUES (LineStringFromText(@g));

SET @g = 'POLYGON((0 0,10 0,10 10,0 10,0 0),(5 5,7 5,7 7,5 7, 5 5))';
INSERT INTO geom VALUES (PolygonFromText(@g));

SET @g = 'GEOMETRYCOLLECTION(POINT(1 1),LINESTRING(0 0,1 1,2 2,3 3,4 4))';
INSERT INTO geom VALUES (GeomCollFromText(@g));
```

Note that if a client application program wants to use WKB representations of geometry values, it is responsible for sending correctly formed WKB in queries to the server. However, there are several ways of satisfying this requirement. For example:

- Inserting a `POINT(1 1)` value with hex literal syntax:

```
mysql> INSERT INTO geom VALUES
    -> (GeomFromWKB(0x0101000000000000000000F03F000000000000F03F));
```

- An ODBC application can send a WKB representation, binding it to a placeholder using an argument of `BLOB` type:

  ```
  INSERT INTO geom VALUES (GeomFromWKB(?))
  ```

  Other programming interfaces may support a similar placeholder mechanism.
- In a C program, you can escape a binary value using `mysql_real_escape_string()` and include the result in a query string that is sent to the server. See Section 11.1.3.43 [`mysql_real_escape_string()`], page 754.

10.4.5 Fetching Spatial Data

Geometry values stored in a table can be fetched with conversion in internal format. You can also convert them into WKT or WKB format.

10.4.5.1 Fetching Spatial Data in Internal Format

Fetching geometry values using internal format can be useful in table-to-table transfers:

```
CREATE TABLE geom2 (g GEOMETRY) SELECT g FROM geom;
```

10.4.5.2 Fetching Spatial Data in WKT Format

The `AsText()` function provides textual access to geometry values. It converts a geometry from internal format into a WKT string.

```
mysql> SELECT AsText(g) FROM geom;
+-------------------------+
| AsText(p1)              |
+-------------------------+
| POINT(1 1)              |
| LINESTRING(0 0,1 1,2 2) |
+-------------------------+
```

10.4.5.3 Fetching Spatial Data in WKB Format

The `AsBinary()` function provides binary access to geometry values. It converts a geometry from internal format into a `BLOB` containing the WKB value.

```
SELECT AsBinary(g) FROM geom;
```

10.5 Analysing Spatial Information

After populating spatial columns with values, you are ready to query and analyse them. MySQL provides a set of functions to perform various operations on spatial data. These functions can be grouped into four major categories according to the type of operation they perform:

- Functions that convert geometries between various formats
- Functions that provide access to qualitative or quantitative properties of a geometry

- Functions that describe relations between two geometries
- Functions that create new geometries from existing ones

Spatial analysis functions can be used in many contexts, such as:

- Any interactive SQL program, like `mysql` or `MySQLCC`
- Application programs written in any language that supports a MySQL client API

10.5.1 Functions to Convert Geometries Between Formats

MySQL supports the following functions for converting geometry values between internal format and either WKT or WKB format:

`GeomFromText(wkt[,srid])`
: Converts a string value from its WKT representation into internal geometry format and returns the result. A number of type-specific functions are also supported, such as `PointFromText()` and `LineFromText()`; see Section 10.4.2.1 [GIS WKT Functions], page 696.

`GeomFromWKB(wkb[,srid])`
: Converts a binary value from its WKB representation into internal geometry format and returns the result. A number of type-specific functions are also supported, such as `PointFromWKB()` and `LineFromWKB()`; see Section 10.4.2.2 [GIS WKB Functions], page 697.

`AsText(g)`
: Converts a value in internal geometry format to its WKT representation and returns the resulting string.

```
mysql> SET @g = 'LineString(1 1,2 2,3 3)';
mysql> SELECT AsText(GeomFromText(@g));
+--------------------------+
| AsText(GeomFromText(@G)) |
+--------------------------+
| LINESTRING(1 1,2 2,3 3)  |
+--------------------------+
```

`AsBinary(g)`
: Converts a value in internal geometry format to its WKB representation and returns the resulting binary value.

10.5.2 `Geometry` Property Analysis Functions

Each function that belongs to this group takes a geometry value as its argument and returns some quantitive or qualitive property of the geometry. Some functions restrict their argument type. Such functions return `NULL` if the argument is of an incorrect geometry type. For example, `Area()` returns `NULL` if the object type is neither `Polygon` nor `MultiPolygon`.

10.5.2.1 General Geometry Property Analysis Functions

The functions listed in this ssection do not restrict their argument and accept a geometry value of any type.

`GeometryType(g)`
: Returns as a string the name of the geometry type of which the geometry instance `g` is a member. The name will correspond to one of the instantiable `Geometry` subclasses.

```
mysql> SELECT GeometryType(GeomFromText('POINT(1 1)'));
+-----------------------------------------+
| GeometryType(GeomFromText('POINT(1 1)')) |
+-----------------------------------------+
| POINT                                   |
+-----------------------------------------+
```

`Dimension(g)`
: Returns the inherent dimension of the geometry value `g`. The result can be −1, 0, 1, or 2. (The meaning of these values is given in Section 10.2.2 [GIS class geometry], page 689.)

```
mysql> SELECT Dimension(GeomFromText('LineString(1 1,2 2)'));
+------------------------------------------------+
| Dimension(GeomFromText('LineString(1 1,2 2)')) |
+------------------------------------------------+
|                                              1 |
+------------------------------------------------+
```

`SRID(g)`
: Returns an integer indicating the Spatial Reference System ID for the geometry value `g`.

```
mysql> SELECT SRID(GeomFromText('LineString(1 1,2 2)',101));
+-----------------------------------------------+
| SRID(GeomFromText('LineString(1 1,2 2)',101)) |
+-----------------------------------------------+
|                                           101 |
+-----------------------------------------------+
```

`Envelope(g)`
: Returns the Minimum Bounding Rectangle (MBR) for the geometry value `g`. The result is returned as a polygon value.

```
mysql> SELECT AsText(Envelope(GeomFromText('LineString(1 1,2 2)')));
+---------------------------------------------------------+
| AsText(Envelope(GeomFromText('LineString(1 1,2 2)'))) |
+---------------------------------------------------------+
| POLYGON((1 1,2 1,2 2,1 2,1 1))                          |
+---------------------------------------------------------+
```

The polygon is defined by the corner points of the bounding box:

```
POLYGON((MINX MINY, MAXX MINY, MAXX MAXY, MINX MAXY, MINX MINY))
```

The OpenGIS specification also defines the following functions, which MySQL does not yet implement:

`Boundary(g)`
: Returns a geometry that is the closure of the combinatorial boundary of the geometry value `g`.

`IsEmpty(g)`
: Returns 1 if the geomtry value `g` is the empty geometry, 0 if it is not empty, and −1 if the argument is `NULL`. If the geometry is empty, it represents the empty point set.

`IsSimple(g)`
: Currently, this function is a placeholder and should not be used. When implemented, its behavior will be as described in the next paragraph.

  Returns 1 if the geometry value `g` has no anomalous geometric points, such as self intersection or self tangency. `IsSimple()` returns 0 if the argument is not simple, and −1 if it is `NULL`.

  The description of each instantiable geometric class given earlier in the chapter includes the specific conditions that cause an instance of that class to be classified as not simple.

10.5.2.2 `Point` Property Analysis Functions

A `Point` consists of its X and Y coordinates, which may be obtained using the following functions:

`X(p)` Returns the X-coordinate value for the point `p` as a double-precision number.

```
mysql> SELECT X(GeomFromText('Point(56.7 53.34)'));
+---------------------------------------+
| X(GeomFromText('Point(56.7 53.34)')) |
+---------------------------------------+
|                                  56.7 |
+---------------------------------------+
```

`Y(p)` Returns the Y-coordinate value for the point `p` as a double-precision number.

```
mysql> SELECT Y(GeomFromText('Point(56.7 53.34)'));
+---------------------------------------+
| Y(GeomFromText('Point(56.7 53.34)')) |
+---------------------------------------+
|                                 53.34 |
+---------------------------------------+
```

10.5.2.3 `LineString` Property Analysis Functions

A `LineString` consists of `Point` values. You can extract particular points of a `LineString`, count the number of points that it contains, or obtain its length.

`EndPoint(ls)`

Returns the `Point` that is the end point of the `LineString` value `ls`.

```
mysql> SELECT AsText(EndPoint(GeomFromText('LineString(1 1,2 2,3 3)')));
+-----------------------------------------------------------+
| AsText(EndPoint(GeomFromText('LineString(1 1,2 2,3 3)'))) |
+-----------------------------------------------------------+
| POINT(3 3)                                                |
+-----------------------------------------------------------+
```

`GLength(ls)`

Returns as a double-precision number the length of the `LineString` value `ls` in its associated spatial reference.

```
mysql> SELECT GLength(GeomFromText('LineString(1 1,2 2,3 3)'));
+------------------------------------------------+
| GLength(GeomFromText('LineString(1 1,2 2,3 3)')) |
+------------------------------------------------+
|                              2.8284271247462 |
+------------------------------------------------+
```

`IsClosed(ls)`

Returns 1 if the `LineString` value `ls` is closed (that is, it s`StartPoint()` and `EndPoint()` values are the same). Returns 0 if `ls` is not closed, and −1 if it is `NULL`.

```
mysql> SELECT IsClosed(GeomFromText('LineString(1 1,2 2,3 3)'));
+------------------------------------------------+
| IsClosed(GeomFromText('LineString(1 1,2 2,3 3)')) |
+------------------------------------------------+
|                                              0 |
+------------------------------------------------+
```

`NumPoints(ls)`

Returns the number of points in the `LineString` value `ls`.

```
mysql> SELECT NumPoints(GeomFromText('LineString(1 1,2 2,3 3)'));
+------------------------------------------------+
| NumPoints(GeomFromText('LineString(1 1,2 2,3 3)')) |
+------------------------------------------------+
|                                              3 |
+------------------------------------------------+
```

`PointN(ls,n)`

Returns the `n`-th point in the `Linestring` value `ls`. Point numbers begin at 1.

```
mysql> SELECT AsText(PointN(GeomFromText('LineString(1 1,2 2,3 3)'),2));
+-----------------------------------------------------------+
| AsText(PointN(GeomFromText('LineString(1 1,2 2,3 3)'),2)) |
+-----------------------------------------------------------+
| POINT(2 2)                                                |
+-----------------------------------------------------------+
```

`StartPoint(ls)`

Returns the `Point` that is the start point of the `LineString` value `ls`.

```
mysql> SELECT AsText(StartPoint(GeomFromText('LineString(1 1,2 2,3 3)')));
+-------------------------------------------------------------+
| AsText(StartPoint(GeomFromText('LineString(1 1,2 2,3 3)'))) |
+-------------------------------------------------------------+
| POINT(1 1)                                                  |
+-------------------------------------------------------------+
```

The OpenGIS specification also defines the following function, which MySQL does not yet implement:

`IsRing(ls)`

Returns 1 if the `LineString` value `ls` is closed (thatis, its `StartPoint()` and `EndPoint()` values are the same) and is simple (does not pass through the same point more than once). Returns 0 if `ls` is not a ring, and −1 if it is `NULL`.

10.5.2.4 `MultiLineString` Property Analysis Functions

`GLength(mls)`

Returns as a double-precision number the length of the `MultiLineString` value `mls`. The length of `mls` is equal to the sum of the lengths of its elements.

```
mysql> SELECT GLength(GeomFromText('MultiLineString((1 1,2 2,3 3),(4 4,5 5))
+-------------------------------------------------------------------+
| GLength(GeomFromText('MultiLineString((1 1,2 2,3 3),(4 4,5 5))')) |
+-------------------------------------------------------------------+
|                                                 4.2426406871193 |
+-------------------------------------------------------------------+
```

`IsClosed(mls)`

Returns 1 if the `MultiLineString` value `mls` is closed (that is, the `StartPoint()` and `EndPoint()` values are the same for each `LineString` in `mls`). Returns 0 if `mls` is not closed, and −1 if it is `NULL`.

```
mysql> SELECT IsClosed(GeomFromText('MultiLineString((1 1,2 2,3 3),(4 4,5 5)
+-----------------------------------------------------------------------+
| IsClosed(GeomFromText('MultiLineString((1 1,2 2,3 3),(4 4,5 5))')) |
+-----------------------------------------------------------------------+
|                                                                     0 |
+-----------------------------------------------------------------------+
```

10.5.2.5 `Polygon` Property Analysis Functions

`Area(poly)`

Returns as a double-precision number the area of the `Polygon` value `poly`, as measured in its spatial reference system.

```
mysql> SELECT Area(GeomFromText('Polygon((0 0,0 3,3 3,3 0,0 0),(1 1,1 2,2 2,
+-----------------------------------------------------------------------------
```

```
| Area(GeomFromText('Polygon((0 0,0 3,3 3,3 0,0 0),(1 1,1 2,2 2,2 1,1 1))'))
+---------------------------------------------------------------------------+
|                                                                         8 |
+---------------------------------------------------------------------------+
```

`NumInteriorRings(poly)`

Returns the number of interior rings in the `Polygon` value `poly`.

```
mysql> SELECT NumInteriorRings(GeomFromText('Polygon((0 0,0 3,3 3,3 0,0 0),(
+---------------------------------------------------------------------------+
| NumInteriorRings(GeomFromText('Polygon((0 0,0 3,3 3,3 0,0 0),(1 1,1 2,2 2,
+---------------------------------------------------------------------------+
|                                                                         1 |
+---------------------------------------------------------------------------+
```

`ExteriorRing(poly)`

Returns the exterior ring of the `Polygon` value `poly` as a `LineString`.

```
mysql> SELECT AsText(ExteriorRing(GeomFromText('Polygon((0 0,0 3,3 3,3 0,0 0
+---------------------------------------------------------------------------+
| AsText(ExteriorRing(GeomFromText('Polygon((0 0,0 3,3 3,3 0,0 0),(1 1,1 2,2
+---------------------------------------------------------------------------+
| LINESTRING(0 0,0 3,3 3,3 0,0 0)                                           |
+---------------------------------------------------------------------------+
```

`InteriorRingN(poly,n)`

Returns the `n`-th interior ring for the `Polygon` value `poly` as a `LineString`. Ring numbers begin at 1.

```
mysql> SELECT AsText(InteriorRingN(GeomFromText('Polygon((0 0,0 3,3 3,3 0,0
+---------------------------------------------------------------------------+
| AsText(InteriorRingN(GeomFromText('Polygon((0 0,0 3,3 3,3 0,0 0),(1 1,1 2,
+---------------------------------------------------------------------------+
| LINESTRING(1 1,1 2,2 2,2 1,1 1)                                           |
+---------------------------------------------------------------------------+
```

The OpenGIS specification also defines the following functions, which MySQL does not yet implement:

`Centroid(poly)`

Returns the mathematical centroid for the `Polygon` value `poly` as a `Point`. The result is not guaranteed to be on the polygon.

`PointOnSurface(poly)`

Returns a `Point` value that is guaranteed to be on the `Polygon` value `poly`.

10.5.2.6 `MultiPolygon` Property Analysis Functions

`Area(mpoly)`

Returns as a double-precision number the area of the `MultiPolygon` value `mpoly`, as measured in its spatial reference system.

```
mysql> SELECT Area(GeomFromText('MultiPolygon(((0 0,0 3,3 3,3 0,0 0),(1 1,1
+-----------------------------------------------------------------------------
| Area(GeomFromText('MultiPolygon(((0 0,0 3,3 3,3 0,0 0),(1 1,1 2,2 2,2 1,1
+-----------------------------------------------------------------------------
|
+-----------------------------------------------------------------------------
```

The OpenGIS specification also defines the following functions, which MySQL does not yet implement:

`Centroid(mpoly)`
: Returns the mathematical centroid for the `MultiPolygon` value `mpoly` as a `Point`. The result is not guaranteed to be on the `MultiPolygon`.

`PointOnSurface(mpoly)`
: Returns a `Point` value that is guaranteed to be on the `MultiPolygon` value `mpoly`.

10.5.2.7 `GeometryCollection` Property Analysis Functions

`NumGeometries(gc)`
: Returns the number of geometries in the `GeometryCollection` value `gc`.

```
mysql> SELECT NumGeometries(GeomFromText('GeometryCollection(Point(1 1),Line
+-----------------------------------------------------------------------------
| NumGeometries(GeomFromText('GeometryCollection(Point(1 1),LineString(2 2,
+-----------------------------------------------------------------------------
|
+-----------------------------------------------------------------------------
```

`GeometryN(gc,n)`
: Returns the `n`-th geometry in the `GeometryCollection` value `gc`. Geometry numbers begin at 1.

```
mysql> SELECT AsText(GeometryN(GeomFromText('GeometryCollection(Point(1 1),L
+-----------------------------------------------------------------------------
| AsText(GeometryN(GeomFromText('GeometryCollection(Point(1 1),LineString(2
+-----------------------------------------------------------------------------
| POINT(1 1)
+-----------------------------------------------------------------------------
```

10.5.3 Functions That Create New Geometries From Existing Ones

10.5.3.1 Geometry Functions That Produce New Geometries

In the section Section 10.5.2 [Geometry property functions], page 702, we've already discussed some functions that can construct new geometries from the existing ones:

- `Envelope(g)`

- `StartPoint(ls)`
- `EndPoint(ls)`
- `PointN(ls,n)`
- `ExteriorRing(poly)`
- `InteriorRingN(poly,n)`
- `GeometryN(gc,n)`

10.5.3.2 Spatial Operators

OpenGIS proposes a number of other functions that can produce geometries. They are designed to implement Spatial Operators.

These functions are not yet implemented in MySQL. They should appear in future releases.

`Intersection(g1,g2)`
: Returns a geometry that represents the point set intersection of the geometry values `g1` with `g2`.

`Union(g1,g2)`
: Returns a geometry that represents the point set union of the geometry values `g1` and `g2`.

`Difference(g1,g2)`
: Returns a geometry that represents the point set difference of the geometry value `g1` with `g2`.

`SymDifference(g1,g2)`
: Returns a geometry that represents the point set symmetric difference of the geometry value `g1` with `g2`.

`Buffer(g,d)`
: Returns a geometry that represents all points whose distance from the geometry value `g` is less than or equal to a distance of `d`.

`ConvexHull(g)`
: Returns a geometry that represents the convex hull of the geometry value `g`.

10.5.4 Functions For Testing Spatial Relations Between Geometric Objects

The functions described in these sections take two geometries as input parameters and return a qualitive or quantitive relation between them.

10.5.5 Relations On Geometry Minimal Bounding Rectangles (MBRs)

MySQL provides some functions that can test relations between mininal bounding rectangles of two geometries `g1` and `g2`. They include:

`MBRContains(g1,g2)`

Returns 1 or 0 to indicate whether or not the Minimum Bounding Rectangle of `g1` contains the Minimum Bounding Rectangle of `g2`.

```
mysql> SET @g1 = GeomFromText('Polygon((0 0,0 3,3 3,3 0,0 0))');
mysql> SET @g2 = GeomFromText('Point(1 1)');
mysql> SELECT MBRContains(@g1,@g2), MBRContains(@g2,@g1);
----------------------+----------------------+
| MBRContains(@g1,@g2) | MBRContains(@g2,@g1) |
+----------------------+----------------------+
|                    1 |                    0 |
+----------------------+----------------------+
```

`MBRWithin(g1,g2)`

Returns 1 or 0 to indicate whether or not the Minimum Bounding Rectangle of `g1` is within the Minimum Bounding Rectangle of `g2`.

```
mysql> SET @g1 = GeomFromText('Polygon((0 0,0 3,3 3,3 0,0 0))');
mysql> SET @g2 = GeomFromText('Polygon((0 0,0 5,5 5,5 0,0 0))');
mysql> SELECT MBRWithin(@g1,@g2), MBRWithin(@g2,@g1);
+--------------------+--------------------+
| MBRWithin(@g1,@g2) | MBRWithin(@g2,@g1) |
+--------------------+--------------------+
|                  1 |                  0 |
+--------------------+--------------------+
```

`MBRDisjoint(g1,g2)`

Returns 1 or 0 to indicate whether or not the Minimum Bounding Rectangles of the two geometries `g1` and `g2` are disjoint (do not intersect).

`MBREquals(g1,g2)`

Returns 1 or 0 to indicate whether or not the Minimum Bounding Rectangles of the two geometries `g1` and `g2` are the same.

`MBRIntersects(g1,g2)`

Returns 1 or 0 to indicate whether or not the Minimum Bounding Rectangles of the two geometries `g1` and `g2` intersect.

`MBROverlaps(g1,g2)`

Returns 1 or 0 to indicate whether or not the Minimum Bounding Rectangles of the two geometries `g1` and `g2` overlap.

`MBRTouches(g1,g2)`

Returns 1 or 0 to indicate whether or not the Minimum Bounding Rectangles of the two geometries `g1` and `g2` touch.

10.5.6 Functions That Test Spatial Relationships Between Geometries

The OpenGIS specification defines the following functions, which MySQL does not yet implement. They should appear in future releases. When implemented, they will provide full support for spatial analysis, not just MBR-based support.

The functions operate on two geometry values `g1` and `g2`.

`Contains(g1,g2)`
: Returns 1 or 0 to indicate whether or not `g1` completely contains `g2`.

`Crosses(g1,g2)`
: Returns 1 if `g1` spatially crosses `g2`. Returns `NULL` if `g1` is a `Polygon` or a `MultiPolygon`, or if `g2` is a `Point` or a `MultiPoint`. Otherwise, returns 0.

  The term **spatially crosses** denotes a spatial relation between two given geometries that has the following properties:

  - The two geometries intersect
  - Their intersection results in a geometry that has a dimension that is one less than the maximum dimension of the two given geometries
  - Their intersection is not equal to either of the two given geometries

`Disjoint(g1,g2)`
: Returns 1 or 0 to indicate whether or not `g1` is spatially disjoint from (does not intersect) `g2`.

`Equals(g1,g2)`
: Returns 1 or 0 to indicate whether or not `g1` is spatially equal to `g2`.

`Intersects(g1,g2)`
: Returns 1 or 0 to indicate whether or not `g1` spatially intersects `g2`.

`Overlaps(g1,g2)`
: Returns 1 or 0 to indicate whether or not `g1` spatially overlaps `g2`. The term `spatially overlaps` is used if two geometries intersect and their intersection results in a geometry of the same dimension but not equal to either of the given geometries.

`Touches(g1,g2)`
: Returns 1 or 0 to indicate whether or not `g1` spatially touches `g2`. Two geometries **spatially touch** if the interiors of the geometries do not intersect, but the boundary of one of the geometries intersects either the boundary or the interior of the other.

`Within(g1,g2)`
: Returns 1 or 0 to indicate whether or not `g1` is spatially within `g2`.

`Distance(g1,g2)`
: Returns as a double-precision number the shortest distance between any two points in the two geometries.

`Related(g1,g2,pattern_matrix)`
: Returns 1 or 0 to indicate whether or not the spatial relationship specified by `pattern_matrix` exists between `g1` and `g2`. Returns −1 if the arguments are `NULL`. The pattern matrix is a string. Its specification will be noted here when this function is implemented.

10.6 Optimising Spatial Analysis

It is known that search operations in non-spatial databases can be optimised using indexes. This is true for spatial databases as well. With the help of a great variety of multi-dimensional indexing methods that have already been designed, it's possible to optimise spatial searches. The most typical of these are:

- Point queries that search for all objects that contain a given point
- Region queries that search for all objects that overlap a given region

MySQL utilises **R-Trees with quadratic splitting** to index spatial columns. A spatial index is built using the MBR of a geometry. For most geometries, the MBR is a minimum rectangle that surrounds the geometries. For a horizontal or a vertical linestring, the MBR is a rectangle degenerated into the linestring. For a point, the MBR is a rectangle degenerated into the point.

10.6.1 Creating Spatial Indexes

MySQL can create spatial indexes using syntax similar to that for creating regular indexes, but extended with the `SPATIAL` keyword. Spatial columns that are indexed currently must be declared `NOT NULL`. The following examples demonstrate how to create spatial indexes.

- With `CREATE TABLE`:

```
mysql> CREATE TABLE geom (g GEOMETRY NOT NULL, SPATIAL INDEX(g));
```

- With `ALTER TABLE`:

```
mysql> ALTER TABLE geom ADD SPATIAL INDEX(g);
```

- With `CREATE INDEX`:

```
mysql> CREATE SPATIAL INDEX sp_index ON geom (g);
```

To drop spatial indexes, use `ALTER TABLE` or `DROP INDEX`:

- With `ALTER TABLE`:

```
mysql> ALTER TABLE geom DROP INDEX g;
```

- With `DROP INDEX`:

```
mysql> DROP INDEX sp_index ON geom;
```

Example: Suppose that a table `geom` contains more than 32000 geometries, which are stored in the column `g` of type `GEOMETRY`. The table also has an `AUTO_INCREMENT` column `fid` for storing object ID values.

```
mysql> SHOW FIELDS FROM geom;
+-------+----------+------+-----+---------+----------------+
| Field | Type     | Null | Key | Default | Extra          |
+-------+----------+------+-----+---------+----------------+
| fid   | int(11)  |      | PRI | NULL    | auto_increment |
| g     | geometry |      |     |         |                |
+-------+----------+------+-----+---------+----------------+
2 rows in set (0.00 sec)
```

```
mysql> SELECT COUNT(*) FROM geom;
+----------+
| count(*) |
+----------+
|    32376 |
+----------+
1 row in set (0.00 sec)
```

To add a spatial index on the column g, use this statement:

```
mysql> ALTER TABLE geom ADD SPATIAL INDEX(g);
Query OK, 32376 rows affected (4.05 sec)
Records: 32376  Duplicates: 0  Warnings: 0
```

10.6.2 Using a Spatial Index

The optimiser investigates whether available spatial indexes can be involved in the search for queries that use a function such as `MBRContains()` or `MBRWithin()` in the `WHERE` clause. For example, let's say we want to find all objects that are in the given rectangle:

```
mysql> SELECT fid,AsText(g) FROM geom WHERE
mysql> MBRContains(GeomFromText('Polygon((30000 15000,31000 15000,31000 16000,30000 16
+-----+-------------------------------------------------------------------------------+
| fid | AsText(g)                                                                     |
+-----+-------------------------------------------------------------------------------+
|  21 | LINESTRING(30350.4 15828.8,30350.6 15845,30333.8 15845,30333.8 15828.8)       |
|  22 | LINESTRING(30350.6 15871.4,30350.6 15887.8,30334 15887.8,30334 15871.4)       |
|  23 | LINESTRING(30350.6 15914.2,30350.6 15930.4,30334 15930.4,30334 15914.2)       |
|  24 | LINESTRING(30290.2 15823,30290.2 15839.4,30273.4 15839.4,30273.4 15823)       |
|  25 | LINESTRING(30291.4 15866.2,30291.6 15882.4,30274.8 15882.4,30274.8 15866.2)   |
|  26 | LINESTRING(30291.6 15918.2,30291.6 15934.4,30275 15934.4,30275 15918.2)       |
| 249 | LINESTRING(30337.8 15938.6,30337.8 15946.8,30320.4 15946.8,30320.4 15938.4)   |
|   1 | LINESTRING(30250.4 15129.2,30248.8 15138.4,30238.2 15136.4,30240 15127.2)     |
|   2 | LINESTRING(30220.2 15122.8,30217.2 15137.8,30207.6 15136,30210.4 15121)       |
|   3 | LINESTRING(30179 15114.4,30176.6 15129.4,30167 15128,30169 15113)             |
|   4 | LINESTRING(30155.2 15121.4,30140.4 15118.6,30142 15109,30157 15111.6)         |
|   5 | LINESTRING(30192.4 15085,30177.6 15082.2,30179.2 15072.4,30194.2 15075.2)     |
|   6 | LINESTRING(30244 15087,30229 15086.2,30229.4 15076.4,30244.6 15077)           |
|   7 | LINESTRING(30200.6 15059.4,30185.6 15058.6,30186 15048.8,30201.2 15049.4)     |
|  10 | LINESTRING(30179.6 15017.8,30181 15002.8,30190.8 15003.6,30189.6 15019)       |
|  11 | LINESTRING(30154.2 15000.4,30168.6 15004.8,30166 15014.2,30151.2 15009.8)     |
|  13 | LINESTRING(30105 15065.8,30108.4 15050.8,30118 15053,30114.6 15067.8)         |
| 154 | LINESTRING(30276.2 15143.8,30261.4 15141,30263 15131.4,30278 15134)           |
| 155 | LINESTRING(30269.8 15084,30269.4 15093.4,30258.6 15093,30259 15083.4)         |
| 157 | LINESTRING(30128.2 15011,30113.2 15010.2,30113.6 15000.4,30128.8 15001)       |
+-----+-------------------------------------------------------------------------------+
20 rows in set (0.00 sec)
```

Now let's check the way this query is executed, using `EXPLAIN`:

```
mysql> EXPLAIN SELECT fid,AsText(g) FROM geom WHERE
mysql> MBRContains(GeomFromText('Polygon((30000 15000,31000 15000,31000 16000,30000 16
+----+-------------+-------+-------+---------------+------+---------+------+------+---
| id | select_type | table | type  | possible_keys | key  | key_len | ref  | rows | Ex
+----+-------------+-------+-------+---------------+------+---------+------+------+---
|  1 | SIMPLE      | geom  | range | g             | g    |      32 | NULL |   50 | Us
+----+-------------+-------+-------+---------------+------+---------+------+------+---
1 row in set (0.00 sec)
```

Now let's check what would happen if we didn't have a spatial index:

```
mysql> EXPLAIN SELECT fid,AsText(g) FROM g IGNORE INDEX (g) WHERE
mysql> MBRContains(GeomFromText('Polygon((30000 15000,31000 15000,31000 16000,30000 16
+----+-------------+-------+------+---------------+------+---------+------+-------+---
| id | select_type | table | type | possible_keys | key  | key_len | ref  | rows  | Ex
+----+-------------+-------+------+---------------+------+---------+------+-------+---
|  1 | SIMPLE      | geom  | ALL  | NULL          | NULL |    NULL | NULL | 32376 | Us
+----+-------------+-------+------+---------------+------+---------+------+-------+---
1 row in set (0.00 sec)
```

Let's execute the above query, ignoring the spatial key we have:

```
mysql> SELECT fid,AsText(g) FROM geom IGNORE INDEX (g) WHERE
mysql> MBRContains(GeomFromText('Polygon((30000 15000,31000 15000,31000 16000,30000 16
+-----+--------------------------------------------------------------------------------+
| fid | AsText(g)                                                                      |
+-----+--------------------------------------------------------------------------------+
|   1 | LINESTRING(30250.4 15129.2,30248.8 15138.4,30238.2 15136.4,30240 15127.2)      |
|   2 | LINESTRING(30220.2 15122.8,30217.2 15137.8,30207.6 15136,30210.4 15121)        |
|   3 | LINESTRING(30179 15114.4,30176.6 15129.4,30167 15128,30169 15113)              |
|   4 | LINESTRING(30155.2 15121.4,30140.4 15118.6,30142 15109,30157 15111.6)          |
|   5 | LINESTRING(30192.4 15085,30177.6 15082.2,30179.2 15072.4,30194.2 15075.2)      |
|   6 | LINESTRING(30244 15087,30229 15086.2,30229.4 15076.4,30244.6 15077)            |
|   7 | LINESTRING(30200.6 15059.4,30185.6 15058.6,30186 15048.8,30201.2 15049.4)      |
|  10 | LINESTRING(30179.6 15017.8,30181 15002.8,30190.8 15003.6,30189.6 15019)        |
|  11 | LINESTRING(30154.2 15000.4,30168.6 15004.8,30166 15014.2,30151.2 15009.8)      |
|  13 | LINESTRING(30105 15065.8,30108.4 15050.8,30118 15053,30114.6 15067.8)          |
|  21 | LINESTRING(30350.4 15828.8,30350.6 15845,30333.8 15845,30333.8 15828.8)        |
|  22 | LINESTRING(30350.6 15871.4,30350.6 15887.8,30334 15887.8,30334 15871.4)        |
|  23 | LINESTRING(30350.6 15914.2,30350.6 15930.4,30334 15930.4,30334 15914.2)        |
|  24 | LINESTRING(30290.2 15823,30290.2 15839.4,30273.4 15839.4,30273.4 15823)        |
|  25 | LINESTRING(30291.4 15866.2,30291.6 15882.4,30274.8 15882.4,30274.8 15866.2)    |
|  26 | LINESTRING(30291.6 15918.2,30291.6 15934.4,30275 15934.4,30275 15918.2)        |
| 154 | LINESTRING(30276.2 15143.8,30261.4 15141,30263 15131.4,30278 15134)            |
| 155 | LINESTRING(30269.8 15084,30269.4 15093.4,30258.6 15093,30259 15083.4)          |
| 157 | LINESTRING(30128.2 15011,30113.2 15010.2,30113.6 15000.4,30128.8 15001)        |
| 249 | LINESTRING(30337.8 15938.6,30337.8 15946.8,30320.4 15946.8,30320.4 15938.4)    |
+-----+--------------------------------------------------------------------------------+
20 rows in set (0.46 sec)
```

When the index is not used, the execution time for this query rises from 0.00 seconds to 0.46 seconds.

In future releases, spatial indexes will also be used for optimising other functions. See Section 10.5.4 [Functions for testing spatial relations between geometric objects], page 709.

10.7 MySQL Conformance and Compatibility

10.7.1 GIS Features That Are Not Yet Implemented

Additional Metadata Views
: OpenGIS specifications propose several additional metadata views. For example, a system view named `GEOMETRY_COLUMNS` contains a description of geometry columns, one row for each geometry column in the database.

Functions to add/drop spatial columns
: OpenGIS assumes that columns can be added or dropped using special `AddGeometryColumn()` and `DropGeometryColumn()` functions. In MySQL, this is done using the `ALTER TABLE`, `CREATE INDEX`, and `DROP INDEX` statements instead.

Factors related to Spatial Reference Systems and their IDs (SRIDs):
- Functions like `Length()` and `Area()` assume a planar coordinate system.
- All objects currently are considered to be in the same planar coordinate system.

The OpenGIS function `Length()` on `LineString` and `MultiLineString` currently should be called in MySQL as `GLength()`
: The problem is that it conflicts with the existing SQL function `Length()` that calculates the length of string values, and sometimes it's not possible to distinguish whether the function is called in a textual or spatial context. We need either to solve this somehow, or decide on another function name.

11 MySQL APIs

This chapter describes the APIs available for MySQL, where to get them, and how to use them. The C API is the most extensively covered, as it was developed by the MySQL team, and is the basis for most of the other APIs.

11.1 MySQL C API

The C API code is distributed with MySQL. It is included in the `mysqlclient` library and allows C programs to access a database.

Many of the clients in the MySQL source distribution are written in C. If you are looking for examples that demonstrate how to use the C API, take a look at these clients. You can find these in the `clients` directory in the MySQL source distribution.

Most of the other client APIs (all except Connector/J) use the `mysqlclient` library to communicate with the MySQL server. This means that, for example, you can take advantage of many of the same environment variables that are used by other client programs, because they are referenced from the library. See Section 4.9 [Client-Side Scripts], page 325, for a list of these variables.

The client has a maximum communication buffer size. The size of the buffer that is allocated initially (16K bytes) is automatically increased up to the maximum size (the maximum is 16M). Because buffer sizes are increased only as demand warrants, simply increasing the default maximum limit does not in itself cause more resources to be used. This size check is mostly a check for erroneous queries and communication packets.

The communication buffer must be large enough to contain a single SQL statement (for client-to-server traffic) and one row of returned data (for server-to-client traffic). Each thread's communication buffer is dynamically enlarged to handle any query or row up to the maximum limit. For example, if you have `BLOB` values that contain up to 16M of data, you must have a communication buffer limit of at least 16M (in both server and client). The client's default maximum is 16M, but the default maximum in the server is 1M. You can increase this by changing the value of the `max_allowed_packet` parameter when the server is started. See Section 5.5.2 [Server parameters], page 427.

The MySQL server shrinks each communication buffer to `net_buffer_length` bytes after each query. For clients, the size of the buffer associated with a connection is not decreased until the connection is closed, at which time client memory is reclaimed.

For programming with threads, see Section 11.1.14 [Threaded clients], page 799. For creating a stand-alone application which includes the "server" and "client" in the same program (and does not communicate with an external MySQL server), see Section 11.1.15 [libmysqld], page 800.

11.1.1 C API Datatypes

`MYSQL` This structure represents a handle to one database connection. It is used for almost all MySQL functions.

`MYSQL_RES`

This structure represents the result of a query that returns rows (`SELECT`, `SHOW`, `DESCRIBE`, `EXPLAIN`). The information returned from a query is called the *result set* in the remainder of this section.

`MYSQL_ROW`

This is a type-safe representation of one row of data. It is currently implemented as an array of counted byte strings. (You cannot treat these as null-terminated strings if field values may contain binary data, because such values may contain null bytes internally.) Rows are obtained by calling `mysql_fetch_row()`.

`MYSQL_FIELD`

This structure contains information about a field, such as the field's name, type, and size. Its members are described in more detail here. You may obtain the `MYSQL_FIELD` structures for each field by calling `mysql_fetch_field()` repeatedly. Field values are not part of this structure; they are contained in a `MYSQL_ROW` structure.

`MYSQL_FIELD_OFFSET`

This is a type-safe representation of an offset into a MySQL field list. (Used by `mysql_field_seek()`.) Offsets are field numbers within a row, beginning at zero.

`my_ulonglong`

The type used for the number of rows and for `mysql_affected_rows()`, `mysql_num_rows()`, and `mysql_insert_id()`. This type provides a range of `0` to `1.84e19`.

On some systems, attempting to print a value of type `my_ulonglong` will not work. To print such a value, convert it to `unsigned long` and use a `%lu` print format. Example:

```
printf ("Number of rows: %lu\n", (unsigned long) mysql_num_rows(result));
```

The `MYSQL_FIELD` structure contains the members listed here:

`char * name`

The name of the field, as a null-terminated string.

`char * table`

The name of the table containing this field, if it isn't a calculated field. For calculated fields, the `table` value is an empty string.

`char * def`

The default value of this field, as a null-terminated string. This is set only if you use `mysql_list_fields()`.

`enum enum_field_types type`

The type of the field. The `type` value may be one of the following:

Type value	Type description
`FIELD_TYPE_TINY`	`TINYINT` field
`FIELD_TYPE_SHORT`	`SMALLINT` field
`FIELD_TYPE_LONG`	`INTEGER` field

FIELD_TYPE_INT24	MEDIUMINT field
FIELD_TYPE_LONGLONG	BIGINT field
FIELD_TYPE_DECIMAL	DECIMAL or NUMERIC field
FIELD_TYPE_FLOAT	FLOAT field
FIELD_TYPE_DOUBLE	DOUBLE or REAL field
FIELD_TYPE_TIMESTAMP	TIMESTAMP field
FIELD_TYPE_DATE	DATE field
FIELD_TYPE_TIME	TIME field
FIELD_TYPE_DATETIME	DATETIME field
FIELD_TYPE_YEAR	YEAR field
FIELD_TYPE_STRING	CHAR field
FIELD_TYPE_VAR_STRING	VARCHAR field
FIELD_TYPE_BLOB	BLOB or TEXT field (use max_length to determine the maximum length)
FIELD_TYPE_SET	SET field
FIELD_TYPE_ENUM	ENUM field
FIELD_TYPE_NULL	NULL-type field
FIELD_TYPE_CHAR	Deprecated; use FIELD_TYPE_TINY instead

You can use the IS_NUM() macro to test whether a field has a numeric type. Pass the type value to IS_NUM() and it will evaluate to TRUE if the field is numeric:

```
if (IS_NUM(field->type))
    printf("Field is numeric\n");
```

unsigned int length

The width of the field, as specified in the table definition.

unsigned int max_length

The maximum width of the field for the result set (the length of the longest field value for the rows actually in the result set). If you use mysql_store_result() or mysql_list_fields(), this contains the maximum length for the field. If you use mysql_use_result(), the value of this variable is zero.

unsigned int flags

Different bit-flags for the field. The flags value may have zero or more of the following bits set:

Flag value	**Flag description**
NOT_NULL_FLAG	Field can't be NULL
PRI_KEY_FLAG	Field is part of a primary key
UNIQUE_KEY_FLAG	Field is part of a unique key
MULTIPLE_KEY_FLAG	Field is part of a non-unique key
UNSIGNED_FLAG	Field has the UNSIGNED attribute
ZEROFILL_FLAG	Field has the ZEROFILL attribute
BINARY_FLAG	Field has the BINARY attribute
AUTO_INCREMENT_FLAG	Field has the AUTO_INCREMENT attribute
ENUM_FLAG	Field is an ENUM (deprecated)
SET_FLAG	Field is a SET (deprecated)
BLOB_FLAG	Field is a BLOB or TEXT (deprecated)

`TIMESTAMP_FLAG`	Field is a `TIMESTAMP` (deprecated)

Use of the `BLOB_FLAG`, `ENUM_FLAG`, `SET_FLAG`, and `TIMESTAMP_FLAG` flags is deprecated because they indicate the type of a field rather than an attribute of its type. It is preferable to test `field->type` against `FIELD_TYPE_BLOB`, `FIELD_TYPE_ENUM`, `FIELD_TYPE_SET`, or `FIELD_TYPE_TIMESTAMP` instead.

The following example illustrates a typical use of the `flags` value:

```
if (field->flags & NOT_NULL_FLAG)
    printf("Field can't be null\n");
```

You may use the following convenience macros to determine the boolean status of the `flags` value:

Flag status	Description
`IS_NOT_NULL(flags)`	True if this field is defined as `NOT NULL`
`IS_PRI_KEY(flags)`	True if this field is a primary key
`IS_BLOB(flags)`	True if this field is a `BLOB` or `TEXT` (deprecated; test `field->type` instead)

`unsigned int decimals`

The number of decimals for numeric fields.

11.1.2 C API Function Overview

The functions available in the C API are summarised here and described in greater detail in a later section. See Section 11.1.3 [C API functions], page 723.

Function	Description
mysql_affected_rows()	Returns the number of rows changed/deleted/inserted by the last `UPDATE`, `DELETE`, or `INSERT` query.
mysql_change_user()	Changes user and database on an open connection.
mysql_character_set_name()	Returns the name of the default character set for the connection.
mysql_close()	Closes a server connection.
mysql_connect()	Connects to a MySQL server. This function is deprecated; use `mysql_real_connect()` instead.
mysql_create_db()	Creates a database. This function is deprecated; use the SQL command `CREATE DATABASE` instead.
mysql_data_seek()	Seeks to an arbitrary row number in a query result set.
mysql_debug()	Does a `DBUG_PUSH` with the given string.
mysql_drop_db()	Drops a database. This function is deprecated; use the SQL command `DROP DATABASE` instead.
mysql_dump_debug_info()	Makes the server write debug information to the log.

mysql_eof()	Determines whether the last row of a result set has been read. This function is deprecated; `mysql_errno()` or `mysql_error()` may be used instead.
mysql_errno()	Returns the error number for the most recently invoked MySQL function.
mysql_error()	Returns the error message for the most recently invoked MySQL function.
mysql_escape_string()	Escapes special characters in a string for use in an SQL statement.
mysql_fetch_field()	Returns the type of the next table field.
mysql_fetch_field_direct()	Returns the type of a table field, given a field number.
mysql_fetch_fields()	Returns an array of all field structures.
mysql_fetch_lengths()	Returns the lengths of all columns in the current row.
mysql_fetch_row()	Fetches the next row from the result set.
mysql_field_seek()	Puts the column cursor on a specified column.
mysql_field_count()	Returns the number of result columns for the most recent query.
mysql_field_tell()	Returns the position of the field cursor used for the last `mysql_fetch_field()`.
mysql_free_result()	Frees memory used by a result set.
mysql_get_client_info()	Returns client version information.
mysql_get_host_info()	Returns a string describing the connection.
mysql_get_server_version()	Returns version number of server as an integer (new in 4.1).
mysql_get_proto_info()	Returns the protocol version used by the connection.
mysql_get_server_info()	Returns the server version number.
mysql_info()	Returns information about the most recently executed query.
mysql_init()	Gets or initialises a `MYSQL` structure.
mysql_insert_id()	Returns the ID generated for an `AUTO_INCREMENT` column by the previous query.
mysql_kill()	Kills a given thread.
mysql_list_dbs()	Returns database names matching a simple regular expression.

mysql_list_fields()	Returns field names matching a simple regular expression.
mysql_list_processes()	Returns a list of the current server threads.
mysql_list_tables()	Returns table names matching a simple regular expression.
mysql_num_fields()	Returns the number of columns in a result set.
mysql_num_rows()	Returns the number of rows in a result set.
mysql_options()	Sets connect options for `mysql_connect()`.
mysql_ping()	Checks whether the connection to the server is working, reconnecting as necessary.
mysql_query()	Executes an SQL query specified as a null-terminated string.
mysql_real_connect()	Connects to a MySQL server.
mysql_real_escape_string()	Escapes special characters in a string for use in an SQL statement, taking into account the current charset of the connection.
mysql_real_query()	Executes an SQL query specified as a counted string.
mysql_reload()	Tells the server to reload the grant tables.
mysql_row_seek()	Seeks to a row offset in a result set, using value returned from `mysql_row_tell()`.
mysql_row_tell()	Returns the row cursor position.
mysql_select_db()	Selects a database.
mysql_set_server_option()	Sets an option for the connection (like `multi-statements`).
mysql_sqlstate()	Returns the SQLSTATE error code for the last error.
mysql_shutdown()	Shuts down the database server.
mysql_stat()	Returns the server status as a string.
mysql_store_result()	Retrieves a complete result set to the client.
mysql_thread_id()	Returns the current thread ID.
mysql_thread_safe()	Returns 1 if the clients are compiled as thread-safe.
mysql_use_result()	Initiates a row-by-row result set retrieval.
mysql_commit()	Commits the transaction (new in 4.1).
mysql_rollback()	Rolls back the transaction (new in 4.1).
mysql_autocommit()	Toggles autocommit mode on/off (new in 4.1).

mysql_more_results()	Checks whether any more results exist (new in 4.1).
mysql_next_result()	Returns/Initiates the next result in multi-query executions (new in 4.1).

To connect to the server, call `mysql_init()` to initialise a connection handler, then call `mysql_real_connect()` with that handler (along with other information such as the hostname, user name, and password). Upon connection, `mysql_real_connect()` sets the `reconnect` flag (part of the MYSQL structure) to a value of `1`. This flag indicates, in the event that a query cannot be performed because of a lost connection, to try reconnecting to the server before giving up. When you are done with the connection, call `mysql_close()` to terminate it.

While a connection is active, the client may send SQL queries to the server using `mysql_query()` or `mysql_real_query()`. The difference between the two is that `mysql_query()` expects the query to be specified as a null-terminated string whereas `mysql_real_query()` expects a counted string. If the string contains binary data (which may include null bytes), you must use `mysql_real_query()`.

For each non-`SELECT` query (for example, `INSERT`, `UPDATE`, `DELETE`), you can find out how many rows were changed (affected) by calling `mysql_affected_rows()`.

For `SELECT` queries, you retrieve the selected rows as a result set. (Note that some statements are `SELECT`-like in that they return rows. These include `SHOW`, `DESCRIBE`, and `EXPLAIN`. They should be treated the same way as `SELECT` statements.)

There are two ways for a client to process result sets. One way is to retrieve the entire result set all at once by calling `mysql_store_result()`. This function acquires from the server all the rows returned by the query and stores them in the client. The second way is for the client to initiate a row-by-row result set retrieval by calling `mysql_use_result()`. This function initialises the retrieval, but does not actually get any rows from the server.

In both cases, you access rows by calling `mysql_fetch_row()`. With `mysql_store_result()`, `mysql_fetch_row()` accesses rows that have already been fetched from the server. With `mysql_use_result()`, `mysql_fetch_row()` actually retrieves the row from the server. Information about the size of the data in each row is available by calling `mysql_fetch_lengths()`.

After you are done with a result set, call `mysql_free_result()` to free the memory used for it.

The two retrieval mechanisms are complementary. Client programs should choose the approach that is most appropriate for their requirements. In practice, clients tend to use `mysql_store_result()` more commonly.

An advantage of `mysql_store_result()` is that because the rows have all been fetched to the client, you not only can access rows sequentially, you can move back and forth in the result set using `mysql_data_seek()` or `mysql_row_seek()` to change the current row position within the result set. You can also find out how many rows there are by calling `mysql_num_rows()`. On the other hand, the memory requirements for `mysql_store_result()` may be very high for large result sets and you are more likely to encounter out-of-memory conditions.

An advantage of `mysql_use_result()` is that the client requires less memory for the result set because it maintains only one row at a time (and because there is less allocation overhead,

`mysql_use_result()` can be faster). Disadvantages are that you must process each row quickly to avoid tying up the server, you don't have random access to rows within the result set (you can only access rows sequentially), and you don't know how many rows are in the result set until you have retrieved them all. Furthermore, you **must** retrieve all the rows even if you determine in mid-retrieval that you've found the information you were looking for.

The API makes it possible for clients to respond appropriately to queries (retrieving rows only as necessary) without knowing whether or not the query is a `SELECT`. You can do this by calling `mysql_store_result()` after each `mysql_query()` (or `mysql_real_query()`). If the result set call succeeds, the query was a `SELECT` and you can read the rows. If the result set call fails, call `mysql_field_count()` to determine whether a result was actually to be expected. If `mysql_field_count()` returns zero, the query returned no data (indicating that it was an `INSERT`, `UPDATE`, `DELETE`, etc.), and was not expected to return rows. If `mysql_field_count()` is non-zero, the query should have returned rows, but didn't. This indicates that the query was a `SELECT` that failed. See the description for `mysql_field_count()` for an example of how this can be done.

Both `mysql_store_result()` and `mysql_use_result()` allow you to obtain information about the fields that make up the result set (the number of fields, their names and types, etc.). You can access field information sequentially within the row by calling `mysql_fetch_field()` repeatedly, or by field number within the row by calling `mysql_fetch_field_direct()`. The current field cursor position may be changed by calling `mysql_field_seek()`. Setting the field cursor affects subsequent calls to `mysql_fetch_field()`. You can also get information for fields all at once by calling `mysql_fetch_fields()`.

For detecting and reporting errors, MySQL provides access to error information by means of the `mysql_errno()` and `mysql_error()` functions. These return the error code or error message for the most recently invoked function that can succeed or fail, allowing you to determine when an error occurred and what it was.

11.1.3 C API Function Descriptions

In the descriptions here, a parameter or return value of `NULL` means `NULL` in the sense of the C programming language, not a MySQL `NULL` value.

Functions that return a value generally return a pointer or an integer. Unless specified otherwise, functions returning a pointer return a non-`NULL` value to indicate success or a `NULL` value to indicate an error, and functions returning an integer return zero to indicate success or non-zero to indicate an error. Note that "non-zero" means just that. Unless the function description says otherwise, do not test against a value other than zero:

```
if (result)                  /* correct */
    ... error ...

if (result < 0)              /* incorrect */
    ... error ...

if (result == -1)            /* incorrect */
    ... error ...
```

When a function returns an error, the **Errors** subsection of the function description lists the possible types of errors. You can find out which of these occurred by calling `mysql_errno()`. A string representation of the error may be obtained by calling `mysql_error()`.

11.1.3.1 `mysql_affected_rows()`

```
my_ulonglong mysql_affected_rows(MYSQL *mysql)
```

Description

Returns the number of rows changed by the last `UPDATE`, deleted by the last `DELETE` or inserted by the last `INSERT` statement. May be called immediately after `mysql_query()` for `UPDATE`, `DELETE`, or `INSERT` statements. For `SELECT` statements, `mysql_affected_rows()` works like `mysql_num_rows()`.

Return Values

An integer greater than zero indicates the number of rows affected or retrieved. Zero indicates that no records where updated for an `UPDATE` statement, no rows matched the `WHERE` clause in the query or that no query has yet been executed. -1 indicates that the query returned an error or that, for a `SELECT` query, `mysql_affected_rows()` was called prior to calling `mysql_store_result()`.

Errors

None.

Example

```
mysql_query(&mysql,"UPDATE products SET cost=cost*1.25 WHERE group=10");
printf("%ld products updated",(long) mysql_affected_rows(&mysql));
```

If one specifies the flag `CLIENT_FOUND_ROWS` when connecting to `mysqld`, `mysql_affected_rows()` will return the number of rows matched by the `WHERE` statement for `UPDATE` statements.

Note that when one uses a `REPLACE` command, `mysql_affected_rows()` will return 2 if the new row replaced and old row. This is because in this case one row was inserted after the duplicate was deleted.

11.1.3.2 `mysql_change_user()`

```
my_bool mysql_change_user(MYSQL *mysql, const char *user, const char
*password, const char *db)
```

Description

Changes the user and causes the database specified by `db` to become the default (current) database on the connection specified by `mysql`. In subsequent queries, this database is the default for table references that do not include an explicit database specifier.

This function was introduced in MySQL Version 3.23.3.

`mysql_change_user()` fails unless the connected user can be authenticated or if he doesn't have permission to use the database. In this case the user and database are not changed

The `db` parameter may be set to `NULL` if you don't want to have a default database.

Starting from MySQL 4.0.6 this command will always `ROLLBACK` any active transactions, close all temporary tables, unlock all locked tables and reset the state as if one had done a new connect. This will happen even if the user didn't change.

Return Values

Zero for success. Non-zero if an error occurred.

Errors

The same that you can get from `mysql_real_connect()`.

`CR_COMMANDS_OUT_OF_SYNC`
: Commands were executed in an improper order.

`CR_SERVER_GONE_ERROR`
: The MySQL server has gone away.

`CR_SERVER_LOST`
: The connection to the server was lost during the query.

`CR_UNKNOWN_ERROR`
: An unknown error occurred.

`ER_UNKNOWN_COM_ERROR`
: The MySQL server doesn't implement this command (probably an old server).

`ER_ACCESS_DENIED_ERROR`
: The user or password was wrong.

`ER_BAD_DB_ERROR`
: The database didn't exist.

`ER_DBACCESS_DENIED_ERROR`
: The user did not have access rights to the database.

`ER_WRONG_DB_NAME`
: The database name was too long.

Example

```
if (mysql_change_user(&mysql, "user", "password", "new_database"))
{
   fprintf(stderr, "Failed to change user.  Error: %s\n",
           mysql_error(&mysql));
}
```

11.1.3.3 mysql_character_set_name()

```
const char *mysql_character_set_name(MYSQL *mysql)
```

Description

Returns the default character set for the current connection.

Return Values

The default character set

Errors

None.

11.1.3.4 mysql_close()

```
void mysql_close(MYSQL *mysql)
```

Description

Closes a previously opened connection. `mysql_close()` also deallocates the connection handle pointed to by `mysql` if the handle was allocated automatically by `mysql_init()` or `mysql_connect()`.

Return Values

None.

Errors

None.

11.1.3.5 mysql_connect()

```
MYSQL *mysql_connect(MYSQL *mysql, const char *host, const char *user, const
char *passwd)
```

Description

This function is deprecated. It is preferable to use `mysql_real_connect()` instead.

`mysql_connect()` attempts to establish a connection to a MySQL database engine running on `host`. `mysql_connect()` must complete successfully before you can execute any of the other API functions, with the exception of `mysql_get_client_info()`.

The meanings of the parameters are the same as for the corresponding parameters for `mysql_real_connect()` with the difference that the connection parameter may be `NULL`. In this case the C API allocates memory for the connection structure automatically and frees it when you call `mysql_close()`. The disadvantage of this approach is that you can't retrieve an error message if the connection fails. (To get error information from `mysql_errno()` or `mysql_error()`, you must provide a valid `MYSQL` pointer.)

Return Values

Same as for `mysql_real_connect()`.

Errors

Same as for `mysql_real_connect()`.

11.1.3.6 mysql_create_db()

```
int mysql_create_db(MYSQL *mysql, const char *db)
```

Description

Creates the database named by the `db` parameter.

This function is deprecated. It is preferable to use `mysql_query()` to issue an SQL `CREATE DATABASE` statement instead.

Return Values

Zero if the database was created successfully. Non-zero if an error occurred.

Errors

`CR_COMMANDS_OUT_OF_SYNC`
: Commands were executed in an improper order.

`CR_SERVER_GONE_ERROR`
: The MySQL server has gone away.

`CR_SERVER_LOST`
: The connection to the server was lost during the query.

`CR_UNKNOWN_ERROR`
: An unknown error occurred.

Example

```
if(mysql_create_db(&mysql, "my_database"))
{
   fprintf(stderr, "Failed to create new database.  Error: %s\n",
           mysql_error(&mysql));
}
```

11.1.3.7 mysql_data_seek()

`void mysql_data_seek(MYSQL_RES *result, my_ulonglong offset)`

Description

Seeks to an arbitrary row in a query result set. The `offset` value is a row number and should be in the range from `0` to `mysql_num_rows(stmt)-1`.

This function requires that the result set structure contains the entire result of the query, so `mysql_data_seek()` may be used only in conjunction with `mysql_store_result()`, not with `mysql_use_result()`.

Return Values

None.

Errors

None.

11.1.3.8 mysql_debug()

`void mysql_debug(const char *debug)`

Description

Does a `DBUG_PUSH` with the given string. `mysql_debug()` uses the Fred Fish debug library. To use this function, you must compile the client library to support debugging. See Section E.1 [Debugging server], page 1007. See Section E.2 [Debugging client], page 1012.

Return Values

None.

Errors

None.

Example

The call shown here causes the client library to generate a trace file in '`/tmp/client.trace`' on the client machine:

```
mysql_debug("d:t:O,/tmp/client.trace");
```

11.1.3.9 mysql_drop_db()

```
int mysql_drop_db(MYSQL *mysql, const char *db)
```

Description

Drops the database named by the `db` parameter.

This function is deprecated. It is preferable to use `mysql_query()` to issue an SQL `DROP DATABASE` statement instead.

Return Values

Zero if the database was dropped successfully. Non-zero if an error occurred.

Errors

`CR_COMMANDS_OUT_OF_SYNC`
: Commands were executed in an improper order.

`CR_SERVER_GONE_ERROR`
: The MySQL server has gone away.

`CR_SERVER_LOST`
: The connection to the server was lost during the query.

`CR_UNKNOWN_ERROR`
: An unknown error occurred.

Example

```
if(mysql_drop_db(&mysql, "my_database"))
  fprintf(stderr, "Failed to drop the database: Error: %s\n",
          mysql_error(&mysql));
```

11.1.3.10 mysql_dump_debug_info()

```
int mysql_dump_debug_info(MYSQL *mysql)
```

Description

Instructs the server to write some debug information to the log. For this to work, the connected user must have the `SUPER` privilege.

Return Values

Zero if the command was successful. Non-zero if an error occurred.

Errors

`CR_COMMANDS_OUT_OF_SYNC`
: Commands were executed in an improper order.

`CR_SERVER_GONE_ERROR`
: The MySQL server has gone away.

`CR_SERVER_LOST`
: The connection to the server was lost during the query.

`CR_UNKNOWN_ERROR`
: An unknown error occurred.

11.1.3.11 `mysql_eof()`

```
my_bool mysql_eof(MYSQL_RES *result)
```

Description

This function is deprecated. `mysql_errno()` or `mysql_error()` may be used instead.

`mysql_eof()` determines whether the last row of a result set has been read.

If you acquire a result set from a successful call to `mysql_store_result()`, the client receives the entire set in one operation. In this case, a `NULL` return from `mysql_fetch_row()` always means the end of the result set has been reached and it is unnecessary to call `mysql_eof()`. When used with `mysql_store_result()`, `mysql_eof()` will always return true.

On the other hand, if you use `mysql_use_result()` to initiate a result set retrieval, the rows of the set are obtained from the server one by one as you call `mysql_fetch_row()` repeatedly. Because an error may occur on the connection during this process, a `NULL` return value from `mysql_fetch_row()` does not necessarily mean the end of the result set was reached normally. In this case, you can use `mysql_eof()` to determine what happened. `mysql_eof()` returns a non-zero value if the end of the result set was reached and zero if an error occurred.

Historically, `mysql_eof()` predates the standard MySQL error functions `mysql_errno()` and `mysql_error()`. Because those error functions provide the same information, their use is preferred over `mysql_eof()`, which is now deprecated. (In fact, they provide more information, because `mysql_eof()` returns only a boolean value whereas the error functions indicate a reason for the error when one occurs.)

Return Values

Zero if no error occurred. Non-zero if the end of the result set has been reached.

Errors

None.

Example

The following example shows how you might use `mysql_eof()`:

```
mysql_query(&mysql,"SELECT * FROM some_table");
result = mysql_use_result(&mysql);
while((row = mysql_fetch_row(result)))
{
    // do something with data
}
if(!mysql_eof(result))  // mysql_fetch_row() failed due to an error
{
    fprintf(stderr, "Error: %s\n", mysql_error(&mysql));
}
```

However, you can achieve the same effect with the standard MySQL error functions:

```
mysql_query(&mysql,"SELECT * FROM some_table");
result = mysql_use_result(&mysql);
while((row = mysql_fetch_row(result)))
{
    // do something with data
}
if(mysql_errno(&mysql))  // mysql_fetch_row() failed due to an error
{
    fprintf(stderr, "Error: %s\n", mysql_error(&mysql));
}
```

11.1.3.12 `mysql_errno()`

`unsigned int mysql_errno(MYSQL *mysql)`

Description

For the connection specified by `mysql`, `mysql_errno()` returns the error code for the most recently invoked API function that can succeed or fail. A return value of zero means that no error occurred. Client error message numbers are listed in the MySQL '`errmsg.h`' header file. Server error message numbers are listed in '`mysqld_error.h`'. In the MySQL source distribution you can find a complete list of error messages and error numbers in the file '`Docs/mysqld_error.txt`'. The server error codes also are listed at Section 12.1 [Error-returns], page 825.

Note that some functions like `mysql_fetch_row()` don't set `mysql_errno()` if they succeed.

A rule of thumb is that all functions that have to ask the server for information will reset `mysql_errno()` if they succeed.

Return Values

An error code value for the last mysql_xxx call, if it failed. zero means no error occurred.

Errors

None.

11.1.3.13 mysql_error()

```
const char *mysql_error(MYSQL *mysql)
```

Description

For the connection specified by `mysql`, `mysql_error()` returns a null-terminated string containing the error message for the most recently invoked API function that failed. If a function didn't fail, the return value of `mysql_error()` may be the previous error or an empty string to indicate no error.

A rule of thumb is that all functions that have to ask the server for information will reset `mysql_error()` if they succeed.

For functions that resets `mysql_errno`, the following two tests are equivalent:

```
if(mysql_errno(&mysql))
{
    // an error occurred
}

if(mysql_error(&mysql)[0] != '\0')
{
    // an error occurred
}
```

The language of the client error messages may be changed by recompiling the MySQL client library. Currently you can choose error messages in several different languages. See Section 4.7.2 [Languages], page 307.

Return Values

A null-terminated character string that describes the error. An empty string if no error occurred.

Errors

None.

11.1.3.14 mysql_escape_string()

You should use `mysql_real_escape_string()` instead!

This function is identical to `mysql_real_escape_string()` except that `mysql_real_escape_string()` takes a connection handler as its first argument and escapes the string according to the current character set. `mysql_escape_string()` does not take a connection argument and does not respect the current charset setting.

11.1.3.15 mysql_fetch_field()

```
MYSQL_FIELD *mysql_fetch_field(MYSQL_RES *result)
```

Description

Returns the definition of one column of a result set as a `MYSQL_FIELD` structure. Call this function repeatedly to retrieve information about all columns in the result set. `mysql_fetch_field()` returns `NULL` when no more fields are left.

`mysql_fetch_field()` is reset to return information about the first field each time you execute a new `SELECT` query. The field returned by `mysql_fetch_field()` is also affected by calls to `mysql_field_seek()`.

If you've called `mysql_query()` to perform a `SELECT` on a table but have not called `mysql_store_result()`, MySQL returns the default blob length (8K bytes) if you call `mysql_fetch_field()` to ask for the length of a `BLOB` field. (The 8K size is chosen because MySQL doesn't know the maximum length for the `BLOB`. This should be made configurable sometime.) Once you've retrieved the result set, `field->max_length` contains the length of the largest value for this column in the specific query.

Return Values

The `MYSQL_FIELD` structure for the current column. `NULL` if no columns are left.

Errors

None.

Example

```
MYSQL_FIELD *field;

while((field = mysql_fetch_field(result)))
{
    printf("field name %s\n", field->name);
}
```

11.1.3.16 mysql_fetch_fields()

```
MYSQL_FIELD *mysql_fetch_fields(MYSQL_RES *result)
```

Description

Returns an array of all `MYSQL_FIELD` structures for a result set. Each structure provides the field definition for one column of the result set.

Return Values

An array of `MYSQL_FIELD` structures for all columns of a result set.

Errors

None.

Example

```
unsigned int num_fields;
unsigned int i;
MYSQL_FIELD *fields;

num_fields = mysql_num_fields(result);
fields = mysql_fetch_fields(result);
for(i = 0; i < num_fields; i++)
{
   printf("Field %u is %s\n", i, fields[i].name);
}
```

11.1.3.17 mysql_fetch_field_direct()

```
MYSQL_FIELD *mysql_fetch_field_direct(MYSQL_RES *result, unsigned int
fieldnr)
```

Description

Given a field number `fieldnr` for a column within a result set, returns that column's field definition as a `MYSQL_FIELD` structure. You may use this function to retrieve the definition for an arbitrary column. The value of `fieldnr` should be in the range from 0 to `mysql_num_fields(result)-1`.

Return Values

The `MYSQL_FIELD` structure for the specified column.

Errors

None.

Example

```
unsigned int num_fields;
unsigned int i;
MYSQL_FIELD *field;

num_fields = mysql_num_fields(result);
for(i = 0; i < num_fields; i++)
{
    field = mysql_fetch_field_direct(result, i);
    printf("Field %u is %s\n", i, field->name);
}
```

11.1.3.18 mysql_fetch_lengths()

```
unsigned long *mysql_fetch_lengths(MYSQL_RES *result)
```

Description

Returns the lengths of the columns of the current row within a result set. If you plan to copy field values, this length information is also useful for optimisation, because you can avoid calling `strlen()`. In addition, if the result set contains binary data, you **must** use this function to determine the size of the data, because `strlen()` returns incorrect results for any field containing null characters.

The length for empty columns and for columns containing `NULL` values is zero. To see how to distinguish these two cases, see the description for `mysql_fetch_row()`.

Return Values

An array of unsigned long integers representing the size of each column (not including any terminating null characters). `NULL` if an error occurred.

Errors

`mysql_fetch_lengths()` is valid only for the current row of the result set. It returns `NULL` if you call it before calling `mysql_fetch_row()` or after retrieving all rows in the result.

Example

```
MYSQL_ROW row;
unsigned long *lengths;
```

```
unsigned int num_fields;
unsigned int i;

row = mysql_fetch_row(result);
if (row)
{
    num_fields = mysql_num_fields(result);
    lengths = mysql_fetch_lengths(result);
    for(i = 0; i < num_fields; i++)
    {
         printf("Column %u is %lu bytes in length.\n", i, lengths[i]);
    }
}
```

11.1.3.19 mysql_fetch_row()

`MYSQL_ROW mysql_fetch_row(MYSQL_RES *result)`

Description

Retrieves the next row of a result set. When used after `mysql_store_result()`, `mysql_fetch_row()` returns `NULL` when there are no more rows to retrieve. When used after `mysql_use_result()`, `mysql_fetch_row()` returns `NULL` when there are no more rows to retrieve or if an error occurred.

The number of values in the row is given by `mysql_num_fields(result)`. If `row` holds the return value from a call to `mysql_fetch_row()`, pointers to the values are accessed as `row[0]` to `row[mysql_num_fields(result)-1]`. `NULL` values in the row are indicated by `NULL` pointers.

The lengths of the field values in the row may be obtained by calling `mysql_fetch_lengths()`. Empty fields and fields containing `NULL` both have length 0; you can distinguish these by checking the pointer for the field value. If the pointer is `NULL`, the field is `NULL`; otherwise, the field is empty.

Return Values

A `MYSQL_ROW` structure for the next row. `NULL` if there are no more rows to retrieve or if an error occurred.

Errors

Note that error is not reset between calls to `mysql_fetch_row()`

`CR_SERVER_LOST`
: The connection to the server was lost during the query.

`CR_UNKNOWN_ERROR`
: An unknown error occurred.

Example

```
MYSQL_ROW row;
unsigned int num_fields;
unsigned int i;

num_fields = mysql_num_fields(result);
while ((row = mysql_fetch_row(result)))
{
   unsigned long *lengths;
   lengths = mysql_fetch_lengths(result);
   for(i = 0; i < num_fields; i++)
   {
       printf("[%.*s] ", (int) lengths[i], row[i] ? row[i] : "NULL");
   }
   printf("\n");
}
```

11.1.3.20 mysql_field_count()

`unsigned int mysql_field_count(MYSQL *mysql)`

If you are using a version of MySQL earlier than Version 3.22.24, you should use `unsigned int mysql_num_fields(MYSQL *mysql)` instead.

Description

Returns the number of columns for the most recent query on the connection.

The normal use of this function is when `mysql_store_result()` returned `NULL` (and thus you have no result set pointer). In this case, you can call `mysql_field_count()` to determine whether `mysql_store_result()` should have produced a non-empty result. This allows the client program to take proper action without knowing whether the query was a `SELECT` (or `SELECT`-like) statement. The example shown here illustrates how this may be done.

See Section 11.1.12.1 [`NULL mysql_store_result()`], page 797.

Return Values

An unsigned integer representing the number of fields in a result set.

Errors

None.

Example

```
MYSQL_RES *result;
unsigned int num_fields;
unsigned int num_rows;

if (mysql_query(&mysql,query_string))
{
    // error
}
else // query succeeded, process any data returned by it
{
    result = mysql_store_result(&mysql);
    if (result)  // there are rows
    {
        num_fields = mysql_num_fields(result);
        // retrieve rows, then call mysql_free_result(result)
    }
    else  // mysql_store_result() returned nothing; should it have?
    {
        if(mysql_field_count(&mysql) == 0)
        {
            // query does not return data
            // (it was not a SELECT)
            num_rows = mysql_affected_rows(&mysql);
        }
        else // mysql_store_result() should have returned data
        {
            fprintf(stderr, "Error: %s\n", mysql_error(&mysql));
        }
    }
}
```

An alternative is to replace the `mysql_field_count(&mysql)` call with `mysql_errno(&mysql)`. In this case, you are checking directly for an error from `mysql_store_result()` rather than inferring from the value of `mysql_field_count()` whether the statement was a `SELECT`.

11.1.3.21 mysql_field_seek()

```
MYSQL_FIELD_OFFSET mysql_field_seek(MYSQL_RES *result, MYSQL_FIELD_OFFSET
offset)
```

Description

Sets the field cursor to the given offset. The next call to `mysql_fetch_field()` will retrieve the field definition of the column associated with that offset.

To seek to the beginning of a row, pass an `offset` value of zero.

Return Values

The previous value of the field cursor.

Errors

None.

11.1.3.22 `mysql_field_tell()`

```
MYSQL_FIELD_OFFSET mysql_field_tell(MYSQL_RES *result)
```

Description

Returns the position of the field cursor used for the last `mysql_fetch_field()`. This value can be used as an argument to `mysql_field_seek()`.

Return Values

The current offset of the field cursor.

Errors

None.

11.1.3.23 `mysql_free_result()`

```
void mysql_free_result(MYSQL_RES *result)
```

Description

Frees the memory allocated for a result set by `mysql_store_result()`, `mysql_use_result()`, `mysql_list_dbs()`, etc. When you are done with a result set, you must free the memory it uses by calling `mysql_free_result()`.

Return Values

None.

Errors

None.

11.1.3.24 mysql_get_client_info()

```
char *mysql_get_client_info(void)
```

Description

Returns a string that represents the client library version.

Return Values

A character string that represents the MySQL client library version.

Errors

None.

11.1.3.25 mysql_get_server_version()

```
unsigned long mysql_get_server_version(MYSQL *mysql)
```

Description

Returns version number of server as an integer (new in 4.1).

Return Values

A number that represents the MySQL server version in format:

main_version*10000 + minor_version *100 + sub_version

For example, 4.1.0 is returned as 40100.

This is useful to quickly determine the version of the server in a client program to know if some capability exits.

Errors

None.

11.1.3.26 mysql_get_host_info()

```
char *mysql_get_host_info(MYSQL *mysql)
```

Description

Returns a string describing the type of connection in use, including the server host name.

Return Values

A character string representing the server host name and the connection type.

Errors

None.

11.1.3.27 mysql_get_proto_info()

```
unsigned int mysql_get_proto_info(MYSQL *mysql)
```

Description

Returns the protocol version used by current connection.

Return Values

An unsigned integer representing the protocol version used by the current connection.

Errors

None.

11.1.3.28 mysql_get_server_info()

```
char *mysql_get_server_info(MYSQL *mysql)
```

Description

Returns a string that represents the server version number.

Return Values

A character string that represents the server version number.

Errors

None.

11.1.3.29 mysql_info()

```
char *mysql_info(MYSQL *mysql)
```

Description

Retrieves a string providing information about the most recently executed query, but only for the statements listed here. For other statements, `mysql_info()` returns `NULL`. The format of the string varies depending on the type of query, as described here. The numbers are illustrative only; the string will contain values appropriate for the query.

`INSERT INTO ... SELECT ...`
String format: `Records: 100 Duplicates: 0 Warnings: 0`

`INSERT INTO ... VALUES (...),(...),(...)...`
String format: `Records: 3 Duplicates: 0 Warnings: 0`

`LOAD DATA INFILE ...`
String format: `Records: 1 Deleted: 0 Skipped: 0 Warnings: 0`

`ALTER TABLE`
String format: `Records: 3 Duplicates: 0 Warnings: 0`

`UPDATE` String format: `Rows matched: 40 Changed: 40 Warnings: 0`

Note that `mysql_info()` returns a non-`NULL` value for `INSERT ... VALUES` only for the multiple-row form of the statement (that is, only if multiple value lists are specified).

Return Values

A character string representing additional information about the most recently executed query. `NULL` if no information is available for the query.

Errors

None.

11.1.3.30 `mysql_init()`

```
MYSQL *mysql_init(MYSQL *mysql)
```

Description

Allocates or initialises a `MYSQL` object suitable for `mysql_real_connect()`. If `mysql` is a `NULL` pointer, the function allocates, initialises, and returns a new object. Otherwise, the object is initialised and the address of the object is returned. If `mysql_init()` allocates a new object, it will be freed when `mysql_close()` is called to close the connection.

Return Values

An initialised `MYSQL*` handle. `NULL` if there was insufficient memory to allocate a new object.

Errors

In case of insufficient memory, `NULL` is returned.

11.1.3.31 mysql_insert_id()

```
my_ulonglong mysql_insert_id(MYSQL *mysql)
```

Description

Returns the ID generated for an `AUTO_INCREMENT` column by the previous query. Use this function after you have performed an `INSERT` query into a table that contains an `AUTO_INCREMENT` field.

Note that `mysql_insert_id()` returns `0` if the previous query does not generate an `AUTO_INCREMENT` value. If you need to save the value for later, be sure to call `mysql_insert_id()` immediately after the query that generates the value.

If the previous query returned an error, the value of `mysql_insert_id()` is undefined.

`mysql_insert_id()` is updated after `INSERT` and `UPDATE` statements that generate an `AUTO_INCREMENT` value or that set a column value to `LAST_INSERT_ID(expr)`. See Section 6.3.6.2 [Miscellaneous functions], page 515.

Also note that the value of the SQL `LAST_INSERT_ID()` function always contains the most recently generated `AUTO_INCREMENT` value, and is not reset between queries because the value of that function is maintained in the server.

Return Values

The value of the `AUTO_INCREMENT` field that was updated by the previous query. Returns zero if there was no previous query on the connection or if the query did not update an `AUTO_INCREMENT` value.

Errors

None.

11.1.3.32 mysql_kill()

```
int mysql_kill(MYSQL *mysql, unsigned long pid)
```

Description

Asks the server to kill the thread specified by `pid`.

Return Values

Zero for success. Non-zero if an error occurred.

Errors

`CR_COMMANDS_OUT_OF_SYNC`
Commands were executed in an improper order.

`CR_SERVER_GONE_ERROR`
The MySQL server has gone away.

`CR_SERVER_LOST`
The connection to the server was lost during the query.

`CR_UNKNOWN_ERROR`
An unknown error occurred.

11.1.3.33 mysql_list_dbs()

```
MYSQL_RES *mysql_list_dbs(MYSQL *mysql, const char *wild)
```

Description

Returns a result set consisting of database names on the server that match the simple regular expression specified by the `wild` parameter. `wild` may contain the wildcard characters '`%`' or '`_`', or may be a `NULL` pointer to match all databases. Calling `mysql_list_dbs()` is similar to executing the query `SHOW databases [LIKE wild]`.

You must free the result set with `mysql_free_result()`.

Return Values

A `MYSQL_RES` result set for success. `NULL` if an error occurred.

Errors

`CR_COMMANDS_OUT_OF_SYNC`
Commands were executed in an improper order.

`CR_OUT_OF_MEMORY`
Out of memory.

`CR_SERVER_GONE_ERROR`
The MySQL server has gone away.

`CR_SERVER_LOST`
The connection to the server was lost during the query.

`CR_UNKNOWN_ERROR`
An unknown error occurred.

11.1.3.34 mysql_list_fields()

```
MYSQL_RES *mysql_list_fields(MYSQL *mysql, const char *table, const char
*wild)
```

Description

Returns a result set consisting of field names in the given table that match the simple regular expression specified by the `wild` parameter. `wild` may contain the wildcard characters '`%`' or '`_`', or may be a `NULL` pointer to match all fields. Calling `mysql_list_fields()` is similar to executing the query `SHOW COLUMNS FROM tbl_name [LIKE wild]`.

Note that it's recommended that you use `SHOW COLUMNS FROM tbl_name` instead of `mysql_list_fields()`.

You must free the result set with `mysql_free_result()`.

Return Values

A `MYSQL_RES` result set for success. `NULL` if an error occurred.

Errors

`CR_COMMANDS_OUT_OF_SYNC`
: Commands were executed in an improper order.

`CR_SERVER_GONE_ERROR`
: The MySQL server has gone away.

`CR_SERVER_LOST`
: The connection to the server was lost during the query.

`CR_UNKNOWN_ERROR`
: An unknown error occurred.

11.1.3.35 `mysql_list_processes()`

```
MYSQL_RES *mysql_list_processes(MYSQL *mysql)
```

Description

Returns a result set describing the current server threads. This is the same kind of information as that reported by `mysqladmin processlist` or a `SHOW PROCESSLIST` query.

You must free the result set with `mysql_free_result()`.

Return Values

A `MYSQL_RES` result set for success. `NULL` if an error occurred.

Errors

`CR_COMMANDS_OUT_OF_SYNC`
Commands were executed in an improper order.

`CR_SERVER_GONE_ERROR`
The MySQL server has gone away.

`CR_SERVER_LOST`
The connection to the server was lost during the query.

`CR_UNKNOWN_ERROR`
An unknown error occurred.

11.1.3.36 mysql_list_tables()

```
MYSQL_RES *mysql_list_tables(MYSQL *mysql, const char *wild)
```

Description

Returns a result set consisting of table names in the current database that match the simple regular expression specified by the `wild` parameter. `wild` may contain the wildcard characters '`%`' or '`_`', or may be a `NULL` pointer to match all tables. Calling `mysql_list_tables()` is similar to executing the query `SHOW tables [LIKE wild]`.

You must free the result set with `mysql_free_result()`.

Return Values

A `MYSQL_RES` result set for success. `NULL` if an error occurred.

Errors

`CR_COMMANDS_OUT_OF_SYNC`
Commands were executed in an improper order.

`CR_SERVER_GONE_ERROR`
The MySQL server has gone away.

`CR_SERVER_LOST`
The connection to the server was lost during the query.

`CR_UNKNOWN_ERROR`
An unknown error occurred.

11.1.3.37 mysql_num_fields()

```
unsigned int mysql_num_fields(MYSQL_RES *result)
```

or

`unsigned int mysql_num_fields(MYSQL *mysql)`

The second form doesn't work on MySQL Version 3.22.24 or newer. To pass a `MYSQL*` argument, you must use `unsigned int mysql_field_count(MYSQL *mysql)` instead.

Description

Returns the number of columns in a result set.

Note that you can get the number of columns either from a pointer to a result set or to a connection handle. You would use the connection handle if `mysql_store_result()` or `mysql_use_result()` returned `NULL` (and thus you have no result set pointer). In this case, you can call `mysql_field_count()` to determine whether `mysql_store_result()` should have produced a non-empty result. This allows the client program to take proper action without knowing whether or not the query was a `SELECT` (or `SELECT`-like) statement. The example shown here illustrates how this may be done.

See Section 11.1.12.1 [`NULL mysql_store_result()`], page 797.

Return Values

An unsigned integer representing the number of fields in a result set.

Errors

None.

Example

```
MYSQL_RES *result;
unsigned int num_fields;
unsigned int num_rows;

if (mysql_query(&mysql,query_string))
{
    // error
}
else // query succeeded, process any data returned by it
{
    result = mysql_store_result(&mysql);
    if (result)  // there are rows
    {
        num_fields = mysql_num_fields(result);
        // retrieve rows, then call mysql_free_result(result)
    }
    else  // mysql_store_result() returned nothing; should it have?
    {
        if (mysql_errno(&mysql))
```

```
            {
               fprintf(stderr, "Error: %s\n", mysql_error(&mysql));
            }
            else if (mysql_field_count(&mysql) == 0)
            {
                // query does not return data
                // (it was not a SELECT)
                num_rows = mysql_affected_rows(&mysql);
            }
        }
    }
```

An alternative (if you know that your query should have returned a result set) is to replace the `mysql_errno(&mysql)` call with a check if `mysql_field_count(&mysql)` is = 0. This will only happen if something went wrong.

11.1.3.38 mysql_num_rows()

```
my_ulonglong mysql_num_rows(MYSQL_RES *result)
```

Description

Returns the number of rows in the result set.

The use of `mysql_num_rows()` depends on whether you use `mysql_store_result()` or `mysql_use_result()` to return the result set. If you use `mysql_store_result()`, `mysql_num_rows()` may be called immediately. If you use `mysql_use_result()`, `mysql_num_rows()` will not return the correct value until all the rows in the result set have been retrieved.

Return Values

The number of rows in the result set.

Errors

None.

11.1.3.39 mysql_options()

```
int mysql_options(MYSQL *mysql, enum mysql_option option, const char *arg)
```

Description

Can be used to set extra connect options and affect behaviour for a connection. This function may be called multiple times to set several options.

`mysql_options()` should be called after `mysql_init()` and before `mysql_connect()` or `mysql_real_connect()`.

The `option` argument is the option that you want to set; the `arg` argument is the value for the option. If the option is an integer, then `arg` should point to the value of the integer.

Possible options values:

Option	Argument type	Function
`MYSQL_OPT_CONNECT_TIMEOUT`	`unsigned int *`	Connect timeout in seconds.
`MYSQL_OPT_COMPRESS`	Not used	Use the compressed client/server protocol.
`MYSQL_OPT_LOCAL_INFILE`	optional pointer to uint	If no pointer is given or if pointer points to an `unsigned int != 0` the command `LOAD LOCAL INFILE` is enabled.
`MYSQL_OPT_NAMED_PIPE`	Not used	Use named pipes to connect to a MySQL server on NT.
`MYSQL_INIT_COMMAND`	`char *`	Command to execute when connecting to the MySQL server. Will automatically be re-executed when reconnecting.
`MYSQL_READ_DEFAULT_FILE`	`char *`	Read options from the named option file instead of from '`my.cnf`'.
`MYSQL_READ_DEFAULT_GROUP`	`char *`	Read options from the named group from '`my.cnf`' or the file specified with `MYSQL_READ_DEFAULT_FILE`.

Note that the group `client` is always read if you use `MYSQL_READ_DEFAULT_FILE` or `MYSQL_READ_DEFAULT_GROUP`.

The specified group in the option file may contain the following options:

Option	Description
`connect-timeout`	Connect timeout in seconds. On Linux this timeout is also used for waiting for the first answer from the server.
`compress`	Use the compressed client/server protocol.
`database`	Connect to this database if no database was specified in the connect command.
`debug`	Debug options.
`disable-local-infile`	Disable use of `LOAD DATA LOCAL`.
`host`	Default host name.
`init-command`	Command to execute when connecting to MySQL server. Will automatically be re-executed when reconnecting.
`interactive-timeout`	Same as specifying `CLIENT_INTERACTIVE` to `mysql_real_connect()`. See Section 11.1.3.42 [mysql_real_connect], page 752.
`local-infile[=(0|1)]`	If no argument or argument != 0 then enable use of `LOAD DATA LOCAL`.

`max_allowed_packet`	Max size of packet client can read from server.
`password`	Default password.
`pipe`	Use named pipes to connect to a MySQL server on NT.
`protocol=(TCP | SOCKET | PIPE | MEMORY)`	Which protocol to use when connecting to server (New in 4.1)
`port`	Default port number.
`return-found-rows`	Tell `mysql_info()` to return found rows instead of updated rows when using `UPDATE`.
`shared-memory-base-name=name`	Shared memory name to use to connect to server (default is "MySQL"). New in MySQL 4.1.
`socket`	Default socket number.
`user`	Default user.

Note that `timeout` has been replaced by `connect-timeout`, but `timeout` will still work for a while.

For more information about option files, see Section 4.1.2 [Option files], page 203.

Return Values

Zero for success. Non-zero if you used an unknown option.

Example

```
MYSQL mysql;

mysql_init(&mysql);
mysql_options(&mysql,MYSQL_OPT_COMPRESS,0);
mysql_options(&mysql,MYSQL_READ_DEFAULT_GROUP,"odbc");
if (!mysql_real_connect(&mysql,"host","user","passwd","database",0,NULL,0))
{
    fprintf(stderr, "Failed to connect to database: Error: %s\n",
          mysql_error(&mysql));
}
```

The above requests the client to use the compressed client/server protocol and read the additional options from the `odbc` section in the '`my.cnf`' file.

11.1.3.40 `mysql_ping()`

```
int mysql_ping(MYSQL *mysql)
```

Description

Checks whether the connection to the server is working. If it has gone down, an automatic reconnection is attempted.

This function can be used by clients that remain idle for a long while, to check whether the server has closed the connection and reconnect if necessary.

Return Values

Zero if the server is alive. Non-zero if an error occurred.

Errors

`CR_COMMANDS_OUT_OF_SYNC`
: Commands were executed in an improper order.

`CR_SERVER_GONE_ERROR`
: The MySQL server has gone away.

`CR_UNKNOWN_ERROR`
: An unknown error occurred.

11.1.3.41 `mysql_query()`

```
int mysql_query(MYSQL *mysql, const char *query)
```

Description

Executes the SQL query pointed to by the null-terminated string `query`. The query must consist of a single SQL statement. You should not add a terminating semicolon (‘`;`’) or `\g` to the statement.

`mysql_query()` cannot be used for queries that contain binary data; you should use `mysql_real_query()` instead. (Binary data may contain the ‘`\0`’ character, which `mysql_query()` interprets as the end of the query string.)

If you want to know if the query should return a result set or not, you can use `mysql_field_count()` to check for this. See Section 11.1.3.20 [`mysql_field_count()`], page 737.

Return Values

Zero if the query was successful. Non-zero if an error occurred.

Errors

`CR_COMMANDS_OUT_OF_SYNC`
: Commands were executed in an improper order.

`CR_SERVER_GONE_ERROR`
: The MySQL server has gone away.

`CR_SERVER_LOST`
: The connection to the server was lost during the query.

`CR_UNKNOWN_ERROR`
: An unknown error occurred.

11.1.3.42 mysql_real_connect()

```
MYSQL *mysql_real_connect(MYSQL *mysql, const char *host, const char *user,
const char *passwd, const char *db, unsigned int port, const char *unix_socket,
unsigned long client_flag)
```

Description

`mysql_real_connect()` attempts to establish a connection to a MySQL database engine running on `host`. `mysql_real_connect()` must complete successfully before you can execute any of the other API functions, with the exception of `mysql_get_client_info()`.

The parameters are specified as follows:

- The first parameter should be the address of an existing `MYSQL` structure. Before calling `mysql_real_connect()` you must call `mysql_init()` to initialise the `MYSQL` structure. You can change a lot of connect options with the `mysql_options()` call. See Section 11.1.3.39 [mysql_options], page 748.
- The value of `host` may be either a hostname or an IP address. If `host` is `NULL` or the string `"localhost"`, a connection to the local host is assumed. If the OS supports sockets (Unix) or named pipes (Windows), they are used instead of TCP/IP to connect to the server.
- The `user` parameter contains the user's MySQL login ID. If `user` is `NULL` or the empty string `""`, the current user is assumed. Under Unix, this is the current login name. Under Windows ODBC, the current user name must be specified explicitly. See Section 11.2.2 [ODBC administrator], page 807.
- The `passwd` parameter contains the password for `user`. If `passwd` is `NULL`, only entries in the `user` table for the user that have a blank (empty) password field will be checked for a match. This allows the database administrator to set up the MySQL privilege system in such a way that users get different privileges depending on whether or not they have specified a password.

  Note: Do not attempt to encrypt the password before calling `mysql_real_connect()`; password encryption is handled automatically by the client API.
- `db` is the database name. If `db` is not `NULL`, the connection will set the default database to this value.
- If `port` is not 0, the value will be used as the port number for the TCP/IP connection. Note that the `host` parameter determines the type of the connection.
- If `unix_socket` is not `NULL`, the string specifies the socket or named pipe that should be used. Note that the `host` parameter determines the type of the connection.
- The value of `client_flag` is usually 0, but can be set to a combination of the following flags in very special circumstances:

Flag name	Flag description
`CLIENT_COMPRESS`	Use compression protocol.
`CLIENT_FOUND_ROWS`	Return the number of found (matched) rows, not the number of affected rows.
`CLIENT_IGNORE_SPACE`	Allow spaces after function names. Makes all functions names reserved words.

`CLIENT_INTERACTIVE`	Allow `interactive_timeout` seconds (instead of `wait_timeout` seconds) of inactivity before closing the connection.
`CLIENT_LOCAL_FILES`	Enable `LOAD DATA LOCAL` handling.
`CLIENT_MULTI_STATEMENTS`	Tell the server that the client may send multi-row-queries (separated with '`;`'). If this flag is not set, multi-row-queries are disabled. New in 4.1.
`CLIENT_MULTI_RESULTS`	Tell the server that the client can handle multiple-result sets from multi-queries or stored procedures. This is automatically set if `CLIENT_MULTI_STATEMENTS` is set. New in 4.1.
`CLIENT_NO_SCHEMA`	Don't allow the `db_name.tbl_name.col_name` syntax. This is for ODBC. It causes the parser to generate an error if you use that syntax, which is useful for trapping bugs in some ODBC programs.
`CLIENT_ODBC`	The client is an ODBC client. This changes `mysqld` to be more ODBC-friendly.
`CLIENT_SSL`	Use SSL (encrypted protocol). This option should not be set by application programs; it is set internally in the client library.

Return Values

A `MYSQL*` connection handle if the connection was successful, `NULL` if the connection was unsuccessful. For a successful connection, the return value is the same as the value of the first parameter.

Errors

`CR_CONN_HOST_ERROR`
: Failed to connect to the MySQL server.

`CR_CONNECTION_ERROR`
: Failed to connect to the local MySQL server.

`CR_IPSOCK_ERROR`
: Failed to create an IP socket.

`CR_OUT_OF_MEMORY`
: Out of memory.

`CR_SOCKET_CREATE_ERROR`
: Failed to create a Unix socket.

`CR_UNKNOWN_HOST`
: Failed to find the IP address for the hostname.

`CR_VERSION_ERROR`
: A protocol mismatch resulted from attempting to connect to a server with a client library that uses a different protocol version. This can happen if you use a very old client library to connect to a new server that wasn't started with the `--old-protocol` option.

`CR_NAMEDPIPEOPEN_ERROR`
: Failed to create a named pipe on Windows.

`CR_NAMEDPIPEWAIT_ERROR`
: Failed to wait for a named pipe on Windows.

`CR_NAMEDPIPESETSTATE_ERROR`
: Failed to get a pipe handler on Windows.

`CR_SERVER_LOST`
: If `connect_timeout` > 0 and it took longer than `connect_timeout` seconds to connect to the server or if the server died while executing the `init-command`.

Example

```
MYSQL mysql;

mysql_init(&mysql);
mysql_options(&mysql,MYSQL_READ_DEFAULT_GROUP,"your_prog_name");
if (!mysql_real_connect(&mysql,"host","user","passwd","database",0,NULL,0))
{
    fprintf(stderr, "Failed to connect to database: Error: %s\n",
          mysql_error(&mysql));
}
```

By using `mysql_options()` the MySQL library will read the `[client]` and `[your_prog_name]` sections in the '`my.cnf`' file which will ensure that your program will work, even if someone has set up MySQL in some non-standard way.

Note that upon connection, `mysql_real_connect()` sets the `reconnect` flag (part of the `MYSQL` structure) to a value of `1`. This flag indicates, in the event that a query cannot be performed because of a lost connection, to try reconnecting to the server before giving up.

11.1.3.43 `mysql_real_escape_string()`

```
unsigned long mysql_real_escape_string(MYSQL *mysql, char *to, const char
*from, unsigned long length)
```

Description

This function is used to create a legal SQL string that you can use in a SQL statement. See Section 6.1.1.1 [String syntax], page 441.

The string in `from` is encoded to an escaped SQL string, taking into account the current character set of the connection. The result is placed in `to` and a terminating null byte is appended. Characters encoded are `NUL` (ASCII 0), '`\n`', '`\r`', '`\`', '`'`', '`"`', and Control-Z (see Section 6.1.1 [Literals], page 441). (Strictly speaking, MySQL requires only that backslash and the quote character used to quote the string in the query be escaped. This function quotes the other characters to make them easier to read in log files.)

The string pointed to by `from` must be `length` bytes long. You must allocate the `to` buffer to be at least `length*2+1` bytes long. (In the worst case, each character may need to be

encoded as using two bytes, and you need room for the terminating null byte.) When `mysql_real_escape_string()` returns, the contents of `to` will be a null-terminated string. The return value is the length of the encoded string, not including the terminating null character.

Example

```
char query[1000],*end;

end = strmov(query,"INSERT INTO test_table values(");
*end++ = '\'';
end += mysql_real_escape_string(&mysql, end,"What's this",11);
*end++ = '\'';
*end++ = ',';
*end++ = '\'';
end += mysql_real_escape_string(&mysql, end,"binary data: \0\r\n",16);
*end++ = '\'';
*end++ = ')';

if (mysql_real_query(&mysql,query,(unsigned int) (end - query)))
{
   fprintf(stderr, "Failed to insert row, Error: %s\n",
           mysql_error(&mysql));
}
```

The `strmov()` function used in the example is included in the `mysqlclient` library and works like `strcpy()` but returns a pointer to the terminating null of the first parameter.

Return Values

The length of the value placed into `to`, not including the terminating null character.

Errors

None.

11.1.3.44 `mysql_real_query()`

`int mysql_real_query(MYSQL *mysql, const char *query, unsigned long length)`

Description

Executes the SQL query pointed to by `query`, which should be a string `length` bytes long. The query must consist of a single SQL statement. You should not add a terminating semicolon (';') or `\g` to the statement.

You **must** use `mysql_real_query()` rather than `mysql_query()` for queries that contain binary data, because binary data may contain the '`\0`' character. In addition, `mysql_real_query()` is faster than `mysql_query()` because it does not call `strlen()` on the query string.

If you want to know if the query should return a result set or not, you can use `mysql_field_count()` to check for this. See Section 11.1.3.20 [mysql_field_count], page 737.

Return Values

Zero if the query was successful. Non-zero if an error occurred.

Errors

`CR_COMMANDS_OUT_OF_SYNC`
: Commands were executed in an improper order.

`CR_SERVER_GONE_ERROR`
: The MySQL server has gone away.

`CR_SERVER_LOST`
: The connection to the server was lost during the query.

`CR_UNKNOWN_ERROR`
: An unknown error occurred.

11.1.3.45 `mysql_reload()`

```
int mysql_reload(MYSQL *mysql)
```

Description

Asks the MySQL server to reload the grant tables. The connected user must have the `RELOAD` privilege.

This function is deprecated. It is preferable to use `mysql_query()` to issue an SQL `FLUSH PRIVILEGES` statement instead.

Return Values

Zero for success. Non-zero if an error occurred.

Errors

`CR_COMMANDS_OUT_OF_SYNC`
: Commands were executed in an improper order.

`CR_SERVER_GONE_ERROR`
: The MySQL server has gone away.

`CR_SERVER_LOST`
: The connection to the server was lost during the query.

`CR_UNKNOWN_ERROR`
: An unknown error occurred.

11.1.3.46 `mysql_row_seek()`

```
MYSQL_ROW_OFFSET mysql_row_seek(MYSQL_RES *result, MYSQL_ROW_OFFSET offset)
```

Description

Sets the row cursor to an arbitrary row in a query result set. The `offset` value is a row offset that should be a value returned from `mysql_row_tell()` or from `mysql_row_seek()`. This value is not a row number; if you want to seek to a row within a result set by number, use `mysql_data_seek()` instead.

This function requires that the result set structure contains the entire result of the query, so `mysql_row_seek()` may be used only in conjunction with `mysql_store_result()`, not with `mysql_use_result()`.

Return Values

The previous value of the row cursor. This value may be passed to a subsequent call to `mysql_row_seek()`.

Errors

None.

11.1.3.47 `mysql_row_tell()`

```
MYSQL_ROW_OFFSET mysql_row_tell(MYSQL_RES *result)
```

Description

Returns the current position of the row cursor for the last `mysql_fetch_row()`. This value can be used as an argument to `mysql_row_seek()`.

You should use `mysql_row_tell()` only after `mysql_store_result()`, not after `mysql_use_result()`.

Return Values

The current offset of the row cursor.

Errors

None.

11.1.3.48 mysql_select_db()

```
int mysql_select_db(MYSQL *mysql, const char *db)
```

Description

Causes the database specified by `db` to become the default (current) database on the connection specified by `mysql`. In subsequent queries, this database is the default for table references that do not include an explicit database specifier.

`mysql_select_db()` fails unless the connected user can be authenticated as having permission to use the database.

Return Values

Zero for success. Non-zero if an error occurred.

Errors

`CR_COMMANDS_OUT_OF_SYNC`
: Commands were executed in an improper order.

`CR_SERVER_GONE_ERROR`
: The MySQL server has gone away.

`CR_SERVER_LOST`
: The connection to the server was lost during the query.

`CR_UNKNOWN_ERROR`
: An unknown error occurred.

11.1.3.49 mysql_set_server_option()

```
int mysql_set_server_option(MYSQL *mysql, enum enum_mysql_set_option option)
```

Description

Sets or reset an option for the connection. `option` can have one of the following values:

MYSQL_OPTION_MULTI_STATEMENTS_ON
: Enable multi-statement support.

MYSQL_OPTION_MULTI_STATEMENTS_OFF
: Disable multi-statement support.

Return Values

Zero for success. Non-zero if an error occurred.

Errors

`CR_COMMANDS_OUT_OF_SYNC`
: Commands were executed in an improper order.

`CR_SERVER_GONE_ERROR`
: The MySQL server has gone away.

`CR_SERVER_LOST`
: The connection to the server was lost during the query.

`ER_UNKNOWN_COM_ERROR`
: The server didn't support `mysql_set_server_option()` (which is the case that the server is older than 4.1.1) or the server didn't support the option one tried to set.

11.1.3.50 `mysql_sqlstate()`

```
const char *mysql_sqlstate(MYSQL *mysql)
```

Description

Returns a null-terminated string containing the SQLSTATE error code for the last error. The error code consists of five characters. `'00000'` means "no error". The values are specified by ANSI SQL and ODBC. For a list of possible values, see Section 12.1 [Error-returns], page 825.

Note that not all MySQL errors are yet mapped to SQLSTATE's. The value `'HY000'` (general error) is used for unmapped errors.

This function was added to MySQL 4.1.1.

Return Values

A null-terminated character string containing the SQLSTATE error code.

See Also

See Section 11.1.3.12 [mysql_errno], page 731. See Section 11.1.3.13 [mysql_error], page 732. See Section 11.1.7.18 [mysql_stmt_sqlstate], page 791.

11.1.3.51 `mysql_shutdown()`

```
int mysql_shutdown(MYSQL *mysql)
```

Description

Asks the database server to shut down. The connected user must have `SHUTDOWN` privileges.

Return Values

Zero for success. Non-zero if an error occurred.

Errors

`CR_COMMANDS_OUT_OF_SYNC`
: Commands were executed in an improper order.

`CR_SERVER_GONE_ERROR`
: The MySQL server has gone away.

`CR_SERVER_LOST`
: The connection to the server was lost during the query.

`CR_UNKNOWN_ERROR`
: An unknown error occurred.

11.1.3.52 `mysql_stat()`

```
char *mysql_stat(MYSQL *mysql)
```

Description

Returns a character string containing information similar to that provided by the `mysqladmin status` command. This includes uptime in seconds and the number of running threads, questions, reloads, and open tables.

Return Values

A character string describing the server status. `NULL` if an error occurred.

Errors

`CR_COMMANDS_OUT_OF_SYNC`
: Commands were executed in an improper order.

`CR_SERVER_GONE_ERROR`
: The MySQL server has gone away.

`CR_SERVER_LOST`
: The connection to the server was lost during the query.

`CR_UNKNOWN_ERROR`
: An unknown error occurred.

11.1.3.53 `mysql_store_result()`

```
MYSQL_RES *mysql_store_result(MYSQL *mysql)
```

Description

You must call `mysql_store_result()` or `mysql_use_result()` for every query that successfully retrieves data (`SELECT`, `SHOW`, `DESCRIBE`, `EXPLAIN`).

You don't have to call `mysql_store_result()` or `mysql_use_result()` for other queries, but it will not do any harm or cause any notable performance if you call `mysql_store_result()` in all cases. You can detect if the query didn't have a result set by checking if `mysql_store_result()` returns 0 (more about this later one).

If you want to know if the query should return a result set or not, you can use `mysql_field_count()` to check for this. See Section 11.1.3.20 [mysql_field_count], page 737.

`mysql_store_result()` reads the entire result of a query to the client, allocates a `MYSQL_RES` structure, and places the result into this structure.

`mysql_store_result()` returns a null pointer if the query didn't return a result set (if the query was, for example, an `INSERT` statement).

`mysql_store_result()` also returns a null pointer if reading of the result set failed. You can check if you got an error by checking if `mysql_error()` doesn't return a null pointer, if `mysql_errno()` returns `<>` 0, or if `mysql_field_count()` returns `<>` 0.

An empty result set is returned if there are no rows returned. (An empty result set differs from a null pointer as a return value.)

Once you have called `mysql_store_result()` and got a result back that isn't a null pointer, you may call `mysql_num_rows()` to find out how many rows are in the result set.

You can call `mysql_fetch_row()` to fetch rows from the result set, or `mysql_row_seek()` and `mysql_row_tell()` to obtain or set the current row position within the result set.

You must call `mysql_free_result()` once you are done with the result set.

See Section 11.1.12.1 [`NULL mysql_store_result()`], page 797.

Return Values

A `MYSQL_RES` result structure with the results. `NULL` if an error occurred.

Errors

`mysql_store_result()` resets `mysql_error` and `mysql_errno` if it succeeds.

`CR_COMMANDS_OUT_OF_SYNC`
: Commands were executed in an improper order.

`CR_OUT_OF_MEMORY`
: Out of memory.

`CR_SERVER_GONE_ERROR`
: The MySQL server has gone away.

`CR_SERVER_LOST`
: The connection to the server was lost during the query.

`CR_UNKNOWN_ERROR`
: An unknown error occurred.

11.1.3.54 mysql_thread_id()

```
unsigned long mysql_thread_id(MYSQL *mysql)
```

Description

Returns the thread ID of the current connection. This value can be used as an argument to `mysql_kill()` to kill the thread.

If the connection is lost and you reconnect with `mysql_ping()`, the thread ID will change. This means you should not get the thread ID and store it for later. You should get it when you need it.

Return Values

The thread ID of the current connection.

Errors

None.

11.1.3.55 mysql_use_result()

```
MYSQL_RES *mysql_use_result(MYSQL *mysql)
```

Description

You must call `mysql_store_result()` or `mysql_use_result()` for every query that successfully retrieves data (`SELECT`, `SHOW`, `DESCRIBE`, `EXPLAIN`).

`mysql_use_result()` initiates a result set retrieval but does not actually read the result set into the client like `mysql_store_result()` does. Instead, each row must be retrieved individually by making calls to `mysql_fetch_row()`. This reads the result of a query directly from the server without storing it in a temporary table or local buffer, which is somewhat faster and uses much less memory than `mysql_store_result()`. The client will only allocate memory for the current row and a communication buffer that may grow up to `max_allowed_packet` bytes.

On the other hand, you shouldn't use `mysql_use_result()` if you are doing a lot of processing for each row on the client side, or if the output is sent to a screen on which the user may type a `^S` (stop scroll). This will tie up the server and prevent other threads from updating any tables from which the data is being fetched.

When using `mysql_use_result()`, you must execute `mysql_fetch_row()` until a `NULL` value is returned, otherwise, the unfetched rows will be returned as part of the result set for your next query. The C API will give the error `Commands out of sync; you can't run this command now` if you forget to do this!

You may not use `mysql_data_seek()`, `mysql_row_seek()`, `mysql_row_tell()`, `mysql_num_rows()`, or `mysql_affected_rows()` with a result returned from `mysql_use_result()`, nor may you issue other queries until the `mysql_use_result()` has finished. (However, after you have fetched all the rows, `mysql_num_rows()` will accurately return the number of rows fetched.)

You must call `mysql_free_result()` once you are done with the result set.

Return Values

A `MYSQL_RES` result structure. `NULL` if an error occurred.

Errors

`mysql_use_result()` resets `mysql_error` and `mysql_errno` if it succeeds.

`CR_COMMANDS_OUT_OF_SYNC`
: Commands were executed in an improper order.

`CR_OUT_OF_MEMORY`
: Out of memory.

`CR_SERVER_GONE_ERROR`
: The MySQL server has gone away.

`CR_SERVER_LOST`
: The connection to the server was lost during the query.

`CR_UNKNOWN_ERROR`
: An unknown error occurred.

11.1.3.56 `mysql_commit()`

```
my_bool mysql_commit(MYSQL *mysql)
```

Description

Commits the current transaction. Available from MySQL 4.1.

Return Values

Zero if successful. Non-zero if an error occurred.

Errors

None.

11.1.3.57 `mysql_rollback()`

```
my_bool mysql_rollback(MYSQL *mysql)
```

Description

Rolls back the current transaction. Available from MySQL 4.1.

Return Values

Zero if successful. Non-zero if an error occurred.

Errors

None.

11.1.3.58 mysql_autocommit()

```
my_bool mysql_autocommit(MYSQL *mysql, my_bool mode)
```

Description

Sets autocommit mode on if `mode` is 1, off if `mode` is 0. Available from MySQL 4.1.

Return Values

Zero if successful. Non-zero if an error occurred.

Errors

None.

11.1.3.59 mysql_more_results()

```
my_bool mysql_more_results(MYSQL *mysql)
```

Description

Returns true if more results exist from the currently executed query, and the application must call `mysql_next_result()` to fetch the results. Available from MySQL 4.1.

Return Values

`TRUE` if more results exist. `FALSE` if no more results exist.

Errors

None.

11.1.3.60 mysql_next_result()

```
int mysql_next_result(MYSQL *mysql)
```

Description

If more query results exist, `mysql_next_result()` reads the next query results and returns the status back to application. Available from MySQL 4.1.

Return Values

Zero if successful. Non-zero if an error occurred.

Errors

None.

11.1.4 C API Prepared Statements

As of MySQL 4.1, the client/server protocol provides for the use of prepared statements. This capability uses the `MYSQL_STMT` statement handler data structure. Prepared execution is an efficient way to execute a statement more than once. The statement is first parsed to prepare it for execution. Then it is executed one or more times at a later time, using the statement handle returned by the prepare function.

Prepared execution is faster than direct execution for statements executed more than once, primarly because the query is parsed only once. In the case of direct execution, the query is parsed every time it is executed. Prepared execution also can provide a reduction of network traffic because for each execution of the prepared statement, it is necessary only to send the data for the parameters.

Another advantage of prepared statements is that it uses a binary protocol that makes data transfer between client and server more efficient. Prepared statements also can support input and output binding for multiple query execution.

11.1.5 C API Prepared Statement Datatypes

Note: The API for prepared statements is still subject to revision. This information is provided for early adopters, but please be aware that the API may change.

Prepared statements mainly use the `MYSQL_STMT` and `MYSQL_BIND` data structures. A third structure, `MYSQL_TIME`, is used to transfer temporal data.

`MYSQL_STMT`

> This structure represents a prepared statement. A statement is prepared by calling `mysql_prepare()`, which returns a statement handle, that is, a pointer to a `MYSQL_STMT`. The handle is used for all subsequent statement-related functions.

The MYSQL_STMT structure has no members that are for application use.

Multiple statement handles can be associated with a single connection. The limit on the number of handles depends on the available system resources.

MYSQL_BIND

This structure is used both for query input (data values sent to the server) and output (result values returned from the server). For input, it is used with mysql_bind_param() to bind parameter data values to buffers for use by mysql_execute(). For output, it is used with mysql_bind_result() to bind result set buffers for use in fetching rows with mysql_fetch().

The MYSQL_BIND structure contains the following members for use by application programs. Each is used both for input and for output, though sometimes for different purposes depending on the direction of data transfer.

enum enum_field_types buffer_type

The type of the buffer. The allowable buffer_type values are listed later in this section. For input, buffer_type indicates what type of value you are binding to a query parameter. For output, it indicates what type of value you expect to receive in a result buffer.

void *buffer

For input, this is a pointer to the buffer in which a query parameter's data value is stored. For output, it is a pointer to the buffer in which to return a result set column value. For numeric column types, buffer should point to a variable of the proper C type. (If you are associating the variable with a column that has the UNSIGNED attribute, the variable should be an unsigned C type.) For date and time column types, buffer should point to a MYSQL_TIME structure. For character and binary string column types, buffer should point to a character buffer.

unsigned long buffer_length

The actual size of *buffer in bytes. This indicates the maximum amount of data that can be stored in the buffer. For character and binary C data, the buffer_length value specifies the length of *buffer when used with mysql_bind_param(), or the maximum number of data bytes that can be fetched into the buffer when used with mysql_bind_result().

unsigned long *length

A pointer to an unsigned long variable that indicates the actual number of bytes of data stored in *buffer. length is used for character or binary C data. For input parameter data binding, length points to an unsigned long variable that indicates the length of the parameter value stored in *buffer; this is used by mysql_execute(). If length is a null pointer, the protocol assumes that all character and binary data are null-terminated. For output value binding, mysql_fetch() places the length of the column value that is returned into the variable that length points to.

`length` is ignored for numeric and temporal datatypes because the length of the data value is determined by the `buffer_type` value.

`my_bool *is_null`
: This member points to a `my_bool` variable that is true if a value is `NULL`, false if it is not `NULL`. For input, set `*is_null` to true to indicate that you are passing a `NULL` value as a query parameter. For output, this value will be set to true after you fetch a row if the result value returned from the query is `NULL`.

`MYSQL_TIME`
: This structure is used to send and receive `DATE`, `TIME`, `DATETIME`, and `TIMESTAMP` data directly to and from the server. This is done by setting the `buffer_type` member of a `MYSQL_BIND` structure to one of the temporal types, and setting the `buffer` member to point to a `MYSQL_TIME` structure.

  The `MYSQL_TIME` structure contains the following members:

  `unsigned int year`
  : The year.

  `unsigned int month`
  : The month of the year.

  `unsigned int day`
  : The day of the month.

  `unsigned int hour`
  : The hour of the day.

  `unsigned int minute`
  : The minute of the hour.

  `unsigned int second`
  : The second of the minute.

  `my_bool neg`
  : A boolean flag to indicate whether the time is negative.

  `unsigned long second_part`
  : The fractional part of the second. This member currently is unused.

  Only those parts of a `MYSQL_TIME` structure that apply to a given type of temporal value are used: The `year`, `month`, and `day` elements are used for `DATE`, `DATETIME`, and `TIMESTAMP` values. The `hour`, `minute`, and `second` elements are used for `TIME`, `DATETIME`, and `TIMESTAMP` values. See Section 11.1.9 [C API date handling], page 793.

The following table shows the allowable values that may be specified in the `buffer_type` member of `MYSQL_BIND` structures. The table also shows those SQL types that correspond most closely to each `buffer_type` value, and, for numeric and temporal types, the corresponding C type.

`buffer_type` **Value**	**SQL Type**	**C Type**
`MYSQL_TYPE_TINY`	`TINYINT`	`char`

MYSQL_TYPE_SHORT	SMALLINT	short int
MYSQL_TYPE_LONG	INT	long int
MYSQL_TYPE_LONGLONG	BIGINT	long long int
MYSQL_TYPE_FLOAT	FLOAT	float
MYSQL_TYPE_DOUBLE	DOUBLE	double
MYSQL_TYPE_TIME	TIME	MYSQL_TIME
MYSQL_TYPE_DATE	DATE	MYSQL_TIME
MYSQL_TYPE_DATETIME	DATETIME	MYSQL_TIME
MYSQL_TYPE_TIMESTAMP	TIMESTAMP	MYSQL_TIME
MYSQL_TYPE_STRING	CHAR	
MYSQL_TYPE_VAR_STRING	VARCHAR	
MYSQL_TYPE_TINY_BLOB	TINYBLOB/TINYTEXT	
MYSQL_TYPE_BLOB	BLOB/TEXT	
MYSQL_TYPE_MEDIUM_BLOB	MEDIUMBLOB/MEDIUMTEXT	
MYSQL_TYPE_LONG_BLOB	LONGBLOB/LONGTEXT	

Implicit type conversion may be performed in both directions.

11.1.6 C API Prepared Statement Function Overview

Note: The API for prepared statements is still subject to revision. This information is provided for early adopters, but please be aware that the API may change.

The functions available for prepared statement processing are summarised here and described in greater detail in a later section. See Section 11.1.7 [C API Prepared statement functions], page 770.

Function	Description
mysql_prepare()	Prepares an SQL string for execution.
mysql_param_count()	Returns the number of parameters in a prepared SQL statement.
mysql_get_metadata()	Returns prepared statement metadata in the form of a result set.
mysql_bind_param()	Associates application data buffers with the parameter markers in a prepared SQL statement.
mysql_execute()	Executes the prepared statement.
mysql_stmt_affected_rows()	Returns the number of rows changes, deleted, or inserted by the last `UPDATE`, `DELETE`, or `INSERT` query.
mysql_bind_result()	Associates application data buffers with columns in the result set.
mysql_stmt_store_result()	Retrieves the complete result set to the client.
mysql_stmt_data_seek()	Seeks to an arbitrary row number in a statement result set.

mysql_stmt_row_seek()	Seeks to a row offset in a statement result set, using value returned from `mysql_stmt_row_tell()`.
mysql_stmt_row_tell()	Returns the statement row cursor position.
mysql_stmt_num_rows()	Returns total rows from the statement buffered result set.
mysql_fetch()	Fetches the next row of data from the result set and returns data for all bound columns.
mysql_stmt_close()	Frees memory used by prepared statement.
mysql_stmt_errno()	Returns the error number for the last statement execution.
mysql_stmt_error()	Returns the error message for the last statement execution.
mysql_stmt_sqlstate()	Returns the SQLSTATE error code for the last statement execution.
mysql_send_long_data()	Sends long data in chunks to server.

Call `mysql_prepare()` to prepare and initialise the statement handle, `mysql_bind_param()` to supply the parameter data, and `mysql_execute()` to execute the query. You can repeat the `mysql_execute()` by changing parameter values in the respective buffers supplied through `mysql_bind_param()`.

If the query is a `SELECT` statement or any other query that produces a result set, `mysql_prepare()` will also return the result set metadata information in the form of a `MYSQL_RES` result set through `mysql_get_metadata()`.

You can supply the result buffers using `mysql_bind_result()`, so that the `mysql_fetch()` will automatically return data to these buffers. This is row-by-row fetching.

You can also send the text or binary data in chunks to server using `mysql_send_long_data()`, by specifying the option `is_long_data=1` or `length=MYSQL_LONG_DATA` or `-2` in the `MYSQL_BIND` structure supplied with `mysql_bind_param()`.

When statement execution has been completed, the statement handle must be closed using `mysql_stmt_close()` so that all resources associated with it can be freed.

If you obtained a `SELECT` statement's result set metadata by calling `mysql_get_metadata()`, you should also free it using `mysql_free_result()`.

Execution Steps

To prepare and execute a statement, an application follows these steps:

1. Call `mysql_prepare()` and pass it a string containing the SQL statement. For a successful prepare operation, `mysql_prepare()` returns a valid statement handle to the application.
2. If the query produces a result set, call `mysql_get_metadata()` to obtain the result set metadata. This metadata is itself in the form of result set, albeit a separate one from the one that contains the rows returned by the query. The metadata result set indicates how many columns are in the result and contains information about each column.

3. Set the values of any parameters using `mysql_bind_param()`. All parameters must be set. Otherwise, query execution will return an error or produce unexpected results.
4. Call `mysql_execute()` to execute the statement.
5. If the query produces a result set, bind the data buffers to use for retrieving the row values by calling `mysql_bind_result()`.
6. Fetch the data into the buffers row by row by calling `mysql_fetch()` repeatedly until no more rows are found.
7. Repeat steps 3 through 6 as necessary, by changing the parameter values and re-executing the statement.

When `mysql_prepare()` is called, the MySQL client/server protocol performs these actions:

- The server parses the query and sends the OK status back to the client by assigning a statement ID. It also sends total number of parameters, a column count, and its meta information if it is a result set oriented query. All syntax and semantics of the query are checked by the server during this call.
- The client uses this statement ID for the further operations, so that the server can identify the statement from among its pool of statements. The client also allocates a statement handle with this ID and returns the handle to the application.

When `mysql_execute()` is called, the MySQL client/server protocol performs these actions:

- The client uses the statement handle and sends the parameter data to the server.
- The server identifies the statement using the ID provided by the client, replaces the parameter markers with the newly supplied data, and executes the query. If the query produces a result set, the server sends the data back to the client. Otherwise, it sends an OK status and total number of rows changed, deleted, or inserted.

When `mysql_fetch()` is called, the MySQL client/server protocol performs these actions:

- The client reads the data from the packet row by row and places it into the application data buffers by doing the necessary conversions. If the application buffer type is same as that of the field type returned from the server, the conversions are straightforward.

You can get the statement error code, error message, and SQLSTATE value using `mysql_stmt_errno()`, `mysql_stmt_error()`, and `mysql_stmt_sqlstate()`, respectively.

11.1.7 C API Prepared Statement Function Descriptions

To prepare and execute queries, use the following functions.

11.1.7.1 `mysql_prepare()`

```
MYSQL_STMT * mysql_prepare(MYSQL *mysql, const char *query, unsigned long
length)
```

Description

Prepares the SQL query pointed to by the null-terminated string `query`, and returns a statement handle to be used for further operations on the statement. The query must consist of a single SQL statement. You should not add a terminating semicolon (‘`;`’) or `\g` to the statement.

The application can include one or more parameter markers in the SQL statement by embedding question mark (‘`?`’) characters into the SQL string at the appropriate positions.

The markers are legal only in certain places in SQL statements. For example, they are allowed in the `VALUES()` list of an `INSERT` statement (to specify column values for a row), or in a comparison with a column in a `WHERE` clause to specify a comparison value. However, they are not allowed for identifiers (such as table or column names), in the select list that names the columns to be returned by a `SELECT` statement), or to specify both operands of a binary operator such as the `=` equal sign. The latter restriction is necessary because it would be impossible to determine the parameter type. In general, parameters are legal only in Data Manipulation Languange (DML) statements, and not in Data Defination Language (DDL) statements.

The parameter markers must be bound to application variables using `mysql_bind_param()` before executing the statement.

Return Values

A pointer to a `MYSQL_STMT` structure if the prepare was successful. `NULL` if an error occurred.

Errors

`CR_COMMANDS_OUT_OF_SYNC`
: Commands were executed in an improper order.

`CR_OUT_OF_MEMORY`
: Out of memory.

`CR_SERVER_GONE_ERROR`
: The MySQL server has gone away.

`CR_SERVER_LOST`
: The connection to the server was lost during the query

`CR_UNKNOWN_ERROR`
: An unknown error occurred.

If the prepare is not successful (that is, `mysql_prepare()` returns `NULL`), the error message can be obtained by calling `mysql_error()`.

Example

For the usage of `mysql_prepare()`, refer to the Example from Section 11.1.7.5 [`mysql_execute()`], page 774.

11.1.7.2 mysql_param_count()

```
unsigned long mysql_param_count(MYSQL_STMT *stmt)
```

Description

Returns the number of parameter markers present in the prepared statement.

Return Values

An unsigned long integer representing the number of parameters in a statement.

Errors

None.

Example

For the usage of `mysql_param_count()`, refer to the Example from Section 11.1.7.5 [`mysql_execute()`], page 774.

11.1.7.3 mysql_get_metadata()

```
MYSQL_RES *mysql_get_metadata(MYSQL_STMT *stmt)
```

Description

If a statement passed to `mysql_prepare()` is one that produces a result set, `mysql_get_metadata()` returns the result set metadata in the form of a pointer to a `MYSQL_RES` structure that can be used to process the meta information such as total number of fields and individual field information. This result set pointer can be passed as an argument to any of the field-based API functions that process result set metadata, such as:

- `mysql_num_fields()`
- `mysql_fetch_field()`
- `mysql_fetch_field_direct()`
- `mysql_fetch_fields()`
- `mysql_field_count()`
- `mysql_field_seek()`
- `mysql_field_tell()`
- `mysql_free_result()`

The result set structure should be freed when you are done with it, which you can do by passing it to `mysql_free_result()`. This is similar to the way you free a result set obtained from a call to `mysql_store_result()`.

The result set returned by `mysql_get_metadata()` contains only metadata. It does not contain any row results. The rows are obtained by using the statement handle with `mysql_fetch()`.

Return Values

A `MYSQL_RES` result structure. `NULL` if no meta information exists for the prepared query.

Errors

`CR_OUT_OF_MEMORY`
: Out of memory.

`CR_UNKNOWN_ERROR`
: An unknown error occurred.

Example

For the usage of `mysql_get_metadata()`, refer to the Example from Section 11.1.7.13 [`mysql_fetch()`], page 782.

11.1.7.4 `mysql_bind_param()`

```
my_bool mysql_bind_param(MYSQL_STMT *stmt, MYSQL_BIND *bind)
```

Description

`mysql_bind_param()` is used to bind data for the parameter markers in the SQL statement that was passed to `mysql_prepare()`. It uses `MYSQL_BIND` structures to supply the data. `bind` is the address of an array of `MYSQL_BIND` structures. The client library expects the array to contain an element for each '`?`' parameter marker that is present in the query.

Suppose you prepare the following statment:

```
INSERT INTO mytbl VALUES(?,?,?)
```

When you bind the parameters, the array of `MYSQL_BIND` structures must contain three elements, and can be declared like this:

```
MYSQL_BIND bind[3];
```

The members of each `MYSQL_BIND` element that should be set are described in Section 11.1.5 [C API Prepared statement datatypes], page 765.

Return Values

Zero if the bind was successful. Non-zero if an error occurred.

Errors

`CR_NO_PREPARE_STMT`
: No prepared statement exists.

`CR_NO_PARAMETERS_EXISTS`
: No parameters exist to bind.

`CR_INVALID_BUFFER_USE`
: Indicates if the bind is to supply the long data in chunks and if the buffer type is non string or binary.

`CR_UNSUPPORTED_PARAM_TYPE`
: The conversion is not supported. Possibly the `buffer_type` value is illegal or is not one of the supported types.

`CR_OUT_OF_MEMORY`
: Out of memory.

`CR_UNKNOWN_ERROR`
: An unknown error occurred.

Example

For the usage of `mysql_bind_param()`, refer to the Example from Section 11.1.7.5 [`mysql_execute()`], page 774.

11.1.7.5 `mysql_execute()`

```
int mysql_execute(MYSQL_STMT *stmt)
```

Description

`mysql_execute()` executes the prepared query associated with the statement handle. The currently bound parameter marker values are sent to server during this call, and the server replaces the markers with this newly supplied data.

If the statement is an `UPDATE`, `DELETE`, or `INSERT`, the total number of changed, deleted, or inserted rows can be found by calling `mysql_stmt_affected_rows()`. If this is a result set query such as `SELECT`, you must call `mysql_fetch()` to fetch the data prior to calling any other functions that result in query processing. For more information on how to fetch the results, refer to Section 11.1.7.13 [`mysql_fetch()`], page 782.

Return Values

Zero if execution was successful. Non-zero if an error occurred. The error code and message can be obtained by calling `mysql_stmt_errno()` and `mysql_stmt_error()`.

Errors

`CR_NO_PREPARE_QUERY`
: No query prepared prior to execution.

`CR_ALL_PARAMS_NOT_BOUND`
: Not all parameter data is supplied.

`CR_COMMANDS_OUT_OF_SYNC`
: Commands were executed in an improper order.

`CR_OUT_OF_MEMORY`
: Out of memory.

`CR_SERVER_GONE_ERROR`
: The MySQL server has gone away.

`CR_SERVER_LOST`
: The connection to the server was lost during the query.

`CR_UNKNOWN_ERROR`
: An unknown error occurred.

Example

The following example demonstrates how to create and populate a table using `mysql_prepare()`, `mysql_param_count()`, `mysql_bind_param()`, `mysql_execute()`, and `mysql_stmt_affected_rows()`. The `mysql` variable is assumed to be a valid connection handle.

```
#define STRING_SIZE 50

#define DROP_SAMPLE_TABLE "DROP TABLE IF EXISTS test_table"
#define CREATE_SAMPLE_TABLE "CREATE TABLE test_table(col1 INT,\
                                                     col2 VARCHAR(40),\
                                                     col3 SMALLINT,\
                                                     col4 TIMESTAMP)"
#define INSERT_SAMPLE "INSERT INTO test_table(col1,col2,col3) VALUES(?,?,?)"

MYSQL_STMT    *stmt;
MYSQL_BIND    bind[3];
my_ulonglong  affected_rows;
int           param_count;
short         small_data;
int           int_data;
char          str_data[STRING_SIZE];
unsigned long str_length;
my_bool       is_null;

if (mysql_query(mysql, DROP_SAMPLE_TABLE))
{
  fprintf(stderr, " DROP TABLE failed\n");
```

```
  fprintf(stderr, " %s\n", mysql_error(mysql));
  exit(0);
}

if (mysql_query(mysql, CREATE_SAMPLE_TABLE))
{
  fprintf(stderr, " CREATE TABLE failed\n");
  fprintf(stderr, " %s\n", mysql_error(mysql));
  exit(0);
}

/* Prepare an INSERT query with 3 parameters */
/* (the TIMESTAMP column is not named; it will */
/* be set to the current date and time) */
stmt = mysql_prepare(mysql, INSERT_SAMPLE, strlen(INSERT_SAMPLE));
if (!stmt)
{
  fprintf(stderr, " mysql_prepare(), INSERT failed\n");
  fprintf(stderr, " %s\n", mysql_error(mysql));
  exit(0);
}
fprintf(stdout, " prepare, INSERT successful\n");

/* Get the parameter count from the statement */
param_count= mysql_param_count(stmt);
fprintf(stdout, " total parameters in INSERT: %d\n", param_count);

if (param_count != 3) /* validate parameter count */
{
  fprintf(stderr, " invalid parameter count returned by MySQL\n");
  exit(0);
}

/* Bind the data for all 3 parameters */

/* INTEGER PARAM */
/* This is a number type, so there is no need to specify buffer_length */
bind[0].buffer_type= MYSQL_TYPE_LONG;
bind[0].buffer= (char *)&int_data;
bind[0].is_null= 0;
bind[0].length= 0;

/* STRING PARAM */
bind[1].buffer_type= MYSQL_TYPE_VAR_STRING;
bind[1].buffer= (char *)str_data;
bind[1].buffer_length= STRING_SIZE;
bind[1].is_null= 0;
```

```
bind[1].length= &str_length;

/* SMALLINT PARAM */
bind[2].buffer_type= MYSQL_TYPE_SHORT;
bind[2].buffer= (char *)&small_data;
bind[2].is_null= &is_null;
bind[2].length= 0;

/* Bind the buffers */
if (mysql_bind_param(stmt, bind))
{
  fprintf(stderr, " mysql_bind_param() failed\n");
  fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
  exit(0);
}

/* Specify the data values for the first row */
int_data= 10;             /* integer */
strncpy(str_data, "MySQL", STRING_SIZE); /* string  */
str_length= strlen(str_data);

/* INSERT SMALLINT data as NULL */
is_null= 1;

/* Execute the INSERT statement - 1*/
if (mysql_execute(stmt))
{
  fprintf(stderr, " mysql_execute(), 1 failed\n");
  fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
  exit(0);
}

/* Get the total number of affected rows */
affected_rows= mysql_stmt_affected_rows(stmt);
fprintf(stdout, " total affected rows(insert 1): %ld\n", affected_rows);

if (affected_rows != 1) /* validate affected rows */
{
  fprintf(stderr, " invalid affected rows by MySQL\n");
  exit(0);
}

/* Specify data values for second row, then re-execute the statement */
int_data= 1000;
strncpy(str_data, "The most popular open source database", STRING_SIZE);
str_length= strlen(str_data);
small_data= 1000;         /* smallint */
```

```
is_null= 0;               /* reset */

/* Execute the INSERT statement - 2*/
if (mysql_execute(stmt))
{
  fprintf(stderr, " mysql_execute, 2 failed\n");
  fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
  exit(0);
}

/* Get the total rows affected */
affected_rows= mysql_stmt_affected_rows(stmt);
fprintf(stdout, " total affected rows(insert 2): %ld\n", affected_rows);

if (affected_rows != 1) /* validate affected rows */
{
  fprintf(stderr, " invalid affected rows by MySQL\n");
  exit(0);
}

/* Close the statement */
if (mysql_stmt_close(stmt))
{
  fprintf(stderr, " failed while closing the statement\n");
  fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
  exit(0);
}
```

Note: For complete examples on the use of prepared statement functions, refer to the file '`tests/client_test.c`'. This file can be obtained from a MySQL source distribution or from the BitKeeper source repository.

11.1.7.6 `mysql_stmt_affected_rows()`

`my_ulonglong mysql_stmt_affected_rows(MYSQL_STMT *stmt)`

Description

Returns the total number of rows changed, deleted, or inserted by the last executed statement. May be called immediatlely after `mysql_execute()` for `UPDATE`, `DELETE`, or `INSERT` statements. For `SELECT` statements, `mysql_stmt_affected()` rows works like `mysql_num_rows()`.

Return Values

An integer greater than zero indicates the number of rows affected or retrieved. Zero indicates that no records were updated for an `UPDATE` statement, no rows matched the

`WHERE` clause in the query, or that no query has yet been executed. −1 indicates that the query returned an error or that, for a `SELECT` query, `mysql_stmt_affected_rows()` was called prior to calling `mysql_fetch()`.

Errors

None.

Example

For the usage of `mysql_stmt_affected_rows()`, refer to the Example from Section 11.1.7.5 [`mysql_execute()`], page 774.

11.1.7.7 `mysql_bind_result()`

```
my_bool mysql_bind_result(MYSQL_STMT *stmt, MYSQL_BIND *bind)
```

Description

`mysql_bind_result()` is used to associate (bind) columns in the result set to data buffers and length buffers. When `mysql_fetch()` is called to fetch data, the MySQL client/server protocol places the data for the bound columns into the specified buffers.

Note that all columns must be bound to buffers prior to calling `mysql_fetch()`. `bind` is the address of an array of `MYSQL_BIND` structures. The client library expects the array to contain an element for each column of the result set. Otherwise, `mysql_fetch()` simply ignores the data fetch. Also, the buffers should be large enough to hold the data values, because the protocol doesn't return data values in chunks.

A column can be bound or rebound at any time, even after a result set has been partially retrieved. The new binding takes effect the next time `mysql_fetch()` is called. Suppose an application binds the columns in a result set and calls `mysql_fetch()`. The client/server protocol returns data in the bound buffers. Then suppose the application binds the columns to a different set of buffers. The protocol does not place data into the newly bound buffers until the next call to `mysql_fetch()` occurs.

To bind a column, an application calls `mysql_bind_result()` and passes the type, address, and the address of the length buffer. The members of each `MYSQL_BIND` element that should be set are described in Section 11.1.5 [C API Prepared statement datatypes], page 765.

Return Values

Zero if the bind was successful. Non-zero if an error occurred.

Errors

`CR_NO_PREPARE_STMT`
: No prepared statement exists.

`CR_UNSUPPORTED_PARAM_TYPE`
: The conversion is not supported. Possibly the `buffer_type` value is illegal or is not one of the supported types.

`CR_OUT_OF_MEMORY`
: Out of memory.

`CR_UNKNOWN_ERROR`
: An unknown error occurred.

Example

For the usage of `mysql_bind_result()`, refer to the Example from Section 11.1.7.13 [`mysql_fetch()`], page 782.

11.1.7.8 `mysql_stmt_store_result()`

```
int mysql_stmt_store_result(MYSQL_STMT *stmt)
```

Description

You must call `mysql_stmt_store_result()` for every query that successfully produces a result set (`SELECT`, `SHOW`, `DESCRIBE`, `EXPLAIN`), and only if you want to buffer the complete result set by the client, so that the subsequent `mysql_fetch()` call returns buffered data.

It is unnecessary to call `mysql_stmt_store_result()` for other queries, but if you do, it will not harm or cause any notable performance in all cases. You can detect whether the query produced a result set by checking if `mysql_get_metadata()` returns `NULL`. For more information, refer to Section 11.1.7.3 [`mysql_get_metadata()`], page 772.

Return Values

Zero if the results are buffered successfully. Non-zero if an error occurred.

Errors

`CR_COMMANDS_OUT_OF_SYNC`
: Commands were executed in an improper order.

`CR_OUT_OF_MEMORY`
: Out of memory.

`CR_SERVER_GONE_ERROR`
: The MySQL server has gone away.

`CR_SERVER_LOST`
: The connection to the server was lost during the query.

`CR_UNKNOWN_ERROR`
: An unknown error occurred.

11.1.7.9 mysql_stmt_data_seek()

```
void mysql_stmt_data_seek(MYSQL_STMT *stmt, my_ulonglong offset)
```

Description

Seeks to an arbitrary row in a statement result set. The `offset` value is a row number and should be in the range from `0` to `mysql_stmt_num_rows(stmt)-1`.

This function requires that the statement result set structure contains the entire result of the last executed query, so `mysql_stmt_data_seek()` may be used only in conjunction with `mysql_stmt_store_result()`.

Return Values

None.

Errors

None.

11.1.7.10 mysql_stmt_row_seek()

```
MYSQL_ROW_OFFSET mysql_stmt_row_seek(MYSQL_STMT *stmt, MYSQL_ROW_OFFSET
offset)
```

Description

Sets the row cursor to an arbitrary row in a statement result set. The `offset` value is a row offset that should be a value returned from `mysql_stmt_row_tell()` or from `mysql_stmt_row_seek()`. This value is not a row number; if you want to seek to a row within a result set by number, use `mysql_stmt_data_seek()` instead.

This function requires that the result set structure contains the entire result of the query, so `mysql_stmt_row_seek()` may be used only in conjunction with `mysql_stmt_store_result()`.

Return Values

The previous value of the row cursor. This value may be passed to a subsequent call to `mysql_stmt_row_seek()`.

Errors

None.

11.1.7.11 mysql_stmt_row_tell()

```
MYSQL_ROW_OFFSET mysql_stmt_row_tell(MYSQL_STMT *stmt)
```

Description

Returns the current position of the row cursor for the last `mysql_fetch()`. This value can be used as an argument to `mysql_stmt_row_seek()`.

You should use `mysql_stmt_row_tell()` only after `mysql_stmt_store_result()`.

Return Values

The current offset of the row cursor.

Errors

None.

11.1.7.12 mysql_stmt_num_rows()

```
my_ulonglong mysql_stmt_num_rows(MYSQL_STMT *stmt)
```

Description

Returns the number of rows in the result set.

The use of `mysql_stmt_num_rows()` depends on whether or not you used `mysql_stmt_store_result()` to buffer the entire result set in the statement handle.

If you use `mysql_stmt_store_result()`, `mysql_stmt_num_rows()` may be called immediately.

Return Values

The number of rows in the result set.

Errors

None.

11.1.7.13 mysql_fetch()

```
int mysql_fetch(MYSQL_STMT *stmt)
```

Description

`mysql_fetch()` returns the next row in the result set. It can be called only while the result set exists, that is, after a call to `mysql_execute()` that creates a result set or after `mysql_stmt_store_result()`, which is called after `mysql_execute()` to buffer the entire result set.

`mysql_fetch()` returns row data using the buffers bound by `mysql_bind_result()`. It returns the data in those buffers for all the columns in the current row set and the lengths are returned to the `length` pointer.

Note that all columns must be bound by the application before calling `mysql_fetch()`.

If a fetched data value is a `NULL` value, the `*is_null` value of the corresponding `MYSQL_BIND` structure contains TRUE (1). Otherwise, the data and its length are returned in the `*buffer` and `*length` elements based on the buffer type specified by the application. Each numeric and temporal type has a fixed length, as listed in the following table. The length of the string types depends on the length of the actual data value, as indicated by `data_length`.

Type	Length
MYSQL_TYPE_TINY	1
MYSQL_TYPE_SHORT	2
MYSQL_TYPE_LONG	4
MYSQL_TYPE_LONGLONG	8
MYSQL_TYPE_FLOAT	4
MYSQL_TYPE_DOUBLE	8
MYSQL_TYPE_TIME	sizeof(MYSQL_TIME)
MYSQL_TYPE_DATE	sizeof(MYSQL_TIME)
MYSQL_TYPE_DATETIME	sizeof(MYSQL_TIME)
MYSQL_TYPE_TIMESTAMP	sizeof(MYSQL_TIME)
MYSQL_TYPE_STRING	data length
MYSQL_TYPE_VAR_STRING	data_length
MYSQL_TYPE_TINY_BLOB	data_length
MYSQL_TYPE_BLOB	data_length
MYSQL_TYPE_MEDIUM_BLOB	data_length
MYSQL_TYPE_LONG_BLOB	data_length

Return Values

Return Value	Description
0	Successful, the data has been fetched to application data buffers.
1	Error occurred. Error code and message can be obtained by calling `mysql_stmt_errno()` and `mysql_stmt_error()`.
MYSQL_NO_DATA	No more rows/data exists

Errors

`CR_COMMANDS_OUT_OF_SYNC`
: Commands were executed in an improper order.

`CR_OUT_OF_MEMORY`
: Out of memory.

`CR_SERVER_GONE_ERROR`
: The MySQL server has gone away.

`CR_SERVER_LOST`
: The connection to the server was lost during the query.

`CR_UNKNOWN_ERROR`
: An unknown error occurred.

`CR_UNSUPPORTED_PARAM_TYPE`
: The buffer type is `MYSQL_TYPE_DATE`, `MYSQL_TYPE_TIME`, `MYSQL_TYPE_DATETIME`, or `MYSQL_TYPE_TIMESTAMP`, but the datatype is not `DATE`, `TIME`, `DATETIME`, or `TIMESTAMP`.

  All other unsupported conversion errors are returned from `mysql_bind_result()`.

Example

The following example demonstrates how to fetch data from a table using `mysql_get_metadata()`, `mysql_bind_result()`, and `mysql_fetch()`. (This example expects to retrieve the two rows inserted by the example shown in Section 11.1.7.5 [`mysql_execute()`], page 774.) The `mysql` variable is assumed to be a valid connection handle.

```
#define STRING_SIZE 50

#define SELECT_SAMPLE "SELECT col1, col2, col3, col4 FROM test_table"

MYSQL_STMT    *stmt;
MYSQL_BIND    bind[4];
MYSQL_RES     *prepare_meta_result;
MYSQL_TIME    ts;
unsigned long length[4];
int           param_count, column_count, row_count;
short         small_data;
int           int_data;
char          str_data[STRING_SIZE];
my_bool       is_null[4];

/* Prepare a SELECT query to fetch data from test_table */
stmt = mysql_prepare(mysql, SELECT_SAMPLE, strlen(SELECT_SAMPLE));
if (!stmt)
{
```

```
  fprintf(stderr, " mysql_prepare(), SELECT failed\n");
  fprintf(stderr, " %s\n", mysql_error(mysql));
  exit(0);
}
fprintf(stdout, " prepare, SELECT successful\n");

/* Get the parameter count from the statement */
param_count= mysql_param_count(stmt);
fprintf(stdout, " total parameters in SELECT: %d\n", param_count);

if (param_count != 0) /* validate parameter count */
{
  fprintf(stderr, " invalid parameter count returned by MySQL\n");
  exit(0);
}

/* Fetch result set meta information */
prepare_meta_result = mysql_get_metadata(stmt);
if (!prepare_meta_result)
{
  fprintf(stderr, " mysql_get_metadata(), returned no meta information\n");
  fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
  exit(0);
}

/* Get total columns in the query */
column_count= mysql_num_fields(prepare_meta_result);
fprintf(stdout, " total columns in SELECT statement: %d\n", column_count);

if (column_count != 4) /* validate column count */
{
  fprintf(stderr, " invalid column count returned by MySQL\n");
  exit(0);
}

/* Execute the SELECT query */
if (mysql_execute(stmt))
{
  fprintf(stderr, " mysql_execute(), failed\n");
  fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
  exit(0);
}

/* Bind the result buffers for all 4 columns before fetching them */

/* INTEGER COLUMN */
bind[0].buffer_type= MYSQL_TYPE_LONG;
```

```
bind[0].buffer= (char *)&int_data;
bind[0].is_null= &is_null[0];
bind[0].length= &length[0];

/* STRING COLUMN */
bind[1].buffer_type= MYSQL_TYPE_VAR_STRING;
bind[1].buffer= (char *)str_data;
bind[1].buffer_length= STRING_SIZE;
bind[1].is_null= &is_null[1];
bind[1].length= &length[1];

/* SMALLINT COLUMN */
bind[2].buffer_type= MYSQL_TYPE_SHORT;
bind[2].buffer= (char *)&small_data;
bind[2].is_null= &is_null[2];
bind[2].length= &length[2];

/* TIMESTAMP COLUMN */
bind[3].buffer_type= MYSQL_TYPE_TIMESTAMP;
bind[3].buffer= (char *)&ts;
bind[3].is_null= &is_null[3];
bind[3].length= &length[3];

/* Bind the result buffers */
if (mysql_bind_result(stmt, bind))
{
  fprintf(stderr, " mysql_bind_result() failed\n");
  fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
  exit(0);
}

/* Now buffer all results to client */
if (mysql_stmt_store_result(stmt))
{
  fprintf(stderr, " mysql_stmt_store_result() failed\n");
  fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
  exit(0);
}

/* Fetch all rows */
row_count= 0;
fprintf(stdout, "Fetching results ...\n");
while (!mysql_fetch(stmt))
{
  row_count++;
  fprintf(stdout, "  row %d\n", row_count);
```

```
  /* column 1 */
  fprintf(stdout, "   column1 (integer)  : ");
  if (is_null[0])
    fprintf(stdout, " NULL\n");
  else
    fprintf(stdout, " %d(%ld)\n", int_data, length[0]);

  /* column 2 */
  fprintf(stdout, "   column2 (string)   : ");
  if (is_null[1])
    fprintf(stdout, " NULL\n");
  else
    fprintf(stdout, " %s(%ld)\n", str_data, length[1]);

  /* column 3 */
  fprintf(stdout, "   column3 (smallint) : ");
  if (is_null[2])
    fprintf(stdout, " NULL\n");
  else
    fprintf(stdout, " %d(%ld)\n", small_data, length[2]);

  /* column 4 */
  fprintf(stdout, "   column4 (timestamp): ");
  if (is_null[3])
    fprintf(stdout, " NULL\n");
  else
    fprintf(stdout, " %04d-%02d-%02d %02d:%02d:%02d (%ld)\n",
                                          ts.year, ts.month, ts.day,
                                          ts.hour, ts.minute, ts.second,
                                          length[3]);
  fprintf(stdout, "\n");
}

/* Validate rows fetched */
fprintf(stdout, " total rows fetched: %d\n", row_count);
if (row_count != 2)
{
  fprintf(stderr, " MySQL failed to return all rows\n");
  exit(0);
}

/* Free the prepared result metadata */
mysql_free_result(prepare_meta_result);


/* Close the statement */
if (mysql_stmt_close(stmt))
```

```
{
  fprintf(stderr, " failed while closing the statement\n");
  fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
  exit(0);
}
```

11.1.7.14 mysql_send_long_data()

```
my_bool mysql_send_long_data(MYSQL_STMT *stmt, unsigned int parameter_number,
const char *data, unsigned long length)
```

Description

Allows an application to send parameter data to the server in pieces (or "chunks"). This function can be called multiple times to send the parts of a character or binary data value for a column, which must be one of the `TEXT` or `BLOB` datatypes.

`parameter_number` indicates which parameter to associate the data with. Parameters are numbered beginning with 0. `data` is a pointer to a buffer containing data to be sent, and `length` indicates the number of bytes in the buffer.

Return Values

Zero if the data is sent successfully to server. Non-zero if an error occurred.

Errors

`CR_INVALID_PARAMETER_NO`
: Invalid parameter number.

`CR_COMMANDS_OUT_OF_SYNC`
: Commands were executed in an improper order.

`CR_SERVER_GONE_ERROR`
: The MySQL server has gone away.

`CR_OUT_OF_MEMORY`
: Out of memory.

`CR_UNKNOWN_ERROR`
: An unknown error occurred.

Example

The following example demonstrates how to send the data for a `TEXT` column in chunks. It inserts the data value `'MySQL - The most popular open source database'` into the `text_column` column. The `mysql` variable is assumed to be a valid connection handle.

```
#define INSERT_QUERY "INSERT INTO test_long_data(text_column) VALUES(?)"

MYSQL_BIND bind[1];
long       length;

if (!mysql_prepare(mysql, INSERT_QUERY, strlen(INSERT_QUERY))
{
  fprintf(stderr, "\n prepare failed");
  fprintf(stderr, "\n %s", mysql_error(mysql));
  exit(0);
}
 memset(bind, 0, sizeof(bind));
 bind[0].buffer_type= MYSQL_TYPE_STRING;
 bind[0].length= &length;
 bind[0].is_null= 0;

/* Bind the buffers */
if (mysql_bind_param(stmt, bind))
{
  fprintf(stderr, "\n param bind failed");
  fprintf(stderr, "\n %s", mysql_stmt_error(stmt));
  exit(0);
}

 /* Supply data in chunks to server */
 if (!mysql_send_long_data(stmt,0,"MySQL",5))
{
  fprintf(stderr, "\n send_long_data failed");
  fprintf(stderr, "\n %s", mysql_stmt_error(stmt));
  exit(0);
}

 /* Supply the next piece of data */
 if (mysql_send_long_data(stmt,0," - The most popular open source database",40))
{
  fprintf(stderr, "\n send_long_data failed");
  fprintf(stderr, "\n %s", mysql_stmt_error(stmt));
  exit(0);
}

 /* Now, execute the query */
 if (mysql_execute(stmt))
{
  fprintf(stderr, "\n mysql_execute failed");
  fprintf(stderr, "\n %s", mysql_stmt_error(stmt));
  exit(0);
}
```

11.1.7.15 mysql_stmt_close()

```
my_bool mysql_stmt_close(MYSQL_STMT *)
```

Description

Closes the prepared statement. `mysql_stmt_close()` also deallocates the statement handle pointed to by `stmt`.

If the current statement has pending or unread results, this function cancels them so that the next query can be executed.

Return Values

Zero if the statement was freed successfully. Non-zero if an error occurred.

Errors

`CR_SERVER_GONE_ERROR`
: The MySQL server has gone away.

`CR_UNKNOWN_ERROR`
: An unknown error occurred.

Example

For the usage of `mysql_stmt_close()`, refer to the Example from Section 11.1.7.5 [`mysql_execute()`], page 774.

11.1.7.16 mysql_stmt_errno()

```
unsigned int mysql_stmt_errno(MYSQL_STMT *stmt)
```

Description

For the statement specified by `stmt`, `mysql_stmt_errno()` returns the error code for the most recently invoked statement API function that can succeed or fail. A return value of zero means that no error occurred. Client error message numbers are listed in the MySQL '`errmsg.h`' header file. Server error message numbers are listed in '`mysqld_error.h`'. In the MySQL source distribution you can find a complete list of error messages and error numbers in the file '`Docs/mysqld_error.txt`'. The server error codes also are listed at Section 12.1 [Error-returns], page 825.

Return Values

An error code value. Zero if no error occurred.

Errors

None.

11.1.7.17 mysql_stmt_error()

```
const char *mysql_stmt_error(MYSQL_STMT *stmt)
```

Description

For the statement specified by `stmt`, `mysql_stmt_error()` returns a null-terminated string containing the error message for the most recently invoked statement API function that can succeed or fail. An empty string (`""`) is returned if no error occurred. This means the following two tests are equivalent:

```
if (mysql_stmt_errno(stmt))
{
  // an error occurred
}

if (mysql_stmt_error(stmt)[0])
{
  // an error occurred
}
```

The language of the client error messages many be changed by recompiling the MySQL client library. Currently you can choose error messages in several different languages.

Return Values

A character string that describes the error. An empty string if no error occurred.

Errors

None.

11.1.7.18 mysql_stmt_sqlstate()

```
const char *mysql_stmt_sqlstate(MYSQL_STMT *stmt)
```

Description

For the statement specified by `stmt`, `mysql_stmt_sqlstate()` returns a null-terminated string containing the SQLSTATE error code for the most recently invoked prepared statement API function that can succeed or fail. The error code consists of five characters.

"00000" means "no error". The values are specified by ANSI SQL and ODBC. For a list of possible values, see Section 12.1 [Error-returns], page 825.

Note that not all MySQL errors are yet mapped to SQLSTATE's. The value "HY000" (general error) is used for unmapped errors.

This function was added to MySQL 4.1.1.

Return Values

A null-terminated character string containing the SQLSTATE error code.

11.1.8 C API Handling of Multiple Query Execution

From version 4.1, MySQL supports the execution of multiple statements specified in a single query string. To use this capability with a given connection, you must specify the CLIENT_MULTI_STATEMENTS option in the flags parameter of mysql_real_connect() when opening the connection. You can also set this for a connection by calling mysql_set_server_option(MYSQL_OPTION_MULTI_STATEMENTS_ON)

By default, mysql_query() and mysql_real_query() return only the first query status and the subsequent queries status can be processed using mysql_more_results() and mysql_next_result().

```
/* Connect to server with option CLIENT_MULTI_STATEMENTS */
mysql_real_connect(..., CLIENT_MULTI_STATEMENTS);

/* Now execute multiple queries */
mysql_query(mysql,"DROP TABLE IF EXISTS test_table;\
                   CREATE TABLE test_table(id INT);\
                   INSERT INTO test_table VALUES(10);\
                   UPDATE test_table SET id=20 WHERE id=10;\
                   SELECT * FROM test_table;\
                   DROP TABLE test_table";
while (mysql_more_results(mysql))
{
  /* Process all results */
  mysql_next_result(mysql);
  ...
  printf("total affected rows: %lld", mysql_affected_rows(mysql));
  ...
  if ((result= mysql_store_result(mysql))
  {
    /* Returned a result set, process it */
  }
}
```

11.1.9 C API Handling of Date and Time Values

The new binary protocol available in MySQL 4.1 and above allows you to send and receive date and time values (`DATE`, `TIME`, `DATETIME`, and `TIMESTAMP`), using the `MYSQL_TIME` structure. The members of this structure are described in Section 11.1.5 [C API Prepared statement datatypes], page 765.

To send temporal data values, you create a prepared statement with `mysql_prepare()`. Then, before calling `mysql_execute()` to execute the statement, use the following procedure to set up each temporal parameter:

1. In the `MYSQL_BIND` structure associated with the data value, set the `buffer_type` member to the type that indicates what kind of temporal value you're sending. For `DATE`, `TIME`, `DATETIME`, or `TIMESTAMP` values, set `buffer_type` to `MYSQL_TYPE_DATE`, `MYSQL_TYPE_TIME`, `MYSQL_TYPE_DATETIME`, or `MYSQL_TYPE_TIMESTAMP`, respectively.
2. Set the `buffer` member of the `MYSQL_BIND` structure to the address of the `MYSQL_TIME` structure in which you will pass the temporal value.
3. Fill in the members of the `MYSQL_TIME` structure that are appropriate for the type of temporal value you're passing.

Use `mysql_bind_param()` to bind the parameter data to the statement. Then you can call `mysql_execute()`.

To retrieve temporal values, the procedure is similar, except that you set the `buffer_type` member to the type of value you expect to receive, and the `buffer` member to the address of a `MYSQL_TIME` structure into which the returned value should be placed. Use `mysql_bind_results()` to bind the buffers to the statement after calling `mysql_execute()` and before fetching the results.

Here is a simple example that inserts `DATE`, `TIME`, and `TIMESTAMP` data. The `mysql` variable is assumed to be a valid connection handle.

```
MYSQL_TIME  ts;
MYSQL_BIND  bind[3];
MYSQL_STMT  *stmt;

  strmov(query, "INSERT INTO test_table(date_field, time_field,
                                        timestamp_field) VALUES(?,?,?");

  stmt= mysql_prepare(mysql, query, strlen(query)));

  /* setup input buffers for all 3 parameters */
  bind[0].buffer_type= MYSQL_TYPE_DATE;
  bind[0].buffer= (char *)&ts;
  bind[0].is_null= 0;
  bind[0].length= 0;
  ..
  bind[1]= bind[2]= bind[0];
  ..
```

```
mysql_bind_param(stmt, bind);

/* supply the data to be sent is the ts structure */
ts.year= 2002;
ts.month= 02;
ts.day= 03;

ts.hour= 10;
ts.minute= 45;
ts.second= 20;

mysql_execute(stmt);
..
```

11.1.10 C API Threaded Function Descriptions

You need to use the following functions when you want to create a threaded client. See Section 11.1.14 [Threaded clients], page 799.

11.1.10.1 `my_init()`

`void my_init(void)`

Description

This function needs to be called once in the program before calling any MySQL function. This initialises some global variables that MySQL needs. If you are using a thread-safe client library, this will also call `mysql_thread_init()` for this thread.

This is automatically called by `mysql_init()`, `mysql_server_init()` and `mysql_connect()`.

Return Values

None.

11.1.10.2 `mysql_thread_init()`

`my_bool mysql_thread_init(void)`

Description

This function needs to be called for each created thread to initialise thread-specific variables.

This is automatically called by `my_init()` and `mysql_connect()`.

Return Values

Zero if successful. Non-zero if an error occurred.

11.1.10.3 `mysql_thread_end()`

```
void mysql_thread_end(void)
```

Description

This function needs to be called before calling `pthread_exit()` to free memory allocated by `mysql_thread_init()`.

Note that this function **is not invoked automatically** by the client library. It must be called explicitly to avoid a memory leak.

Return Values

None.

11.1.10.4 `mysql_thread_safe()`

```
unsigned int mysql_thread_safe(void)
```

Description

This function indicates whether the client is compiled as thread-safe.

Return Values

1 is the client is thread-safe, 0 otherwise.

11.1.11 C API Embedded Server Function Descriptions

You must use the following functions if you want to allow your application to be linked against the embedded MySQL server library. See Section 11.1.15 [libmysqld], page 800.

If the program is linked with `-lmysqlclient` instead of `-lmysqld`, these functions do nothing. This makes it possible to choose between using the embedded MySQL server and a stand-alone server without modifying any code.

11.1.11.1 `mysql_server_init()`

```
int mysql_server_init(int argc, char **argv, char **groups)
```

Description

This function **must** be called once in the program using the embedded server before calling any other MySQL function. It starts up the server and initialises any subsystems (`mysys`, `InnoDB`, etc.) that the server uses. If this function is not called, the program will crash. If you are using the DBUG package that comes with MySQL, you should call this after you have called `MY_INIT()`.

The `argc` and `argv` arguments are analogous to the arguments to `main()`. The first element of `argv` is ignored (it typically contains the program name). For convenience, `argc` may be `0` (zero) if there are no command-line arguments for the server. `mysql_server_init()` makes a copy of the arguments so it's safe to destroy `argv` or `groups` after the call.

The `NULL`-terminated list of strings in `groups` selects which groups in the option files will be active. See Section 4.1.2 [Option files], page 203. For convenience, `groups` may be `NULL`, in which case the `[server]` and `[emedded]` groups will be active.

Example

```
#include <mysql.h>
#include <stdlib.h>

static char *server_args[] = {
  "this_program",       /* this string is not used */
  "--datadir=.",
  "--key_buffer_size=32M"
};
static char *server_groups[] = {
  "embedded",
  "server",
  "this_program_SERVER",
  (char *)NULL
};

int main(void) {
  mysql_server_init(sizeof(server_args) / sizeof(char *),
                    server_args, server_groups);

  /* Use any MySQL API functions here */

  mysql_server_end();

  return EXIT_SUCCESS;
}
```

Return Values

0 if okay, 1 if an error occurred.

11.1.11.2 mysql_server_end()

```
void mysql_server_end(void)
```

Description

This function **must** be called once in the program after all other MySQL functions. It shuts down the embedded server.

Return Values

None.

11.1.12 Common questions and problems when using the C API

11.1.12.1 Why mysql_store_result() Sometimes Returns NULL After mysql_query() Returns Success

It is possible for `mysql_store_result()` to return `NULL` following a successful call to `mysql_query()`. When this happens, it means one of the following conditions occurred:

- There was a `malloc()` failure (for example, if the result set was too large).
- The data couldn't be read (an error occurred on the connection).
- The query returned no data (for example, it was an `INSERT`, `UPDATE`, or `DELETE`).

You can always check whether the statement should have produced a non-empty result by calling `mysql_field_count()`. If `mysql_field_count()` returns zero, the result is empty and the last query was a statement that does not return values (for example, an `INSERT` or a `DELETE`). If `mysql_field_count()` returns a non-zero value, the statement should have produced a non-empty result. See the description of the `mysql_field_count()` function for an example.

You can test for an error by calling `mysql_error()` or `mysql_errno()`.

11.1.12.2 What Results You Can Get from a Query

In addition to the result set returned by a query, you can also get the following information:

- `mysql_affected_rows()` returns the number of rows affected by the last query when doing an `INSERT`, `UPDATE`, or `DELETE`. An exception is that if `DELETE` is used without a `WHERE` clause, the table is re-created empty, which is much faster! In this case, `mysql_affected_rows()` returns zero for the number of records affected.
- `mysql_num_rows()` returns the number of rows in a result set. With `mysql_store_result()`, `mysql_num_rows()` may be called as soon as `mysql_store_result()` returns. With `mysql_use_result()`, `mysql_num_rows()` may be called only after you have fetched all the rows with `mysql_fetch_row()`.

- `mysql_insert_id()` returns the ID generated by the last query that inserted a row into a table with an `AUTO_INCREMENT` index. See Section 11.1.3.31 [`mysql_insert_id()`], page 743.
- Some queries (`LOAD DATA INFILE ...`, `INSERT INTO ... SELECT ...`, `UPDATE`) return additional information. The result is returned by `mysql_info()`. See the description for `mysql_info()` for the format of the string that it returns. `mysql_info()` returns a `NULL` pointer if there is no additional information.

11.1.12.3 How to Get the Unique ID for the Last Inserted Row

If you insert a record in a table containing a column that has the `AUTO_INCREMENT` attribute, you can get the most recently generated ID by calling the `mysql_insert_id()` function.

You can also retrieve the ID by using the `LAST_INSERT_ID()` function in a query string that you pass to `mysql_query()`.

You can check if an `AUTO_INCREMENT` index is used by executing the following code. This also checks if the query was an `INSERT` with an `AUTO_INCREMENT` index:

```
if (mysql_error(&mysql)[0] == 0 &&
    mysql_num_fields(result) == 0 &&
    mysql_insert_id(&mysql) != 0)
{
    used_id = mysql_insert_id(&mysql);
}
```

The most recently generated ID is maintained in the server on a per-connection basis. It will not be changed by another client. It will not even be changed if you update another `AUTO_INCREMENT` column with a non-magic value (that is, a value that is not `NULL` and not `0`).

If you want to use the ID that was generated for one table and insert it into a second table, you can use SQL statements like this:

```
INSERT INTO foo (auto,text)
    VALUES(NULL,'text');              # generate ID by inserting NULL
INSERT INTO foo2 (id,text)
    VALUES(LAST_INSERT_ID(),'text');  # use ID in second table
```

11.1.12.4 Problems Linking with the C API

When linking with the C API, the following errors may occur on some systems:

```
gcc -g -o client test.o -L/usr/local/lib/mysql -lmysqlclient -lsocket -lnsl

Undefined       first referenced
 symbol         in file
floor           /usr/local/lib/mysql/libmysqlclient.a(password.o)
ld: fatal: Symbol referencing errors. No output written to client
```

If this happens on your system, you must include the math library by adding `-lm` to the end of the compile/link line.

11.1.13 Building Client Programs

If you compile MySQL clients that you've written yourself or that you obtain from a third-party, they must be linked using the `-lmysqlclient -lz` option on the link command. You may also need to specify a `-L` option to tell the linker where to find the library. For example, if the library is installed in '`/usr/local/mysql/lib`', use `-L/usr/local/mysql/lib -lmysqlclient -lz` on the link command.

For clients that use MySQL header files, you may need to specify a `-I` option when you compile them (for example, `-I/usr/local/mysql/include`), so the compiler can find the header files.

To make the above simpler on Unix we have provided the `mysql_config` script for you. See Section 4.9.10 [mysql_config], page 348.

You can use this to compile a MySQL client by as follows:

```
CFG=/usr/local/mysql/bin/mysql_config
sh -c "gcc -o progname `$CFG --cflags` progname.c `$CFG --libs`"
```

The `sh -c` is need to get the shell to not threat the output from `mysql_config` as one word.

11.1.14 How to Make a Threaded Client

The client library is almost thread-safe. The biggest problem is that the subroutines in '`net.c`' that read from sockets are not interrupt safe. This was done with the thought that you might want to have your own alarm that can break a long read to a server. If you install interrupt handlers for the `SIGPIPE` interrupt, the socket handling should be thread-safe.

New in 4.0.16: To not abort the program when a connection terminates, MySQL blocks `SIGPIPE` on the first call to `mysql_server_init`(), `mysql_init()` or `mysql_connect()`. If you want to have your own `SIGPIPE` handler, you should first call `mysql_server_init()` and then install your handler. In older versions of MySQL `SIGPIPE` was blocked, but only in the thread safe client library, for every call to `mysql_init()`.

In the older binaries we distribute on our web site (`http://www.mysql.com/`), the client libraries are not normally compiled with the thread-safe option (the Windows binaries are by default compiled to be thread-safe). Newer binary distributions should have both a normal and a thread-safe client library.

To get a threaded client where you can interrupt the client from other threads and set timeouts when talking with the MySQL server, you should use the `-lmysys`, `-lmystrings`, and `-ldbug` libraries and the `net_serv.o` code that the server uses.

If you don't need interrupts or timeouts, you can just compile a thread-safe client library (`mysqlclient_r`) and use this. See Section 11.1 [MySQL C API], page 716. In this case you don't have to worry about the `net_serv.o` object file or the other MySQL libraries.

When using a threaded client and you want to use timeouts and interrupts, you can make great use of the routines in the '`thr_alarm.c`' file. If you are using routines from the `mysys` library, the only thing you must remember is to call `my_init()` first! See Section 11.1.10 [C Thread functions], page 794.

All functions except `mysql_real_connect()` are by default thread-safe. The following notes describe how to compile a thread-safe client library and use it in a thread-safe manner.

(The notes below for `mysql_real_connect()` actually apply to `mysql_connect()` as well, but because `mysql_connect()` is deprecated, you should be using `mysql_real_connect()` anyway.)

To make `mysql_real_connect()` thread-safe, you must recompile the client library with this command:

```
shell> ./configure --enable-thread-safe-client
```

This will create a thread-safe client library `libmysqlclient_r`. (Assuming your OS has a thread-safe `gethostbyname_r()` function.) This library is thread-safe per connection. You can let two threads share the same connection with the following caveats:

- Two threads can't send a query to the MySQL server at the same time on the same connection. In particular, you have to ensure that between a `mysql_query()` and `mysql_store_result()` no other thread is using the same connection.
- Many threads can access different result sets that are retrieved with `mysql_store_result()`.
- If you use `mysql_use_result`, you have to ensure that no other thread is using the same connection until the result set is closed. However, it really is best for threaded clients that share the same connection to use `mysql_store_result()`.
- If you want to use multiple threads on the same connection, you must have a mutex lock around your `mysql_query()` and `mysql_store_result()` call combination. Once `mysql_store_result()` is ready, the lock can be released and other threads may query the same connection.
- If you program with POSIX threads, you can use `pthread_mutex_lock()` and `pthread_mutex_unlock()` to establish and release a mutex lock.

You need to know the following if you have a thread that is calling MySQL functions which did not create the connection to the MySQL database:

When you call `mysql_init()` or `mysql_connect()`, MySQL will create a thread-specific variable for the thread that is used by the debug library (among other things).

If you call a MySQL function, before the thread has called `mysql_init()` or `mysql_connect()`, the thread will not have the necessary thread-specific variables in place and you are likely to end up with a core dump sooner or later.

The get things to work smoothly you have to do the following:

1. Call `my_init()` at the start of your program if it calls any other MySQL function before calling `mysql_real_connect()`.
2. Call `mysql_thread_init()` in the thread handler before calling any MySQL function.
3. In the thread, call `mysql_thread_end()` before calling `pthread_exit()`. This will free the memory used by MySQL thread-specific variables.

You may get some errors because of undefined symbols when linking your client with `libmysqlclient_r`. In most cases this is because you haven't included the thread libraries on the link/compile line.

11.1.15 libmysqld, the Embedded MySQL Server Library

11.1.15.1 Overview of the Embedded MySQL Server Library

The embedded MySQL server library makes it possible to run a full-featured MySQL server inside a client application. The main benefits are increased speed and more simple management for embedded applications.

The embedded server library is based on the client/server version of MySQL, which is written in C/C++. Consequently, the embedded server also is written in C/C++. There is no embedded server available in other languages.

The API is identical for the embedded MySQL version and the client/server version. To change an old threaded application to use the embedded library, you normally only have to add calls to the following functions:

Function	When to call
`mysql_server_init()`	Should be called before any other MySQL function is called, preferably early in the `main()` function.
`mysql_server_end()`	Should be called before your program exits.
`mysql_thread_init()`	Should be called in each thread you create that will access MySQL.
`mysql_thread_end()`	Should be called before calling `pthread_exit()`

Then you must link your code with '`libmysqld.a`' instead of '`libmysqlclient.a`'.

The above `mysql_server_xxx` functions are also included in '`libmysqlclient.a`' to allow you to change between the embedded and the client/server version by just linking your application with the right library. See Section 11.1.11.1 [`mysql_server_init()`], page 795.

11.1.15.2 Compiling Programs with `libmysqld`

To get a `libmysqld` library you should configure MySQL with the `--with-embedded-server` option.

When you link your program with `libmysqld`, you must also include the system-specific `pthread` libraries and some libraries that the MySQL server uses. You can get the full list of libraries by executing `mysql_config --libmysqld-libs`.

The correct flags for compiling and linking a threaded program must be used, even if you do not directly call any thread functions in your code.

11.1.15.3 Restrictions when using the Embedded MySQL Server

The embedded server has the following limitations:

- No support for ISAM tables. (This is mainly done to make the library smaller)
- No user defined functions (UDFs).
- No stack trace on core dump.
- No internal RAID support. (This is not normally needed as most OS has nowadays support for big files).
- You cannot set this up as a server or a master (no replication).
- You can't connect to the embedded server from an outside process with sockets or TCP/IP.

Some of these limitations can be changed by editing the '`mysql_embed.h`' include file and recompiling MySQL.

11.1.15.4 Using Option Files with the Embedded Server

The following is the recommended way to use option files to make it easy to switch between a client/server application and one where MySQL is embedded. See Section 4.1.2 [Option files], page 203.

- Put common options in the `[server]` section. These will be read by both MySQL versions.
- Put client/server-specific options in the `[mysqld]` section.
- Put embedded MySQL-specific options in the `[embedded]` section.
- Put application-specific options in a `[ApplicationName_SERVER]` section.

11.1.15.5 Things left to do in Embedded Server (TODO)

- We are going to provide options to leave out some parts of MySQL to make the library smaller.
- There is still a lot of speed optimisation to do.
- Errors are written to `stderr`. We will add an option to specify a filename for these.
- We have to change `InnoDB` to not be so verbose when using in the embedded version.

11.1.15.6 A Simple Embedded Server Example

This example program and makefile should work without any changes on a Linux or FreeBSD system. For other operating systems, minor changes will be needed. This example is designed to give enough details to understand the problem, without the clutter that is a necessary part of a real application.

To try out the example, create an '`test_libmysqld`' directory at the same level as the mysql-4.0 source directory. Save the '`test_libmysqld.c`' source and the '`GNUmakefile`' in the directory, and run GNU '`make`' from inside the '`test_libmysqld`' directory.

'`test_libmysqld.c`'

```
/*
 * A simple example client, using the embedded MySQL server library
 */

#include <mysql.h>
#include <stdarg.h>
#include <stdio.h>
#include <stdlib.h>

MYSQL *db_connect(const char *dbname);
void db_disconnect(MYSQL *db);
void db_do_query(MYSQL *db, const char *query);
```

```
const char *server_groups[] = {
  "test_libmysqld_SERVER", "embedded", "server", NULL
};

int
main(int argc, char **argv)
{
  MYSQL *one, *two;

  /* mysql_server_init() must be called before any other mysql
   * functions.
   *
   * You can use mysql_server_init(0, NULL, NULL), and it will
   * initialise the server using groups = {
   *   "server", "embedded", NULL
   *  }.
   *
   * In your $HOME/.my.cnf file, you probably want to put:

[test_libmysqld_SERVER]
language = /path/to/source/of/mysql/sql/share/english

   * You could, of course, modify argc and argv before passing
   * them to this function.  Or you could create new ones in any
   * way you like.  But all of the arguments in argv (except for
   * argv[0], which is the program name) should be valid options
   * for the MySQL server.
   *
   * If you link this client against the normal mysqlclient
   * library, this function is just a stub that does nothing.
   */
  mysql_server_init(argc, argv, (char **)server_groups);

  one = db_connect("test");
  two = db_connect(NULL);

  db_do_query(one, "SHOW TABLE STATUS");
  db_do_query(two, "SHOW DATABASES");

  mysql_close(two);
  mysql_close(one);

  /* This must be called after all other mysql functions */
  mysql_server_end();

  exit(EXIT_SUCCESS);
```

```
}

static void
die(MYSQL *db, char *fmt, ...)
{
  va_list ap;
  va_start(ap, fmt);
  vfprintf(stderr, fmt, ap);
  va_end(ap);
  (void)putc('\n', stderr);
  if (db)
    db_disconnect(db);
  exit(EXIT_FAILURE);
}

MYSQL *
db_connect(const char *dbname)
{
  MYSQL *db = mysql_init(NULL);
  if (!db)
    die(db, "mysql_init failed: no memory");
  /*
   * Notice that the client and server use separate group names.
   * This is critical, because the server will not accept the
   * client's options, and vice versa.
   */
  mysql_options(db, MYSQL_READ_DEFAULT_GROUP, "test_libmysqld_CLIENT");
  if (!mysql_real_connect(db, NULL, NULL, NULL, dbname, 0, NULL, 0))
    die(db, "mysql_real_connect failed: %s", mysql_error(db));

  return db;
}

void
db_disconnect(MYSQL *db)
{
  mysql_close(db);
}

void
db_do_query(MYSQL *db, const char *query)
{
  if (mysql_query(db, query) != 0)
    goto err;

  if (mysql_field_count(db) > 0)
  {
```

```
    MYSQL_RES   *res;
    MYSQL_ROW    row, end_row;
    int num_fields;

    if (!(res = mysql_store_result(db)))
      goto err;
    num_fields = mysql_num_fields(res);
    while ((row = mysql_fetch_row(res)))
    {
      (void)fputs(">> ", stdout);
      for (end_row = row + num_fields; row < end_row; ++row)
        (void)printf("%s\t", row ? (char*)*row : "NULL");
      (void)fputc('\n', stdout);
    }
    (void)fputc('\n', stdout);
    mysql_free_result(res);
  }
  else
    (void)printf("Affected rows: %lld\n", mysql_affected_rows(db));

  return;

err:
  die(db, "db_do_query failed: %s [%s]", mysql_error(db), query);
}
```

'GNUmakefile'

```
# This assumes the MySQL software is installed in /usr/local/mysql
inc      := /usr/local/mysql/include/mysql
lib      := /usr/local/mysql/lib

# If you have not installed the MySQL software yet, try this instead
#inc      := $(HOME)/mysql-4.0/include
#lib      := $(HOME)/mysql-4.0/libmysqld

CC       := gcc
CPPFLAGS := -I$(inc) -D_THREAD_SAFE -D_REENTRANT
CFLAGS   := -g -W -Wall
LDFLAGS  := -static
# You can change -lmysqld to -lmysqlclient to use the
# client/server library
LDLIBS    = -L$(lib) -lmysqld -lz -lm -lcrypt

ifneq (,$(shell grep FreeBSD /COPYRIGHT 2>/dev/null))
# FreeBSD
LDFLAGS += -pthread
else
```

```
# Assume Linux
LDLIBS += -lpthread
endif

# This works for simple one-file test programs
sources := $(wildcard *.c)
objects := $(patsubst %c,%o,$(sources))
targets := $(basename $(sources))

all: $(targets)

clean:
        rm -f $(targets) $(objects) *.core
```

11.1.15.7 Licensing the Embedded Server

The MySQL source code is covered by the GNU `GPL` license (see Appendix H [GPL license], page 1023). One result of this is that any program which includes, by linking with `libmysqld`, the MySQL source code must be released as free software (under a license compatible with the `GPL`).

We encourage everyone to promote free software by releasing code under the `GPL` or a compatible license. For those who are not able to do this, another option is to purchase a commercial license for the MySQL code from MySQL AB. For details, please see Section 1.4.3 [MySQL licenses], page 17.

11.2 MySQL ODBC Support

MySQL provides support for ODBC by means of the `MyODBC` program. This chapter will teach you how to install `MyODBC`, and how to use it. Here, you will also find a list of common programs that are known to work with `MyODBC`.

11.2.1 How to Install MyODBC

`MyODBC` 2.50 is a 32-bit ODBC 2.50 specification level 0 (with level 1 and level 2 features) driver for connecting an ODBC-aware application to MySQL. `MyODBC` works on Windows 9x/Me/NT/2000/XP and most Unix platforms. `MyODBC` 3.51 is an enhanced version with ODBC 3.5x specification level 1 (complete core API + level 2 features).

`MyODBC` is `Open Source`, and you can find the newest version at `http://www.mysql.com/downloads/api-myodb`
Please note that the 2.50.x versions are `LGPL` licensed, whereas the 3.51.x versions are `GPL` licensed.

If you have problem with `MyODBC` and your program also works with OLEDB, you should try the OLEDB driver.

Normally you only need to install `MyODBC` on Windows machines. You only need `MyODBC` for Unix if you have a program like ColdFusion that is running on the Unix machine and uses ODBC to connect to the databases.

If you want to install MyODBC on a Unix box, you will also need an ODBC manager. MyODBC is known to work with most of the Unix ODBC managers.

To install MyODBC on Windows, you should download the appropriate MyODBC '.zip' file, unpack it with WinZIP or some similar program, and execute the 'SETUP.EXE' file.

On Windows/NT/XP you may get the following error when trying to install MyODBC:

```
An error occurred while copying C:\WINDOWS\SYSTEM\MFC30.DLL. Restart
Windows and try installing again (before running any applications which
use ODBC)
```

The problem in this case is that some other program is using ODBC and because of how Windows is designed, you may not in this case be able to install a new ODBC drivers with Microsoft's ODBC setup program. In most cases you can continue by just pressing Ignore to copy the rest of the MyODBC files and the final installation should still work. If this doesn't work, the solution is to reboot your computer in "safe mode" (Choose this by pressing F8 just before your machine starts Windows during rebooting), install MyODBC, and reboot to normal mode.

- To make a connection to a Unix box from a Windows box, with an ODBC application (one that doesn't support MySQL natively), you must first install MyODBC on the Windows machine.
- The user and Windows machine must have the access privileges to the MySQL server on the Unix machine. This is set up with the GRANT command. See Section 4.4.1 [GRANT], page 239.
- You must create an ODBC DSN entry as follows:
  - Open the Control Panel on the Windows machine.
  - Double-click the ODBC Data Sources 32-bit icon.
  - Click the tab User DSN.
  - Click the button Add.
  - Select MySQL in the screen Create New Data Source and click the Finish button.
  - The MySQL Driver default configuration screen is shown. See Section 11.2.2 [ODBC administrator], page 807.
- Now start your application and select the ODBC driver with the DSN you specified in the ODBC administrator.

Notice that there are other configuration options on the screen of MySQL (trace, don't prompt on connect, etc) that you can try if you run into problems.

11.2.2 How to Fill in the Various Fields in the ODBC Administrator Program

There are three possibilities for specifying the server name on Windows95:

- Use the IP address of the server.
- Add a file '\windows\lmhosts' with the following information:

  ```
  ip hostname
  ```

  For example:

```
194.216.84.21 my_hostname
```

- Configure the PC to use DNS.

Example of how to fill in the `ODBC setup`:

```
Windows DSN name:   test
Description:        This is my test database
MySQL Database:     test
Server:             194.216.84.21
User:               monty
Password:           my_password
Port:
```

The value for the `Windows DSN name` field is any name that is unique in your Windows ODBC setup.

You don't have to specify values for the `Server`, `User`, `Password`, or `Port` fields in the ODBC setup screen. However, if you do, the values will be used as the defaults later when you attempt to make a connection. You have the option of changing the values at that time.

If the port number is not given, the default port (3306) is used.

If you specify the option `Read options from C:\my.cnf`, the groups `client` and `odbc` will be read from the '`C:\my.cnf`' file. You can use all options that are usable by `mysql_options()`. See Section 11.1.3.39 [`mysql_options()`], page 748.

11.2.3 Connect parameters for MyODBC

One can specify the following parameters for `MyODBC` on the `[Servername]` section of an '`ODBC.INI`' file or through the `InConnectionString` argument in the `SQLDriverConnect()` call.

Parameter	Default value	Comment
user	ODBC (on Windows)	The username used to connect to MySQL.
server	localhost	The hostname of the MySQL server.
database		The default database.
option	0	A integer by which you can specify how `MyODBC` should work. See below.
port	3306	The TCP/IP port to use if `server` is not `localhost`.
stmt		A statement that will be executed when connecting to `MySQL`.
password		The password for the `server user` combination.
socket		The socket or Windows pipe to connect to.

The option argument is used to tell `MyODBC` that the client isn't 100% ODBC compliant. On Windows, one normally sets the option flag by toggling the different options on the connection screen but one can also set this in the option argument. The following options are listed in the same order as they appear in the `MyODBC` connect screen:

Bit	Description
1	The client can't handle that `MyODBC` returns the real width of a column.

2	The client can't handle that MySQL returns the true value of affected rows. If this flag is set then MySQL returns 'found rows' instead. One must have MySQL 3.21.14 or newer to get this to work.
4	Make a debug log in c:\myodbc.log. This is the same as putting `MYSQL_DEBUG=d:t:O,c::\myodbc.log` in '`AUTOEXEC.BAT`'
8	Don't set any packet limit for results and parameters.
16	Don't prompt for questions even if driver would like to prompt
32	Simulate a ODBC 1.0 driver in some context.
64	Ignore use of database name in 'database.table.column'.
128	Force use of ODBC manager cursors (experimental).
256	Disable the use of extended fetch (experimental).
512	Pad CHAR fields to full column length.
1024	SQLDescribeCol() will return fully qualified column names
2048	Use the compressed server/client protocol
4096	Tell server to ignore space after function name and before `'('` (needed by PowerBuilder). This will make all function names keywords!
8192	Connect with named pipes to a `mysqld` server running on NT.
16384	Change LONGLONG columns to INT columns (some applications can't handle LONGLONG).
32768	Return 'user' as Table_qualifier and Table_owner from SQLTables (experimental)
65536	Read parameters from the `client` and `odbc` groups from '`my.cnf`'
131072	Add some extra safety checks (should not bee needed but...)

If you want to have many options, you should add the above flags! For example setting option to 12 (4+8) gives you debugging without package limits!

The default '`MYODBC.DLL`' is compiled for optimal performance. If you want to debug `MyODBC` (for example to enable tracing), you should instead use '`MYODBCD.DLL`'. To install this file, copy '`MYODBCD.DLL`' over the installed '`MYODBC.DLL`' file.

11.2.4 How to Report Problems with MyODBC

`MyODBC` has been tested with Access, Admndemo.exe, C++-Builder, Borland Builder 4, Centura Team Developer (formerly Gupta SQL/Windows), ColdFusion (on Solaris and NT with svc pack 5), Crystal Reports, DataJunction, Delphi, ERwin, Excel, iHTML, FileMaker Pro, FoxPro, Notes 4.5/4.6, SBSS, Perl DBD-ODBC, Paradox, Powerbuilder, Powerdesigner 32 bit, VC++, and Visual Basic.

If you know of any other applications that work with `MyODBC`, please send mail to the `myodbc` mailing list about this! See Section 1.6.1.1 [Mailing-list], page 25.

With some programs you may get an error like: `Another user has modifies the record that you have modified`. In most cases this can be solved by doing one of the following things:

- Add a primary key for the table if there isn't one already.
- Add a timestamp column if there isn't one already.
- Only use double float fields. Some programs may fail when they compare single floats.

If the above doesn't help, you should do a `MyODBC` trace file and try to figure out why things go wrong.

11.2.5 Programs Known to Work with MyODBC

Most programs should work with `MyODBC`, but for each of those listed here, we have tested it ourselves or received confirmation from some user that it works:

Program **Comment**

Access To make Access work:

- If you are using Access 2000, you should get and install the newest (version 2.6 or above) Microsoft MDAC (`Microsoft Data Access Components`) from `http://www.microsoft.com/data/`. This will fix the following bug in Access: when you export data to MySQL, the table and column names aren't specified. Another way to around this bug is to upgrade to MyODBC Version 2.50.33 and MySQL Version 3.23.x, which together provide a workaround for this bug!

  You should also get and apply the Microsoft Jet 4.0 Service Pack 5 (SP5) which can be found here `http://support.microsoft.com/support/kb/articles/Q239/1/14.ASP`. This will fix some cases where columns are marked as `#deleted#` in Access.

  Note that if you are using MySQL Version 3.22, you must to apply the MDAC patch and use MyODBC 2.50.32 or 2.50.34 and above to go around this problem.
- For all Access versions, you should enable the MyODBC option flag `Return matching rows`. For Access 2.0, you should additionally enable `Simulate ODBC 1.0`.
- You should have a timestamp in all tables you want to be able to update. For maximum portability `TIMESTAMP(14)` or simple `TIMESTAMP` is recommended instead of other `TIMESTAMP(X)` variations.
- You should have a primary key in the table. If not, new or updated rows may show up as `#DELETED#`.
- Only use `DOUBLE` float fields. Access fails when comparing with single floats. The symptom usually is that new or updated rows may show up as `#DELETED#` or that you can't find or update rows.
- If you are linking a table through MyODBC, which has `BIGINT` as one of the column, then the results will be displayed as `#DELETED`. The work around solution is:
  - Have one more dummy column with `TIMESTAMP` as the datatype, preferably `TIMESTAMP(14)`.
  - Check the `'Change BIGINT columns to INT'` in connection options dialog in ODBC DSN Administrator
  - Delete the table link from access and re-create it.

  It still displays the previous records as `#DELETED#`, but newly added/updated records will be displayed properly.
- If you still get the error `Another user has changed your data` after adding a `TIMESTAMP` column, the following trick may help you:

Don't use `table` data sheet view. Create instead a form with the fields you want, and use that `form` data sheet view. You should set the `DefaultValue` property for the `TIMESTAMP` column to `NOW()`. It may be a good idea to hide the `TIMESTAMP` column from view so your users are not confused.

- In some cases, Access may generate illegal SQL queries that MySQL can't understand. You can fix this by selecting `"Query|SQLSpecific|Pass-Through"` from the Access menu.
- Access on NT will report `BLOB` columns as `OLE OBJECTS`. If you want to have `MEMO` columns instead, you should change the column to `TEXT` with `ALTER TABLE`.
- Access can't always handle `DATE` columns properly. If you have a problem with these, change the columns to `DATETIME`.
- If you have in Access a column defined as `BYTE`, Access will try to export this as `TINYINT` instead of `TINYINT UNSIGNED`. This will give you problems if you have values > 127 in the column!

ADO
: When you are coding with the ADO API and `MyODBC` you need to put attention in some default properties that aren't supported by the MySQL server. For example, using the `CursorLocation Property` as `adUseServer` will return for the `RecordCount Property` a result of -1. To have the right value, you need to set this property to `adUseClient`, like is showing in the VB code here:

```
Dim myconn As New ADODB.Connection
Dim myrs As New Recordset
Dim mySQL As String
Dim myrows As Long

myconn.Open "DSN=MyODBCsample"
mySQL = "SELECT * from user"
myrs.Source = mySQL
Set myrs.ActiveConnection = myconn
myrs.CursorLocation = adUseClient
myrs.Open
myrows = myrs.RecordCount

myrs.Close
myconn.Close
```

Another workaround is to use a `SELECT COUNT(*)` statement for a similar query to get the correct row count.

Active server pages (ASP)
: You should use the option flag `Return matching rows`.

BDE applications
: To get these to work, you should set the option flags `Don't optimize column widths` and `Return matching rows`.

Borland Builder 4

When you start a query you can use the property `Active` or use the method `Open`. Note that `Active` will start by automatically issuing a `SELECT * FROM ...` query that may not be a good thing if your tables are big!

ColdFusion (On Unix)

The following information is taken from the ColdFusion documentation:

Use the following information to configure ColdFusion Server for Linux to use the unixODBC driver with `MyODBC` for MySQL data sources. Allaire has verified that `MyODBC` Version 2.50.26 works with MySQL Version 3.22.27 and ColdFusion for Linux. (Any newer version should also work.) You can download `MyODBC` at `http://www.mysql.com/downloads/api-myodbc.html`

ColdFusion Version 4.5.1 allows you to us the ColdFusion Administrator to add the MySQL data source. However, the driver is not included with ColdFusion Version 4.5.1. Before the MySQL driver will appear in the ODBC datasources drop-down list, you must build and copy the `MyODBC` driver to '`/opt/coldfusion/lib/libmyodbc.so`'.

The Contrib directory contains the program '`mydsn-xxx.zip`' which allows you to build and remove the DSN registry file for the MyODBC driver on Coldfusion applications.

DataJunction

You have to change it to output `VARCHAR` rather than `ENUM`, as it exports the latter in a manner that causes MySQL grief.

Excel Works. A few tips:

- If you have problems with dates, try to select them as strings using the `CONCAT()` function. For example:

```
select CONCAT(rise_time), CONCAT(set_time)
    from sunrise_sunset;
```

  Values retrieved as strings this way should be correctly recognised as time values by Excel97.

  The purpose of `CONCAT()` in this example is to fool ODBC into thinking the column is of "string type". Without the `CONCAT()`, ODBC knows the column is of time type, and Excel does not understand that.

  Note that this is a bug in Excel, because it automatically converts a string to a time. This would be great if the source was a text file, but is plain stupid when the source is an ODBC connection that reports exact types for each column.

Word

To retrieve data from MySQL to Word/Excel documents, you need to use the `MyODBC` driver and the Add-in Microsoft Query help.

For example, create a db with a table containing 2 columns of text:

- Insert rows using the `mysql` client command-line tool.
- Create a DSN file using the ODBC manager, for example, '`my`' for the db above.

- Open the Word application.
- Create a blank new documentation.
- Using the tool bar called Database, press the button insert database.
- Press the button Get Data.
- At the right hand of the screen Get Data, press the button Ms Query.
- In the Ms Query create a New Data Source using the DSN file my.
- Select the new query.
- Select the columns that you want.
- Make a filter if you want.
- Make a Sort if you want.
- Select Return Data to Microsoft Word.
- Click Finish.
- Click Insert data and select the records.
- Click OK and you see the rows in your Word document.

odbcadmin

Test program for ODBC.

Delphi You must use BDE Version 3.2 or newer. Set the `Don't optimize column width` option field when connecting to MySQL.

Also, here is some potentially useful Delphi code that sets up both an ODBC entry and a BDE entry for `MyODBC` (the BDE entry requires a BDE Alias Editor that is free at a Delphi Super Page near you. (Thanks to Bryan Brunton `bryan@flesherfab.com` for this):

```
fReg:= TRegistry.Create;
  fReg.OpenKey('\Software\ODBC\ODBC.INI\DocumentsFab', True);
  fReg.WriteString('Database', 'Documents');
  fReg.WriteString('Description', ' ');
  fReg.WriteString('Driver', 'C:\WINNT\System32\myodbc.dll');
  fReg.WriteString('Flag', '1');
  fReg.WriteString('Password', '');
  fReg.WriteString('Port', ' ');
  fReg.WriteString('Server', 'xmark');
  fReg.WriteString('User', 'winuser');
  fReg.OpenKey('\Software\ODBC\ODBC.INI\ODBC Data Sources', True);
  fReg.WriteString('DocumentsFab', 'MySQL');
  fReg.CloseKey;
  fReg.Free;

  Memo1.Lines.Add('DATABASE NAME=');
  Memo1.Lines.Add('USER NAME=');
  Memo1.Lines.Add('ODBC DSN=DocumentsFab');
  Memo1.Lines.Add('OPEN MODE=READ/WRITE');
  Memo1.Lines.Add('BATCH COUNT=200');
```

```
Memo1.Lines.Add('LANGDRIVER=');
Memo1.Lines.Add('MAX ROWS=-1');
Memo1.Lines.Add('SCHEMA CACHE DIR=');
Memo1.Lines.Add('SCHEMA CACHE SIZE=8');
Memo1.Lines.Add('SCHEMA CACHE TIME=-1');
Memo1.Lines.Add('SQLPASSTHRU MODE=SHARED AUTOCOMMIT');
Memo1.Lines.Add('SQLQRYMODE=');
Memo1.Lines.Add('ENABLE SCHEMA CACHE=FALSE');
Memo1.Lines.Add('ENABLE BCD=FALSE');
Memo1.Lines.Add('ROWSET SIZE=20');
Memo1.Lines.Add('BLOBS TO CACHE=64');
Memo1.Lines.Add('BLOB SIZE=32');

AliasEditor.Add('DocumentsFab','MySQL',Memo1.Lines);
```

C++ Builder
: Tested with BDE Version 3.0. The only known problem is that when the table schema changes, query fields are not updated. BDE, however, does not seem to recognise primary keys, only the index PRIMARY, though this has not been a problem.

Vision
: You should use the option flag `Return matching rows`.

Visual Basic
: To be able to update a table, you must define a primary key for the table.

  Visual Basic with ADO can't handle big integers. This means that some queries like `SHOW PROCESSLIST` will not work properly. The fix is to set the option `OPTION=16384` in the ODBC connect string or to set the `Change BIGINT columns to INT` option in the MyODBC connect screen. You may also want to set the `Return matching rows` option.

VisualInterDev
: If you get the error `[Microsoft][ODBC Driver Manager] Driver does not support this parameter` the reason may be that you have a `BIGINT` in your result. Try setting the `Change BIGINT columns to INT` option in the MyODBC connect screen.

Visual Objects
: You should use the option flag `Don't optimize column widths`.

11.2.6 How to Get the Value of an `AUTO_INCREMENT` Column in ODBC

A common problem is how to get the value of an automatically generated ID from an `INSERT`. With ODBC, you can do something like this (assuming that `auto` is an `AUTO_INCREMENT` field):

```
INSERT INTO foo (auto,text) VALUES(NULL,'text');
SELECT LAST_INSERT_ID();
```

Or, if you are just going to insert the ID into another table, you can do this:

```
INSERT INTO foo (auto,text) VALUES(NULL,'text');
INSERT INTO foo2 (id,text) VALUES(LAST_INSERT_ID(),'text');
```

See Section 11.1.12.3 [Getting unique ID], page 798.

For the benefit of some ODBC applications (at least Delphi and Access), the following query can be used to find a newly inserted row:

```
SELECT * FROM tbl_name WHERE auto IS NULL;
```

11.2.7 Reporting Problems with MyODBC

If you encounter difficulties with `MyODBC`, you should start by making a log file from the ODBC manager (the log you get when requesting logs from ODBCADMIN) and a `MyODBC` log.

To get a `MyODBC` log, you need to do the following:

1. Ensure that you are using '`myodbcd.dll`' and not '`myodbc.dll`'. The easiest way to do this is to get '`myodbcd.dll`' from the MyODBC distribution and copy it over the '`myodbc.dll`', which is probably in your '`C:\windows\system32`' or '`C:\winnt\system32`' directory.

   Note that you probably want to restore the old myodbc.dll file when you have finished testing, as this is a lot faster than '`myodbcd.dll`'.

2. Tag the 'Trace MyODBC' option flag in the `MyODBC` connect/configure screen. The log will be written to file '`C:\myodbc.log`'.

   If the trace option is not remembered when you are going back to the above screen, it means that you are not using the `myodbcd.dll` driver (see the item above).

3. Start your application and try to get it to fail.

Check the `MyODBC trace file`, to find out what could be wrong. You should be able to find out the issued queries by searching after the string `>mysql_real_query` in the '`myodbc.log`' file.

You should also try duplicating the queries in the `mysql` monitor or `admndemo` to find out if the error is MyODBC or MySQL.

If you find out something is wrong, please only send the relevant rows (max 40 rows) to the `myodbc` mailing list. See Section 1.6.1.1 [Mailing-list], page 25. Please never send the whole MyODBC or ODBC log file!

If you are unable to find out what's wrong, the last option is to make an archive (tar or zip) that contains a MyODBC trace file, the ODBC log file, and a README file that explains the problem. You can send this to `ftp://support.mysql.com/pub/mysql/secret/`. Only we at MySQL AB will have access to the files you upload, and we will be very discrete with the data!

If you can create a program that also shows this problem, please upload this too!

If the program works with some other SQL server, you should make an ODBC log file where you do exactly the same thing in the other SQL server.

Remember that the more information you can supply to us, the more likely it is that we can fix the problem!

11.3 MySQL Java Connectivity (JDBC)

There are 2 supported JDBC drivers for MySQL:

- `MySQL Connector/J` from MySQL AB, implemented in 100% native Java. This product was formerly known as the `mm.mysql` driver. You can download `MySQL Connector/J` from `http://www.mysql.com/products/connector-j/`.
- The Resin JDBC driver, which can be found at `http://www.caucho.com/projects/jdbc-mysql/index.x`

For documentation, consult any JDBC documentation, plus each driver's own documentation for MySQL-specific features.

11.4 MySQL PHP API

PHP is a server-side, HTML-embedded scripting language that may be used to create dynamic web pages. It contains support for accessing several databases, including MySQL. PHP may be run as a separate program or compiled as a module for use with the Apache web server.

The distribution and documentation are available at the PHP web site (`http://www.php.net/`).

11.4.1 Common Problems with MySQL and PHP

- Error: `"Maximum Execution Time Exceeded"` This is a PHP limit; go into the '`php3.ini`' file and set the maximum execution time up from 30 seconds to something higher, as needed. It is also not a bad idea to double the ram allowed per script to 16 MB instead of 8 MB.
- Error: `"Fatal error: Call to unsupported or undefined function mysql_connect() in .."` This means that your PHP version isn't compiled with MySQL support. You can either compile a dynamic MySQL module and load it into PHP or recompile PHP with built-in MySQL support. This is described in detail in the PHP manual.
- Error: `"undefined reference to 'uncompress'"` This means that the client library is compiled with support for a compressed client/server protocol. The fix is to add `-lz` last when linking with `-lmysqlclient`.

11.5 MySQL Perl API

This section documents the Perl `DBI` interface. The former interface was called `mysqlperl`. `DBI/DBD` now is the recommended Perl interface, so `mysqlperl` is obsolete and is not documented here.

11.5.1 `DBI` with `DBD::mysql`

`DBI` is a generic interface for many databases. That means that you can write a script that works with many different database engines without change. You need a DataBase Driver (DBD) defined for each database type. For MySQL, this driver is called `DBD::mysql`.

For more information on the Perl5 DBI, please visit the DBI web page and read the documentation:

```
http://dbi.perl.org/
```

Note that if you want to use transactions with Perl, you need to have DBD-mysql version 1.2216 or newer. Version 2.1022 or newer is recommended.

Installation instructions for MySQL Perl support are given in Section 2.7 [Perl support], page 152.

If you have the MySQL module installed, you can find information about specific MySQL functionality with one of the following command

```
shell> perldoc DBD/mysql
shell> perldoc mysql
```

11.5.2 The DBI Interface

Portable DBI Methods and Attributes

Method/Attribute	Description
connect	Establishes a connection to a database server.
disconnect	Disconnects from the database server.
prepare	Prepares an SQL statement for execution.
execute	Executes prepared statements.
do	Prepares and executes an SQL statement.
quote	Quotes string or BLOB values to be inserted.
fetchrow_array	Fetches the next row as an array of fields.
fetchrow_arrayref	Fetches next row as a reference array of fields.
fetchrow_hashref	Fetches next row as a reference to a hashtable.
fetchall_arrayref	Fetches all data as an array of arrays.
finish	Finishes a statement and lets the system free resources.
rows	Returns the number of rows affected.
data_sources	Returns an array of databases available on localhost.
ChopBlanks	Controls whether fetchrow_* methods trim spaces.
NUM_OF_PARAMS	The number of placeholders in the prepared statement.
NULLABLE	Which columns can be NULL.
trace	Perform tracing for debugging.

MySQL-specific Methods and Attributes

Method/Attribute	Description
mysql_insertid	The latest AUTO_INCREMENT value.
is_blob	Which columns are BLOB values.
is_key	Which columns are keys.
is_num	Which columns are numeric.
is_pri_key	Which columns are primary keys.
is_not_null	Which columns CANNOT be NULL. See NULLABLE.
length	Maximum possible column sizes.
max_length	Maximum column sizes actually present in result.

NAME	Column names.
NUM_OF_FIELDS	Number of fields returned.
table	Table names in returned set.
type	All column types.

The Perl methods are described in more detail in the following sections. Variables used for method return values have these meanings:

$dbh	Database handle
$sth	Statement handle
$rc	Return code (often a status)
$rv	Return value (often a row count)

Portable DBI Methods and Attributes

`connect($data_source, $username, $password)`

Use the `connect` method to make a database connection to the data source. The `$data_source` value should begin with `DBI:driver_name:`. Example uses of `connect` with the `DBD::mysql` driver:

```
$dbh = DBI->connect("DBI:mysql:$database", $user, $password);
$dbh = DBI->connect("DBI:mysql:$database:$hostname",
                    $user, $password);
$dbh = DBI->connect("DBI:mysql:$database:$hostname:$port",
                    $user, $password);
```

If the user name and/or password are undefined, `DBI` uses the values of the `DBI_USER` and `DBI_PASS` environment variables, respectively. If you don't specify a hostname, it defaults to `'localhost'`. If you don't specify a port number, it defaults to the default MySQL port (3306).

As of `Msql-Mysql-modules` Version 1.2009, the `$data_source` value allows certain modifiers:

`mysql_read_default_file=file_name`
: Read '`file_name`' as an option file. For information on option files, see Section 4.1.2 [Option files], page 203.

`mysql_read_default_group=group_name`
: The default group when reading an option file is normally the `[client]` group. By specifying the `mysql_read_default_group` option, the default group becomes the `[group_name]` group.

`mysql_compression=1`
: Use compressed communication between the client and server (MySQL Version 3.22.3 or later).

`mysql_socket=/path/to/socket`
: Specify the pathname of the Unix socket that is used to connect to the server (MySQL Version 3.21.15 or later).

Multiple modifiers may be given; each must be preceded by a semicolon.

For example, if you want to avoid hardcoding the user name and password into a DBI script, you can take them from the user's '~/.my.cnf' option file instead by writing your connect call like this:

```
$dbh = DBI->connect("DBI:mysql:$database"
                    . ";mysql_read_default_file=$ENV{HOME}/.my.cnf",
                    $user, $password);
```

This call will read options defined for the [client] group in the option file. If you wanted to do the same thing but use options specified for the [perl] group as well, you could use this:

```
$dbh = DBI->connect("DBI:mysql:$database"
                    . ";mysql_read_default_file=$ENV{HOME}/.my.cnf"
                    . ";mysql_read_default_group=perl",
                    $user, $password);
```

disconnect

The disconnect method disconnects the database handle from the database. This is typically called right before you exit from the program. Example:

```
$rc = $dbh->disconnect;
```

prepare($statement)

Prepares an SQL statement for execution by the database engine and returns a statement handle ($sth), which you can use to invoke the execute method.

Typically you handle SELECT statements (and SELECT-like statements such as SHOW, DESCRIBE, and EXPLAIN) by means of prepare and execute. Example:

```
$sth = $dbh->prepare($statement)
    or die "Can't prepare $statement: $dbh->errstr\n";
```

If you want to read big results to your client you can tell Perl to use mysql_use_result() with:

```
my $sth = $dbh->prepare($statement { "mysql_use_result" => 1});
```

execute

The execute method executes a prepared statement. For non-SELECT statements, execute returns the number of rows affected. If no rows are affected, execute returns "0E0", which Perl treats as zero but regards as true. If an error occurs, execute returns undef. For SELECT statements, execute only starts the SQL query in the database; you need to use one of the fetch_* methods described here to retrieve the data. Example:

```
$rv = $sth->execute
          or die "can't execute the query: " . $sth->errstr;
```

do($statement)

The do method prepares and executes an SQL statement and returns the number of rows affected. If no rows are affected, do returns "0E0", which Perl treats as zero but regards as true. This method is generally used for non-SELECT statements that cannot be prepared in advance (due to driver limitations) or that do not need to be executed more than once (inserts, deletes, etc.). Example:

```
$rv = $dbh->do($statement)
        or die "Can't execute $statement: $dbh- >errstr\n";
```

Generally the 'do' statement is much faster (and is preferable) than prepare/execute for statements that don't contain parameters.

`quote($string)`

The `quote` method is used to "escape" any special characters contained in the string and to add the required outer quotation marks. Example:

```
$sql = $dbh->quote($string)
```

`fetchrow_array`

This method fetches the next row of data and returns it as an array of field values. Example:

```
while(@row = $sth->fetchrow_array) {
        print qw($row[0]\t$row[1]\t$row[2]\n);
}
```

`fetchrow_arrayref`

This method fetches the next row of data and returns it as a reference to an array of field values. Example:

```
while($row_ref = $sth->fetchrow_arrayref) {
        print qw($row_ref->[0]\t$row_ref->[1]\t$row_ref->[2]\n);
}
```

`fetchrow_hashref`

This method fetches a row of data and returns a reference to a hash table containing field name/value pairs. This method is not nearly as efficient as using array references as demonstrated above. Example:

```
while($hash_ref = $sth->fetchrow_hashref) {
        print qw($hash_ref->{firstname}\t$hash_ref->{lastname}\t\
                $hash_ref->{title}\n);
}
```

`fetchall_arrayref`

This method is used to get all the data (rows) to be returned from the SQL statement. It returns a reference to an array of references to arrays for each row. You access or print the data by using a nested loop. Example:

```
my $table = $sth->fetchall_arrayref
                or die "$sth->errstr\n";
my($i, $j);
for $i ( 0 .. $#{$table} ) {
        for $j ( 0 .. $#{$table->[$i]} ) {
                print "$table->[$i][$j]\t";
        }
        print "\n";
}
```

`finish` Indicates that no more data will be fetched from this statement handle. You call this method to free up the statement handle and any system resources associated with it. Example:

```
$rc = $sth->finish;
```

`rows` Returns the number of rows changed (updated, deleted, etc.) by the last command. This is usually used after a non-`SELECT` `execute` statement. Example:

```
$rv = $sth->rows;
```

`NULLABLE` Returns a reference to an array of values that indicate whether columns may contain `NULL` values. The possible values for each array element are 0 or the empty string if the column cannot be `NULL`, 1 if it can, and 2 if the column's `NULL` status is unknown. Example:

```
$null_possible = $sth->{NULLABLE};
```

`NUM_OF_FIELDS`
This attribute indicates the number of fields returned by a `SELECT` or `SHOW FIELDS` statement. You may use this for checking whether a statement returned a result: A zero value indicates a non-`SELECT` statement like `INSERT`, `DELETE`, or `UPDATE`. Example:

```
$nr_of_fields = $sth->{NUM_OF_FIELDS};
```

`data_sources($driver_name)`
This method returns an array containing names of databases available to the MySQL server on the host `'localhost'`. Example:

```
@dbs = DBI->data_sources("mysql");
```

`ChopBlanks`
This attribute determines whether the `fetchrow_*` methods will chop leading and trailing blanks from the returned values. Example:

```
$sth->{'ChopBlanks'} =1;
```

`trace($trace_level)`
`trace($trace_level, $trace_filename)`
The `trace` method enables or disables tracing. When invoked as a `DBI` class method, it affects tracing for all handles. When invoked as a database or statement handle method, it affects tracing for the given handle (and any future children of the handle). Setting `$trace_level` to 2 provides detailed trace information. Setting `$trace_level` to 0 disables tracing. Trace output goes to the standard error output by default. If `$trace_filename` is specified, the file is opened in append mode and output for **all** traced handles is written to that file. Example:

```
DBI->trace(2);                 # trace everything
DBI->trace(2,"/tmp/dbi.out"); # trace everything to
                               # /tmp/dbi.out
$dth->trace(2);                # trace this database handle
$sth->trace(2);                # trace this statement handle
```

You can also enable `DBI` tracing by setting the `DBI_TRACE` environment variable. Setting it to a numeric value is equivalent to calling `DBI->(value)`. Setting it to a pathname is equivalent to calling `DBI->(2,value)`.

MySQL-specific Methods and Attributes

The methods shown here are MySQL-specific and not part of the DBI standard. Several of them are now deprecated: is_blob, is_key, is_num, is_pri_key, is_not_null, length, max_length, and table. Where DBI-standard alternatives exist, they are noted here:

mysql_insertid
: If you use the AUTO_INCREMENT feature of MySQL, the new auto-incremented values will be stored here. Example:

```
$new_id = $sth->{mysql_insertid};
```

With old versions of the DBI interface, you could use $sth->{'insertid'}.

is_blob
: Returns a reference to an array of boolean values; for each element of the array, a value of TRUE indicates that the respective column is a BLOB. Example:

```
$keys = $sth->{is_blob};
```

is_key
: Returns a reference to an array of boolean values; for each element of the array, a value of TRUE indicates that the respective column is a key. Example:

```
$keys = $sth->{is_key};
```

is_num
: Returns a reference to an array of boolean values; for each element of the array, a value of TRUE indicates that the respective column contains numeric values. Example:

```
$nums = $sth->{is_num};
```

is_pri_key
: Returns a reference to an array of boolean values; for each element of the array, a value of TRUE indicates that the respective column is a primary key. Example:

```
$pri_keys = $sth->{is_pri_key};
```

is_not_null
: Returns a reference to an array of boolean values; for each element of the array, a value of FALSE indicates that this column may contain NULL values. Example:

```
$not_nulls = $sth->{is_not_null};
```

is_not_null is deprecated; it is preferable to use the NULLABLE attribute (described above), because that is a DBI standard.

length
max_length
: Each of these methods returns a reference to an array of column sizes. The length array indicates the maximum possible sizes that each column may be (as declared in the table description). The max_length array indicates the maximum sizes actually present in the result table. Example:

```
$lengths = $sth->{length};
$max_lengths = $sth->{max_length};
```

NAME
: Returns a reference to an array of column names. Example:

```
$names = $sth->{NAME};
```

table
: Returns a reference to an array of table names. Example:

```
$tables = $sth->{table};
```

`type` Returns a reference to an array of column types. Example:

```
$types = $sth->{type};
```

11.5.3 More DBI/DBD Information

You can use the `perldoc` command to get more information about `DBI`.

```
perldoc DBI
perldoc DBI::FAQ
perldoc DBD::mysql
```

You can also use the `pod2man`, `pod2html`, etc., tools to translate to other formats.

You can find the latest `DBI` information at the `DBI` web page: `http://dbi.perl.org/`.

11.6 MySQL C++ API

MySQL Connector/C++ (or `MySQL++`) is the official MySQL API for C++. More information can be found at `http://www.mysql.com/products/mysql++/`.

11.6.1 Borland C++

You can compile the MySQL Windows source with Borland C++ 5.02. (The Windows source includes only projects for Microsoft VC++, for Borland C++ you have to do the project files yourself.)

One known problem with Borland C++ is that it uses a different structure alignment than VC++. This means that you will run into problems if you try to use the default `libmysql.dll` libraries (that was compiled with VC++) with Borland C++. You can do one of the following to avoid this problem.

- You can use the static MySQL libraries for Borland C++ that you can find on `http://www.mysql.com/downloads/os-win32.html`.
- Only call `mysql_init()` with `NULL` as an argument, not a pre-allocated MYSQL struct.

11.7 MySQL Python API

`MySQLdb` provides MySQL support for Python, compliant with the Python DB API version 2.0. It can be found at `http://sourceforge.net/projects/mysql-python/`.

11.8 MySQL Tcl API

MySQLtcl is a simple API for accessing a MySQL database server from the Tcl programming language. It can be found at `http://www.xdobry.de/mysqltcl/`.

11.9 MySQL Eiffel Wrapper

Eiffel MySQL is an interface to the MySQL database server using the Eiffel programming language, written by Michael Ravits. It can be found at `http://efsa.sourceforge.net/archive/ravits/mysql.htm`.

12 Error Handling in MySQL

This chapter describes how MySQL handles errors.

12.1 Error Returns

Following are error codes that may appear when you call MySQL from any host language.

The `Name` and `Error Code` columns correspond to definitions in the MySQL source code file: '`include/mysqld_error.h`'

The `SQLSTATE` column corresponds to definitions in the MySQL source code file: '`include/sql_state.h`'

The SQLSTATE error code will only appear if you use MySQL version 4.1. SQLSTATE codes were added for compatibility with X/Open / ANSI / ODBC behaviour.

A suggested text for each error code can be found in the error-message file: '`share/english/errmsg.sys`'

Because updates are frequent, it is possible that the above sources will contain additional error codes.

Name	Error Code	SQLSTATE
ER_HASHCHK	1000	HY000
ER_NISAMCHK	1001	HY000
ER_NO	1002	HY000
ER_YES	1003	HY000
ER_CANT_CREATE_FILE	1004	HY000
ER_CANT_CREATE_TABLE	1005	HY000
ER_CANT_CREATE_DB	1006	HY000
ER_DB_CREATE_EXISTS	1007	HY000
ER_DB_DROP_EXISTS	1008	HY000
ER_DB_DROP_DELETE	1009	HY000
ER_DB_DROP_RMDIR	1010	HY000
ER_CANT_DELETE_FILE	1011	HY000
ER_CANT_FIND_SYSTEM_REC	1012	HY000
ER_CANT_GET_STAT	1013	HY000
ER_CANT_GET_WD	1014	HY000
ER_CANT_LOCK	1015	HY000
ER_CANT_OPEN_FILE	1016	HY000
ER_FILE_NOT_FOUND	1017	HY000
ER_CANT_READ_DIR	1018	HY000
ER_CANT_SET_WD	1019	HY000
ER_CHECKREAD	1020	HY000
ER_DISK_FULL	1021	HY000
ER_DUP_KEY	1022	23000
ER_ERROR_ON_CLOSE	1023	HY000
ER_ERROR_ON_READ	1024	HY000

ER_ERROR_ON_RENAME	1025	HY000
ER_ERROR_ON_WRITE	1026	HY000
ER_FILE_USED	1027	HY000
ER_FILSORT_ABORT	1028	HY000
ER_FORM_NOT_FOUND	1029	HY000
ER_GET_ERRNO	1030	HY000
ER_ILLEGAL_HA	1031	HY000
ER_KEY_NOT_FOUND	1032	HY000
ER_NOT_FORM_FILE	1033	HY000
ER_NOT_KEYFILE	1034	HY000
ER_OLD_KEYFILE	1035	HY000
ER_OPEN_AS_READONLY	1036	HY000
ER_OUTOFMEMORY	1037	HY001
ER_OUT_OF_SORTMEMORY	1038	HY001
ER_UNEXPECTED_EOF	1039	HY000
ER_CON_COUNT_ERROR	1040	08004
ER_OUT_OF_RESOURCES	1041	08004
ER_BAD_HOST_ERROR	1042	08S01
ER_HANDSHAKE_ERROR	1043	08S01
ER_DBACCESS_DENIED_ERROR	1044	42000
ER_ACCESS_DENIED_ERROR	1045	42000
ER_NO_DB_ERROR	1046	42000
ER_UNKNOWN_COM_ERROR	1047	08S01
ER_BAD_NULL_ERROR	1048	23000
ER_BAD_DB_ERROR	1049	42000
ER_TABLE_EXISTS_ERROR	1050	42S01
ER_BAD_TABLE_ERROR	1051	42S02
ER_NON_UNIQ_ERROR	1052	23000
ER_SERVER_SHUTDOWN	1053	08S01
ER_BAD_FIELD_ERROR	1054	42S22
ER_WRONG_FIELD_WITH_GROUP	1055	42000
ER_WRONG_GROUP_FIELD	1056	42000
ER_WRONG_SUM_SELECT	1057	42000
ER_WRONG_VALUE_COUNT	1058	21S01
ER_TOO_LONG_IDENT	1059	42000
ER_DUP_FIELDNAME	1060	42S21
ER_DUP_KEYNAME	1061	42000
ER_DUP_ENTRY	1062	23000
ER_WRONG_FIELD_SPEC	1063	42000
ER_PARSE_ERROR	1064	42000
ER_EMPTY_QUERY	1065	42000
ER_NONUNIQ_TABLE	1066	42000
ER_INVALID_DEFAULT	1067	42000
ER_MULTIPLE_PRI_KEY	1068	42000
ER_TOO_MANY_KEYS	1069	42000
ER_TOO_MANY_KEY_PARTS	1070	42000
ER_TOO_LONG_KEY	1071	42000

ER_KEY_COLUMN_DOES_NOT_EXITS	1072	42000
ER_BLOB_USED_AS_KEY	1073	42000
ER_TOO_BIG_FIELDLENGTH	1074	42000
ER_WRONG_AUTO_KEY	1075	42000
ER_READY	1076	00000
ER_NORMAL_SHUTDOWN	1077	00000
ER_GOT_SIGNAL	1078	00000
ER_SHUTDOWN_COMPLETE	1079	00000
ER_FORCING_CLOSE	1080	08S01
ER_IPSOCK_ERROR	1081	08S01
ER_NO_SUCH_INDEX	1082	42S12
ER_WRONG_FIELD_TERMINATORS	1083	42000
ER_BLOBS_AND_NO_TERMINATED	1084	42000
ER_TEXTFILE_NOT_READABLE	1085	HY000
ER_FILE_EXISTS_ERROR	1086	HY000
ER_LOAD_INFO	1087	HY000
ER_ALTER_INFO	1088	HY000
ER_WRONG_SUB_KEY	1089	HY000
ER_CANT_REMOVE_ALL_FIELDS	1090	42000
ER_CANT_DROP_FIELD_OR_KEY	1091	42000
ER_INSERT_INFO	1092	HY000
ER_UPDATE_TABLE_USED	1093	HY000
ER_NO_SUCH_THREAD	1094	HY000
ER_KILL_DENIED_ERROR	1095	HY000
ER_NO_TABLES_USED	1096	HY000
ER_TOO_BIG_SET	1097	HY000
ER_NO_UNIQUE_LOGFILE	1098	HY000
ER_TABLE_NOT_LOCKED_FOR_WRITE	1099	HY000
ER_TABLE_NOT_LOCKED	1100	HY000
ER_BLOB_CANT_HAVE_DEFAULT	1101	42000
ER_WRONG_DB_NAME	1102	42000
ER_WRONG_TABLE_NAME	1103	42000
ER_TOO_BIG_SELECT	1104	42000
ER_UNKNOWN_ERROR	1105	HY000
ER_UNKNOWN_PROCEDURE	1106	42000
ER_WRONG_PARAMCOUNT_TO_PROCEDURE	1107	42000
ER_WRONG_PARAMETERS_TO_PROCEDURE	1108	HY000
ER_UNKNOWN_TABLE	1109	42S02
ER_FIELD_SPECIFIED_TWICE	1110	42000
ER_INVALID_GROUP_FUNC_USE	1111	42000
ER_UNSUPPORTED_EXTENSION	1112	42000
ER_TABLE_MUST_HAVE_COLUMNS	1113	42000
ER_RECORD_FILE_FULL	1114	HY000
ER_UNKNOWN_CHARACTER_SET	1115	42000
ER_TOO_MANY_TABLES	1116	HY000
ER_TOO_MANY_FIELDS	1117	HY000
ER_TOO_BIG_ROWSIZE	1118	42000

ER_STACK_OVERRUN	1119	HY000
ER_WRONG_OUTER_JOIN	1120	42000
ER_NULL_COLUMN_IN_INDEX	1121	42000
ER_CANT_FIND_UDF	1122	HY000
ER_CANT_INITIALIZE_UDF	1123	HY000
ER_UDF_NO_PATHS	1124	HY000
ER_UDF_EXISTS	1125	HY000
ER_CANT_OPEN_LIBRARY	1126	HY000
ER_CANT_FIND_DL_ENTRY	1127	HY000
ER_FUNCTION_NOT_DEFINED	1128	HY000
ER_HOST_IS_BLOCKED	1129	HY000
ER_HOST_NOT_PRIVILEGED	1130	HY000
ER_PASSWORD_ANONYMOUS_USER	1131	42000
ER_PASSWORD_NOT_ALLOWED	1132	42000
ER_PASSWORD_NO_MATCH	1133	42000
ER_UPDATE_INFO	1134	HY000
ER_CANT_CREATE_THREAD	1135	HY000
ER_WRONG_VALUE_COUNT_ON_ROW	1136	21S01
ER_CANT_REOPEN_TABLE	1137	HY000
ER_INVALID_USE_OF_NULL	1138	42000
ER_REGEXP_ERROR	1139	42000
ER_MIX_OF_GROUP_FUNC_AND_FIELDS	1140	42000
ER_NONEXISTING_GRANT	1141	42000
ER_TABLEACCESS_DENIED_ERROR	1142	42000
ER_COLUMNACCESS_DENIED_ERROR	1143	42000
ER_ILLEGAL_GRANT_FOR_TABLE	1144	42000
ER_GRANT_WRONG_HOST_OR_USER	1145	42000
ER_NO_SUCH_TABLE	1146	42S02
ER_NONEXISTING_TABLE_GRANT	1147	42000
ER_NOT_ALLOWED_COMMAND	1148	42000
ER_SYNTAX_ERROR	1149	42000
ER_DELAYED_CANT_CHANGE_LOCK	1150	HY000
ER_TOO_MANY_DELAYED_THREADS	1151	HY000
ER_ABORTING_CONNECTION	1152	08S01
ER_NET_PACKET_TOO_LARGE	1153	08S01
ER_NET_READ_ERROR_FROM_PIPE	1154	08S01
ER_NET_FCNTL_ERROR	1155	08S01
ER_NET_PACKETS_OUT_OF_ORDER	1156	08S01
ER_NET_UNCOMPRESS_ERROR	1157	08S01
ER_NET_READ_ERROR	1158	08S01
ER_NET_READ_INTERRUPTED	1159	08S01
ER_NET_ERROR_ON_WRITE	1160	08S01
ER_NET_WRITE_INTERRUPTED	1161	08S01
ER_TOO_LONG_STRING	1162	42000
ER_TABLE_CANT_HANDLE_BLOB	1163	42000
ER_TABLE_CANT_HANDLE_AUTO_INCREMENT	1164	42000
ER_DELAYED_INSERT_TABLE_LOCKED	1165	HY000

ER_WRONG_COLUMN_NAME	1166	42000
ER_WRONG_KEY_COLUMN	1167	42000
ER_WRONG_MRG_TABLE	1168	HY000
ER_DUP_UNIQUE	1169	23000
ER_BLOB_KEY_WITHOUT_LENGTH	1170	42000
ER_PRIMARY_CANT_HAVE_NULL	1171	42000
ER_TOO_MANY_ROWS	1172	42000
ER_REQUIRES_PRIMARY_KEY	1173	42000
ER_NO_RAID_COMPILED	1174	HY000
ER_UPDATE_WITHOUT_KEY_IN_SAFE_MODE	1175	HY000
ER_KEY_DOES_NOT_EXITS	1176	HY000
ER_CHECK_NO_SUCH_TABLE	1177	42000
ER_CHECK_NOT_IMPLEMENTED	1178	42000
ER_CANT_DO_THIS_DURING_AN_TRANSACTION	1179	25000
ER_ERROR_DURING_COMMIT	1180	HY000
ER_ERROR_DURING_ROLLBACK	1181	HY000
ER_ERROR_DURING_FLUSH_LOGS	1182	HY000
ER_ERROR_DURING_CHECKPOINT	1183	HY000
ER_NEW_ABORTING_CONNECTION	1184	08S01
ER_DUMP_NOT_IMPLEMENTED	1185	HY000
ER_FLUSH_MASTER_BINLOG_CLOSED	1186	HY000
ER_INDEX_REBUILD	1187	HY000
ER_MASTER	1188	HY000
ER_MASTER_NET_READ	1189	08S01
ER_MASTER_NET_WRITE	1190	08S01
ER_FT_MATCHING_KEY_NOT_FOUND	1191	HY000
ER_LOCK_OR_ACTIVE_TRANSACTION	1192	HY000
ER_UNKNOWN_SYSTEM_VARIABLE	1193	HY000
ER_CRASHED_ON_USAGE	1194	HY000
ER_CRASHED_ON_REPAIR	1195	HY000
ER_WARNING_NOT_COMPLETE_ROLLBACK	1196	HY000
ER_TRANS_CACHE_FULL	1197	HY000
ER_SLAVE_MUST_STOP	1198	HY000
ER_SLAVE_NOT_RUNNING	1199	HY000
ER_BAD_SLAVE	1200	HY000
ER_MASTER_INFO	1201	HY000
ER_SLAVE_THREAD	1202	HY000
ER_TOO_MANY_USER_CONNECTIONS	1203	42000
ER_SET_CONSTANTS_ONLY	1204	HY000
ER_LOCK_WAIT_TIMEOUT	1205	HY000
ER_LOCK_TABLE_FULL	1206	HY000
ER_READ_ONLY_TRANSACTION	1207	25000
ER_DROP_DB_WITH_READ_LOCK	1208	HY000
ER_CREATE_DB_WITH_READ_LOCK	1209	HY000
ER_WRONG_ARGUMENTS	1210	HY000
ER_NO_PERMISSION_TO_CREATE_USER	1211	42000
ER_UNION_TABLES_IN_DIFFERENT_DIR	1212	HY000

ER_LOCK_DEADLOCK	1213	40001
ER_TABLE_CANT_HANDLE_FULLTEXT	1214	HY000
ER_CANNOT_ADD_FOREIGN	1215	HY000
ER_NO_REFERENCED_ROW	1216	23000
ER_ROW_IS_REFERENCED	1217	23000
ER_CONNECT_TO_MASTER	1218	08S01
ER_QUERY_ON_MASTER	1219	HY000
ER_ERROR_WHEN_EXECUTING_COMMAND	1220	HY000
ER_WRONG_USAGE	1221	HY000
ER_WRONG_NUMBER_OF_COLUMNS_IN_SELECT	1222	21000
ER_CANT_UPDATE_WITH_READLOCK	1223	HY000
ER_MIXING_NOT_ALLOWED	1224	HY000
ER_DUP_ARGUMENT	1225	HY000
ER_USER_LIMIT_REACHED	1226	42000
ER_SPECIFIC_ACCESS_DENIED_ERROR	1227	HY000
ER_LOCAL_VARIABLE	1228	HY000
ER_GLOBAL_VARIABLE	1229	HY000
ER_NO_DEFAULT	1230	42000
ER_WRONG_VALUE_FOR_VAR	1231	42000
ER_WRONG_TYPE_FOR_VAR	1232	42000
ER_VAR_CANT_BE_READ	1233	HY000
ER_CANT_USE_OPTION_HERE	1234	42000
ER_NOT_SUPPORTED_YET	1235	42000
ER_MASTER_FATAL_ERROR_READING_BINLOG	1236	HY000
ER_SLAVE_IGNORED_TABLE	1237	HY000
ER_WRONG_FK_DEF	1238	42000
ER_KEY_REF_DO_NOT_MATCH_TABLE_REF	1239	HY000
ER_CARDINALITY_COL	1240	21000
ER_SUBSELECT_NO_1_ROW	1241	21000
ER_UNKNOWN_STMT_HANDLER	1242	HY000
ER_CORRUPT_HELP_DB	1243	HY000
ER_CYCLIC_REFERENCE	1244	HY000
ER_AUTO_CONVERT	1245	HY000
ER_ILLEGAL_REFERENCE	1246	42S22
ER_DERIVED_MUST_HAVE_ALIAS	1247	42000
ER_SELECT_REDUCED	1248	01000
ER_TABLENAME_NOT_ALLOWED_HERE	1249	42000
ER_NOT_SUPPORTED_AUTH_MODE	1250	08004
ER_SPATIAL_CANT_HAVE_NULL	1251	42000
ER_COLLATION_CHARSET_MISMATCH	1252	42000
ER_SLAVE_WAS_RUNNING	1253	HY000
ER_SLAVE_WAS_NOT_RUNNING	1254	HY000
ER_TOO_BIG_FOR_UNCOMPRESS	1255	HY000
ER_ZLIB_Z_MEM_ERROR	1256	HY000
ER_ZLIB_Z_BUF_ERROR	1257	HY000
ER_ZLIB_Z_DATA_ERROR	1258	HY000
ER_CUT_VALUE_GROUP_CONCAT	1259	HY000

ER_WARN_TOO_FEW_RECORDS	1260	01000
ER_WARN_TOO_MANY_RECORDS	1261	01000
ER_WARN_NULL_TO_NOTNULL	1262	01000
ER_WARN_DATA_OUT_OF_RANGE	1263	01000
ER_WARN_DATA_TRUNCATED	1264	01000
ER_WARN_USING_OTHER_HANDLER	1265	01000
ER_CANT_AGGREGATE_COLLATIONS	1266	42000
ER_DROP_USER	1267	42000
ER_REVOKE_GRANTS	1268	42000
ER_CANT_AGGREGATE_3COLLATIONS	1269	42000
ER_CANT_AGGREGATE_NCOLLATIONS	1270	42000
ER_VARIABLE_IS_NOT_STRUCT	1271	HY000
ER_UNKNOWN_COLLATION	1272	HY000
ER_SLAVE_IGNORED_SSL_PARAMS	1273	HY000
ER_SERVER_IS_IN_SECURE_AUTH_MODE	1274	HY000
ER_WARN_FIELD_RESOLVED	1275	HY000
ER_BAD_SLAVE_UNTIL_COND	1276	HY000
ER_MISSING_SKIP_SLAVE	1277	HY000
ER_UNTIL_COND_IGNORED	1278	HY000

13 Extending MySQL

13.1 MySQL Internals

This chapter describes a lot of things that you need to know when working on the MySQL code. If you plan to contribute to MySQL development, want to have access to the bleeding-edge in-between versions code, or just want to keep track of development, follow the instructions in Section 2.3.4 [Installing source tree], page 94. If you are interested in MySQL internals, you should also subscribe to our `internals` mailing list. This list is relatively low traffic. For details on how to subscribe, please see Section 1.6.1.1 [Mailing-list], page 25. All developers at MySQL AB are on the `internals` list and we help other people who are working on the MySQL code. Feel free to use this list both to ask questions about the code and to send patches that you would like to contribute to the MySQL project!

13.1.1 MySQL Threads

The MySQL server creates the following threads:

- The TCP/IP connection thread handles all connection requests and creates a new dedicated thread to handle the authentication and SQL query processing for each connection.
- On Windows NT there is a named pipe handler thread that does the same work as the TCP/IP connection thread on named pipe connect requests.
- The signal thread handles all signals. This thread also normally handles alarms and calls `process_alarm()` to force timeouts on connections that have been idle too long.
- If `mysqld` is compiled with `-DUSE_ALARM_THREAD`, a dedicated thread that handles alarms is created. This is only used on some systems where there are problems with `sigwait()` or if one wants to use the `thr_alarm()` code in ones application without a dedicated signal handling thread.
- If one uses the `--flush_time=#` option, a dedicated thread is created to flush all tables at the given interval.
- Every connection has its own thread.
- Every different table on which one uses `INSERT DELAYED` gets its own thread.
- If you use `--master-host`, a slave replication thread will be started to read and apply updates from the master.

`mysqladmin processlist` only shows the connection, `INSERT DELAYED`, and replication threads.

13.1.2 MySQL Test Suite

Until recently, our main full-coverage test suite was based on proprietary customer data and for that reason has not been publicly available. The only publicly available part of our testing process consisted of the `crash-me` test, a Perl DBI/DBD benchmark found in the `sql-bench` directory, and miscellaneous tests located in `tests` directory. The lack

of a standardised publicly available test suite has made it difficult for our users, as well developers, to do regression tests on the MySQL code. To address this problem, we have created a new test system that is included in the source and binary distributions starting in Version 3.23.29.

The current set of test cases doesn't test everything in MySQL, but it should catch most obvious bugs in the SQL processing code, OS/library issues, and is quite thorough in testing replication. Our eventual goal is to have the tests cover 100% of the code. We welcome contributions to our test suite. You may especially want to contribute tests that examine the functionality critical to your system, as this will ensure that all future MySQL releases will work well with your applications.

13.1.2.1 Running the MySQL Test Suite

The test system consist of a test language interpreter (`mysqltest`), a shell script to run all tests(`mysql-test-run`), the actual test cases written in a special test language, and their expected results. To run the test suite on your system after a build, type `make test` or `mysql-test/mysql-test-run` from the source root. If you have installed a binary distribution, `cd` to the install root (eg. `/usr/local/mysql`), and do `scripts/mysql-test-run`. All tests should succeed. If not, you should try to find out why and report the problem if this is a bug in MySQL. See Section 13.1.2.3 [Reporting mysqltest bugs], page 834.

If you have a copy of `mysqld` running on the machine where you want to run the test suite you do not have to stop it, as long as it is not using ports `9306` and `9307`. If one of those ports is taken, you should edit `mysql-test-run` and change the values of the master and/or slave port to one that is available.

You can run one individual test case with `mysql-test/mysql-test-run test_name`.

If one test fails, you should test running `mysql-test-run` with the `--force` option to check if any other tests fails.

13.1.2.2 Extending the MySQL Test Suite

You can use the `mysqltest` language to write your own test cases. Unfortunately, we have not yet written full documentation for it. You can, however, look at our current test cases and use them as an example. The following points should help you get started:

- The tests are located in `mysql-test/t/*.test`
- A test case consists of `;` terminated statements and is similar to the input of `mysql` command-line client. A statement by default is a query to be sent to MySQL server, unless it is recognised as internal command (eg. `sleep`).
- All queries that produce results—for example, `SELECT`, `SHOW`, `EXPLAIN`, etc., must be preceded with `@/path/to/result/file`. The file must contain the expected results. An easy way to generate the result file is to run `mysqltest -r < t/test-case-name.test` from `mysql-test` directory, and then edit the generated result files, if needed, to adjust them to the expected output. In that case, be very careful about not adding or deleting any invisible characters - make sure to only change the text and/or delete lines. If you have to insert a line, make sure the fields are separated with a hard tab, and there is a hard tab at the end. You may want to use `od -c` to make sure your

text editor has not messed anything up during edit. We, of course, hope that you will never have to edit the output of `mysqltest -r` as you only have to do it when you find a bug.

- To be consistent with our setup, you should put your result files in `mysql-test/r` directory and name them `test_name.result`. If the test produces more than one result, you should use `test_name.a.result`, `test_name.b.result`, etc.
- If a statement returns an error, you should on the line before the statement specify with the `--error error-number`. The error number can be a list of possible error numbers separated with `','`.
- If you are writing a replication test case, you should on the first line of the test file, put `source include/master-slave.inc;`. To switch between master and slave, use `connection master;` and `connection slave;`. If you need to do something on an alternate connection, you can do `connection master1;` for the master, and `connection slave1;` for the slave.
- If you need to do something in a loop, you can use something like this:

```
let $1=1000;
while ($1)
{
 # do your queries here
 dec $1;
}
```

- To sleep between queries, use the `sleep` command. It supports fractions of a second, so you can do `sleep 1.3;`, for example, to sleep 1.3 seconds.
- To run the slave with additional options for your test case, put them in the command-line format in `mysql-test/t/test_name-slave.opt`. For the master, put them in `mysql-test/t/test_name-master.opt`.
- If you have a question about the test suite, or have a test case to contribute, e-mail to the MySQL internals mailing list. See Section 1.6.1.1 [Mailing-list], page 25. As this list does not accept attachments, you should ftp all the relevant files to: `ftp://support.mysql.com/pub/mysql/Incoming/`

13.1.2.3 Reporting Bugs in the MySQL Test Suite

If your MySQL version doesn't pass the test suite you should do the following:

- Don't send a bug report before you have found out as much as possible of what when wrong! When you do it, please use the `mysqlbug` script so that we can get information about your system and `MySQL` version. See Section 1.6.1.3 [Bug reports], page 27.
- Make sure to include the output of `mysql-test-run`, as well as contents of all `.reject` files in `mysql-test/r` directory.
- If a test in the test suite fails, check if the test fails also when run by its own:

```
cd mysql-test
mysql-test-run --local test-name
```

  If this fails, then you should configure MySQL with `--with-debug` and run `mysql-test-run` with the `--debug` option. If this also fails send the trace file

'`var/tmp/master.trace`' to ftp://support.mysql.com/pub/mysql/secret so that we can examine it. Please remember to also include a full description of your system, the version of the mysqld binary and how you compiled it.

- Try also to run `mysql-test-run` with the `--force` option to see if there is any other test that fails.
- If you have compiled MySQL yourself, check our manual for how to compile MySQL on your platform or, preferable, use one of the binaries we have compiled for you at `http://www.mysql.com/downloads/`. All our standard binaries should pass the test suite !
- If you get an error, like `Result length mismatch` or `Result content mismatch` it means that the output of the test didn't match exactly the expected output. This could be a bug in MySQL or that your mysqld version produces slight different results under some circumstances.

  Failed test results are put in a file with the same base name as the result file with the `.reject` extension. If your test case is failing, you should do a diff on the two files. If you cannot see how they are different, examine both with `od -c` and also check their lengths.
- If a test fails totally, you should check the logs file in the `mysql-test/var/log` directory for hints of what went wrong.
- If you have compiled MySQL with debugging you can try to debug this by running `mysql-test-run` with the `--gdb` and/or `--debug` options. See Section E.1.2 [Making trace files], page 1008.

  If you have not compiled MySQL for debugging you should probably do that. Just specify the `--with-debug` options to `configure`! See Section 2.3 [Installing source], page 88.

13.2 Adding New Functions to MySQL

There are two ways to add new functions to MySQL:

- You can add the function through the user-definable function (UDF) interface. User-definable functions are added and removed dynamically using the `CREATE FUNCTION` and `DROP FUNCTION` statements. See Section 13.2.1 [`CREATE FUNCTION`], page 836.
- You can add the function as a native (built in) MySQL function. Native functions are compiled into the `mysqld` server and become available on a permanent basis.

Each method has advantages and disadvantages:

- If you write a user-definable function, you must install the object file in addition to the server itself. If you compile your function into the server, you don't need to do that.
- You can add UDFs to a binary MySQL distribution. Native functions require you to modify a source distribution.
- If you upgrade your MySQL distribution, you can continue to use your previously installed UDFs. For native functions, you must repeat your modifications each time you upgrade.

Whichever method you use to add new functions, they may be used just like native functions such as `ABS()` or `SOUNDEX()`.

13.2.1 CREATE FUNCTION/DROP FUNCTION Syntax

```
CREATE [AGGREGATE] FUNCTION function_name RETURNS {STRING|REAL|INTEGER}
       SONAME shared_library_name

DROP FUNCTION function_name
```

A user-definable function (UDF) is a way to extend MySQL with a new function that works like native (built in) MySQL function such as `ABS()` and `CONCAT()`.

`AGGREGATE` is a new option for MySQL Version 3.23. An `AGGREGATE` function works exactly like a native MySQL `GROUP` function like `SUM` or `COUNT()`.

`CREATE FUNCTION` saves the function's name, type, and shared library name in the `mysql.func` system table. You must have the `INSERT` and `DELETE` privileges for the `mysql` database to create and drop functions.

All active functions are reloaded each time the server starts, unless you start `mysqld` with the `--skip-grant-tables` option. In this case, UDF initialisation is skipped and UDFs are unavailable. (An active function is one that has been loaded with `CREATE FUNCTION` and not removed with `DROP FUNCTION`.)

For instructions on writing user-definable functions, see Section 13.2 [Adding functions], page 835. For the UDF mechanism to work, functions must be written in C or C++, your operating system must support dynamic loading and you must have compiled `mysqld` dynamically (not statically).

Note that to make `AGGREGATE` work, you must have a `mysql.func` table that contains the column `type`. If you do not have this table, you should run the script `mysql_fix_privilege_tables` to create it.

13.2.2 Adding a New User-definable Function

For the UDF mechanism to work, functions must be written in C or C++ and your operating system must support dynamic loading. The MySQL source distribution includes a file '`sql/udf_example.cc`' that defines 5 new functions. Consult this file to see how UDF calling conventions work.

For `mysqld` to be able to use UDF functions, you should configure MySQL with `--with-mysqld-ldflags=-rdynamic` The reason is that to on many platforms (including Linux) you can load a dynamic library (with `dlopen()`) from a static linked program, which you would get if you are using `--with-mysqld-ldflags=-all-static` If you want to use an UDF that needs to access symbols from `mysqld` (like the `metaphone` example in '`sql/udf_example.cc`' that uses `default_charset_info`), you must link the program with `-rdynamic` (see `man dlopen`).

If you are using a precompiled version of the server, use MySQL-Max, which supports dynamic loading.

For each function that you want to use in SQL statements, you should define corresponding C (or C++) functions. In the discussion below, the name "xxx" is used for an example function name. To distinguish between SQL and C/C++ usage, `XXX()` (uppercase) indicates an SQL function call, and `xxx()` (lowercase) indicates a C/C++ function call.

The C/C++ functions that you write to implement the interface for `XXX()` are:

`xxx()` (required)
: The main function. This is where the function result is computed. The correspondence between the SQL type and return type of your C/C++ function is shown here:

SQL type	C/C++ type
`STRING`	`char *`
`INTEGER`	`long long`
`REAL`	`double`

`xxx_init()` (optional)
: The initialisation function for `xxx()`. It can be used to:

- Check the number of arguments to `XXX()`.
- Check that the arguments are of a required type or, alternatively, tell MySQL to coerce arguments to the types you want when the main function is called.
- Allocate any memory required by the main function.
- Specify the maximum length of the result.
- Specify (for `REAL` functions) the maximum number of decimals.
- Specify whether the result can be `NULL`.

`xxx_deinit()` (optional)
: The deinitialisation function for `xxx()`. It should deallocate any memory allocated by the initialisation function.

When an SQL statement invokes `XXX()`, MySQL calls the initialisation function `xxx_init()` to let it perform any required setup, such as argument checking or memory allocation. If `xxx_init()` returns an error, the SQL statement is aborted with an error message and the main and deinitialisation functions are not called. Otherwise, the main function `xxx()` is called once for each row. After all rows have been processed, the deinitialisation function `xxx_deinit()` is called so it can perform any required cleanup.

For aggregate functions (like `SUM()`), you must also provide the following functions:

`xxx_reset()` (required)
: Reset sum and insert the argument as the initial value for a new group.

`xxx_add()` (required)
: Add the argument to the old sum.

When using aggregate UDFs, MySQL works the following way:

1. Call `xxx_init()` to let the aggregate function allocate the memory it will need to store results.
2. Sort the table according to the `GROUP BY` expression.
3. For the first row in a new group, call the `xxx_reset()` function.
4. For each new row that belongs in the same group, call the `xxx_add()` function.
5. When the group changes or after the last row has been processed, call `xxx()` to get the result for the aggregate.

6. Repeat 3-5 until all rows has been processed
7. Call `xxx_deinit()` to let the UDF free any memory it has allocated.

All functions must be thread-safe (not just the main function, but the initialisation and deinitialisation functions as well). This means that you are not allowed to allocate any global or static variables that change! If you need memory, you should allocate it in `xxx_init()` and free it in `xxx_deinit()`.

13.2.2.1 UDF Calling Sequences for simple functions

The main function should be declared as shown here. Note that the return type and parameters differ, depending on whether you will declare the SQL function `XXX()` to return `STRING`, `INTEGER`, or `REAL` in the `CREATE FUNCTION` statement:

For `STRING` functions:

```
char *xxx(UDF_INIT *initid, UDF_ARGS *args,
          char *result, unsigned long *length,
          char *is_null, char *error);
```

For `INTEGER` functions:

```
long long xxx(UDF_INIT *initid, UDF_ARGS *args,
              char *is_null, char *error);
```

For `REAL` functions:

```
double xxx(UDF_INIT *initid, UDF_ARGS *args,
              char *is_null, char *error);
```

The initialisation and deinitialisation functions are declared like this:

```
my_bool xxx_init(UDF_INIT *initid, UDF_ARGS *args, char *message);

void xxx_deinit(UDF_INIT *initid);
```

The `initid` parameter is passed to all three functions. It points to a `UDF_INIT` structure that is used to communicate information between functions. The `UDF_INIT` structure members are listed below. The initialisation function should fill in any members that it wishes to change. (To use the default for a member, leave it unchanged.):

`my_bool maybe_null`
: `xxx_init()` should set `maybe_null` to `1` if `xxx()` can return `NULL`. The default value is `1` if any of the arguments are declared `maybe_null`.

`unsigned int decimals`
: Number of decimals. The default value is the maximum number of decimals in the arguments passed to the main function. (For example, if the function is passed `1.34`, `1.345`, and `1.3`, the default would be 3, because `1.345` has 3 decimals.

`unsigned int max_length`
: The maximum length of the string result. The default value differs depending on the result type of the function. For string functions, the default is the length of the longest argument. For integer functions, the default is 21 digits. For real

functions, the default is 13 plus the number of decimals indicated by `initid->decimals`. (For numeric functions, the length includes any sign or decimal point characters.)

If you want to return a blob, you can set this to 65K or 16M; this memory is not allocated but used to decide which column type to use if there is a need to temporary store the data.

`char *ptr` A pointer that the function can use for its own purposes. For example, functions can use `initid->ptr` to communicate allocated memory between functions. In `xxx_init()`, allocate the memory and assign it to this pointer:

```
initid->ptr = allocated_memory;
```

In `xxx()` and `xxx_deinit()`, refer to `initid->ptr` to use or deallocate the memory.

13.2.2.2 UDF Calling Sequences for aggregate functions

Here follows a description of the different functions you need to define when you want to create an aggregate UDF function.

Note that the following function is NOT needed or used by MySQL 4.1.1. You can keep still have define his function if you want to have your code work with both MySQL 4.0 and MySQL 4.1.1

```
char *xxx_reset(UDF_INIT *initid, UDF_ARGS *args,
                char *is_null, char *error);
```

This function is called when MySQL finds the first row in a new group. In the function you should reset any internal summary variables and then set the given argument as the first argument in the group.

In many cases this is implemented internally by reseting all variables (for example by calling `xxx_clear()` and then calling `xxx_add()`.

The following function is only required by MySQL 4.1.1 and above:

```
char *xxx_clear(UDF_INIT *initid, char *is_null, char *error);
```

This function is called when MySQL needs to reset the summary results. This will be called at the beginning for each new group but can also be called to reset the values for a query where there was no matching rows. `is_null` will be set to point to `CHAR(0)` before calling `xxx_clear()`.

You can use the `error` pointer to store a byte if something went wrong .

```
char *xxx_add(UDF_INIT *initid, UDF_ARGS *args,
              char *is_null, char *error);
```

This function is called for all rows that belongs to the same group, except for the first row. In this you should add the value in UDF_ARGS to your internal summary variable.

The `xxx()` function should be declared identical as when you define a simple UDF function. See Section 13.2.2.1 [UDF calling], page 838.

This function is called when all rows in the group has been processed. You should normally never access the `args` variable here but return your value based on your internal summary variables.

All argument processing in `xxx_reset()` and `xxx_add()` should be done identically as for normal UDFs. See Section 13.2.2.3 [UDF arguments], page 840.

The return value handling in `xxx()` should be done identically as for a normal UDF. See Section 13.2.2.4 [UDF return values], page 841.

The pointer argument to `is_null` and `error` is the same for all calls to `xxx_reset()`, `xxx_clear()`, `xxx_add()` and `xxx()`. You can use this to remember that you got an error or if the `xxx()` function should return `NULL`. Note that you should not store a string into `*error`! This is just a 1 byte flag!

`is_null` is reset for each group (before calling `xxx_clear()` `error` is never reset.

If `isnull` or `error` are set after `xxx()` then MySQL will return `NULL` as the result for the group function.

13.2.2.3 Argument Processing

The `args` parameter points to a `UDF_ARGS` structure that has the members listed here:

`unsigned int arg_count`
: The number of arguments. Check this value in the initialisation function if you want your function to be called with a particular number of arguments. For example:

```
if (args->arg_count != 2)
{
    strcpy(message,"XXX() requires two arguments");
    return 1;
}
```

`enum Item_result *arg_type`
: The types for each argument. The possible type values are `STRING_RESULT`, `INT_RESULT`, and `REAL_RESULT`.

  To make sure that arguments are of a given type and return an error if they are not, check the `arg_type` array in the initialisation function. For example:

```
if (args->arg_type[0] != STRING_RESULT ||
    args->arg_type[1] != INT_RESULT)
{
    strcpy(message,"XXX() requires a string and an integer");
    return 1;
}
```

  As an alternative to requiring your function's arguments to be of particular types, you can use the initialisation function to set the `arg_type` elements to the types you want. This causes MySQL to coerce arguments to those types for each call to `xxx()`. For example, to specify coercion of the first two arguments to string and integer, do this in `xxx_init()`:

```
args->arg_type[0] = STRING_RESULT;
args->arg_type[1] = INT_RESULT;
```

`char **args`

`args->args` communicates information to the initialisation function about the general nature of the arguments your function was called with. For a constant argument `i`, `args->args[i]` points to the argument value. (See below for instructions on how to access the value properly.) For a non-constant argument, `args->args[i]` is `0`. A constant argument is an expression that uses only constants, such as `3` or `4*7-2` or `SIN(3.14)`. A non-constant argument is an expression that refers to values that may change from row to row, such as column names or functions that are called with non-constant arguments.

For each invocation of the main function, `args->args` contains the actual arguments that are passed for the row currently being processed.

Functions can refer to an argument `i` as follows:

- An argument of type `STRING_RESULT` is given as a string pointer plus a length, to allow handling of binary data or data of arbitrary length. The string contents are available as `args->args[i]` and the string length is `args->lengths[i]`. You should not assume that strings are null-terminated.
- For an argument of type `INT_RESULT`, you must cast `args->args[i]` to a `long long` value:

```
long long int_val;
int_val = *((long long*) args->args[i]);
```

- For an argument of type `REAL_RESULT`, you must cast `args->args[i]` to a `double` value:

```
double    real_val;
real_val = *((double*) args->args[i]);
```

`unsigned long *lengths`

For the initialisation function, the `lengths` array indicates the maximum string length for each argument. You should not change these. For each invocation of the main function, `lengths` contains the actual lengths of any string arguments that are passed for the row currently being processed. For arguments of types `INT_RESULT` or `REAL_RESULT`, `lengths` still contains the maximum length of the argument (as for the initialisation function).

13.2.2.4 Return Values and Error Handling

The initialisation function should return `0` if no error occurred and `1` otherwise. If an error occurs, `xxx_init()` should store a null-terminated error message in the `message` parameter. The message will be returned to the client. The message buffer is `MYSQL_ERRMSG_SIZE` characters long, but you should try to keep the message to less than 80 characters so that it fits the width of a standard terminal screen.

The return value of the main function `xxx()` is the function value, for `long long` and `double` functions. A string functions should return a pointer to the result and store the length of the string in the `length` arguments.

Set these to the contents and length of the return value. For example:

```
memcpy(result, "result string", 13);
*length = 13;
```

The `result` buffer that is passed to the calc function is 255 byte big. If your result fits in this, you don't have to worry about memory allocation for results.

If your string function needs to return a string longer than 255 bytes, you must allocate the space for it with `malloc()` in your `xxx_init()` function or your `xxx()` function and free it in your `xxx_deinit()` function. You can store the allocated memory in the `ptr` slot in the `UDF_INIT` structure for reuse by future `xxx()` calls. See Section 13.2.2.1 [UDF calling], page 838.

To indicate a return value of `NULL` in the main function, set `is_null` to `1`:

```
*is_null = 1;
```

To indicate an error return in the main function, set the `error` parameter to `1`:

```
*error = 1;
```

If `xxx()` sets `*error` to `1` for any row, the function value is `NULL` for the current row and for any subsequent rows processed by the statement in which `XXX()` was invoked. (`xxx()` will not even be called for subsequent rows.) **Note**: in MySQL versions prior to 3.22.10, you should set both `*error` and `*is_null`:

```
*error = 1;
*is_null = 1;
```

13.2.2.5 Compiling and Installing User-definable Functions

Files implementing UDFs must be compiled and installed on the host where the server runs. This process is described below for the example UDF file '`udf_example.cc`' that is included in the MySQL source distribution. This file contains the following functions:

- `metaphon()` returns a metaphon string of the string argument. This is something like a soundex string, but it's more tuned for English.
- `myfunc_double()` returns the sum of the ASCII values of the characters in its arguments, divided by the sum of the length of its arguments.
- `myfunc_int()` returns the sum of the length of its arguments.
- `sequence([const int])` returns an sequence starting from the given number or 1 if no number has been given.
- `lookup()` returns the IP number for a hostname.
- `reverse_lookup()` returns the hostname for an IP number. The function may be called with a string `"xxx.xxx.xxx.xxx"` or four numbers.

A dynamically loadable file should be compiled as a sharable object file, using a command something like this:

```
shell> gcc -shared -o udf_example.so myfunc.cc
```

You can easily find out the correct compiler options for your system by running this command in the '`sql`' directory of your MySQL source tree:

```
shell> make udf_example.o
```

You should run a compile command similar to the one that `make` displays, except that you should remove the `-c` option near the end of the line and add `-o udf_example.so` to the end of the line. (On some systems, you may need to leave the `-c` on the command.)

Once you compile a shared object containing UDFs, you must install it and tell MySQL about it. Compiling a shared object from '`udf_example.cc`' produces a file named something like '`udf_example.so`' (the exact name may vary from platform to platform). Copy this file to some directory searched by the dynamic linker `ld`, such as '`/usr/lib`' or add the directory in which you placed the shared object to the linker configuration file (for example, '`/etc/ld.so.conf`').

On many systems, you can also set the `LD_LIBRARY` or `LD_LIBRARY_PATH` environment variable to point at the directory where you have your UDF function files. The `dlopen` manual page tells you which variable you should use on your system. You should set this in `mysql.server` or `mysqld_safe` startup scripts and restart `mysqld`.

After the library is installed, notify `mysqld` about the new functions with these commands:

```
mysql> CREATE FUNCTION metaphon RETURNS STRING SONAME "udf_example.so";
mysql> CREATE FUNCTION myfunc_double RETURNS REAL SONAME "udf_example.so";
mysql> CREATE FUNCTION myfunc_int RETURNS INTEGER SONAME "udf_example.so";
mysql> CREATE FUNCTION lookup RETURNS STRING SONAME "udf_example.so";
mysql> CREATE FUNCTION reverse_lookup
    ->        RETURNS STRING SONAME "udf_example.so";
mysql> CREATE AGGREGATE FUNCTION avgcost
    ->        RETURNS REAL SONAME "udf_example.so";
```

Functions can be deleted using `DROP FUNCTION`:

```
mysql> DROP FUNCTION metaphon;
mysql> DROP FUNCTION myfunc_double;
mysql> DROP FUNCTION myfunc_int;
mysql> DROP FUNCTION lookup;
mysql> DROP FUNCTION reverse_lookup;
mysql> DROP FUNCTION avgcost;
```

The `CREATE FUNCTION` and `DROP FUNCTION` statements update the system table `func` in the `mysql` database. The function's name, type and shared library name are saved in the table. You must have the `INSERT` and `DELETE` privileges for the `mysql` database to create and drop functions.

You should not use `CREATE FUNCTION` to add a function that has already been created. If you need to reinstall a function, you should remove it with `DROP FUNCTION` and then reinstall it with `CREATE FUNCTION`. You would need to do this, for example, if you recompile a new version of your function, so that `mysqld` gets the new version. Otherwise, the server will continue to use the old version.

Active functions are reloaded each time the server starts, unless you start `mysqld` with the `--skip-grant-tables` option. In this case, UDF initialisation is skipped and UDFs are unavailable. (An active function is one that has been loaded with `CREATE FUNCTION` and not removed with `DROP FUNCTION`.)

13.2.3 Adding a New Native Function

The procedure for adding a new native function is described here. Note that you cannot add native functions to a binary distribution because the procedure involves modifying MySQL source code. You must compile MySQL yourself from a source distribution. Also note that if you migrate to another version of MySQL (for example, when a new version is released), you will need to repeat the procedure with the new version.

To add a new native MySQL function, follow these steps:

1. Add one line to '`lex.h`' that defines the function name in the `sql_functions[]` array.
2. If the function prototype is simple (just takes zero, one, two or three arguments), you should in lex.h specify SYM(FUNC_ARG#) (where # is the number of arguments) as the second argument in the `sql_functions[]` array and add a function that creates a function object in '`item_create.cc`'. Take a look at `"ABS"` and `create_funcs_abs()` for an example of this.

   If the function prototype is complicated (for example takes a variable number of arguments), you should add two lines to '`sql_yacc.yy`'. One indicates the preprocessor symbol that `yacc` should define (this should be added at the beginning of the file). Then define the function parameters and add an "item" with these parameters to the `simple_expr` parsing rule. For an example, check all occurrences of `ATAN` in '`sql_yacc.yy`' to see how this is done.
3. In '`item_func.h`', declare a class inheriting from `Item_num_func` or `Item_str_func`, depending on whether your function returns a number or a string.
4. In '`item_func.cc`', add one of the following declarations, depending on whether you are defining a numeric or string function:

   ```
   double   Item_func_newname::val()
   longlong Item_func_newname::val_int()
   String  *Item_func_newname::Str(String *str)
   ```

   If you inherit your object from any of the standard items (like `Item_num_func`), you probably only have to define one of the above functions and let the parent object take care of the other functions. For example, the `Item_str_func` class defines a `val()` function that executes `atof()` on the value returned by `::str()`.
5. You should probably also define the following object function:

   ```
   void Item_func_newname::fix_length_and_dec()
   ```

   This function should at least calculate `max_length` based on the given arguments. `max_length` is the maximum number of characters the function may return. This function should also set `maybe_null = 0` if the main function can't return a `NULL` value. The function can check if any of the function arguments can return `NULL` by checking the arguments `maybe_null` variable. You can take a look at `Item_func_mod::fix_length_and_dec` for a typical example of how to do this.

All functions must be thread-safe (in other words, don't use any global or static variables in the functions without protecting them with mutexes).

If you want to return `NULL`, from `::val()`, `::val_int()` or `::str()` you should set `null_value` to 1 and return 0.

For `::str()` object functions, there are some additional considerations to be aware of:

- The `String *str` argument provides a string buffer that may be used to hold the result. (For more information about the `String` type, take a look at the '`sql_string.h`' file.)
- The `::str()` function should return the string that holds the result or `(char*) 0` if the result is `NULL`.
- All current string functions try to avoid allocating any memory unless absolutely necessary!

13.3 Adding New Procedures to MySQL

In MySQL, you can define a procedure in C++ that can access and modify the data in a query before it is sent to the client. The modification can be done on row-by-row or `GROUP BY` level.

We have created an example procedure in MySQL Version 3.23 to show you what can be done.

Additionally we recommend you to take a look at `mylua`. With this you can use the LUA language to load a procedure at runtime into `mysqld`.

13.3.1 Procedure Analyse

`analyse([max elements,[max memory]])`

This procedure is defined in the '`sql/sql_analyse.cc`'. This examines the result from your query and returns an analysis of the results:

- `max elements` (default 256) is the maximum number of distinct values `analyse` will notice per column. This is used by `analyse` to check if the optimal column type should be of type `ENUM`.
- `max memory` (default 8192) is the maximum memory `analyse` should allocate per column while trying to find all distinct values.

```
SELECT ... FROM ... WHERE ... PROCEDURE ANALYSE([max elements,[max memory]])
```

13.3.2 Writing a Procedure

For the moment, the only documentation for this is the source.

You can find all information about procedures by examining the following files:

- '`sql/sql_analyse.cc`'
- '`sql/procedure.h`'
- '`sql/procedure.cc`'
- '`sql/sql_select.cc`'

Appendix A Problems and Common Errors

This chapter lists some common problems and error messages that users have run into. You will learn how to figure out what the problem is, and what to do to solve it. You will also find proper solutions to some common problems.

A.1 How to Determine What Is Causing Problems

When you run into problems, the first thing you should do is to find out which program / piece of equipment is causing problems:

- If you have one of the following symptoms, then it is probably a hardware (like memory, motherboard, CPU, or hard disk) or kernel problem:
  - The keyboard doesn't work. This can normally be checked by pressing Caps Lock. If the Caps Lock light doesn't change you have to replace your keyboard. (Before doing this, you should try to reboot your computer and check all cables to the keyboard.)
  - The mouse pointer doesn't move.
  - The machine doesn't answer to a remote machine's pings.
  - Different, unrelated programs don't behave correctly.
  - If your system rebooted unexpectedly (a faulty user level program should **never** be able to take down your system).

  In this case you should start by checking all your cables and run some diagnostic tool to check your hardware! You should also check if there are any patches, updates, or service packs for your operating system that could likely solve your problems. Check also that all your libraries (like glibc) are up to date.

  It's always good to use a machine with ECC memory to discover memory problems early!
- If your keyboard is locked up, you may be able to fix this by logging into your machine from another machine and execute `kbd_mode -a` on it.
- Please examine your system log file (/var/log/messages or similar) for reasons for your problems. If you think the problem is in MySQL then you should also examine MySQL's log files. See Section 4.10.4 [Binary log], page 351.
- If you don't think you have hardware problems, you should try to find out which program is causing problems.

  Try using `top`, `ps`, `taskmanager`, or some similar program, to check which program is taking all CPU or is locking the machine.
- Check with `top`, `df`, or a similar program if you are out of memory, disk space, open files, or some other critical resource.
- If the problem is some runaway process, you can always try to kill it. If it doesn't want to die, there is probably a bug in the operating system.

If after you have examined all other possibilities and you have concluded that it's the MySQL server or a MySQL client that is causing the problem, it's time to do a bug report

for our mailing list or our support team. In the bug report, try to give a very detailed description of how the system is behaving and what you think is happening. You should also state why you think it's MySQL that is causing the problems. Take into consideration all the situations in this chapter. State any problems exactly how they appear when you examine your system. Use the 'cut and paste' method for any output and/or error messages from programs and/or log files!

Try to describe in detail which program is not working and all symptoms you see! We have in the past received many bug reports that just state "the system doesn't work". This doesn't provide us with any information about what could be the problem.

If a program fails, it's always useful to know:

- Has the program in question made a segmentation fault (core dumped)?
- Is the program taking up the whole CPU? Check with `top`. Let the program run for a while, it may be evaluating something heavy.
- If it's the `mysqld` server that is causing problems, can you do `mysqladmin -u root ping` or `mysqladmin -u root processlist`?
- What does a client program say (try with `mysql`, for example) when you try to connect to the MySQL server? Does the client jam? Do you get any output from the program?

When sending a bug report, you should of follow the outlines described in this manual. See Section 1.6.1.2 [Asking questions], page 27.

A.2 Common Errors When Using MySQL

This section lists some errors that users frequently get. You will find descriptions of the errors, and how to solve the problem here.

A.2.1 `Access denied` Error

See Section 4.3.12 [Access denied], page 235. See Section 4.3.6 [Privileges], page 219.

A.2.2 `MySQL server has gone away` Error

This section also covers the related `Lost connection to server during query` error.

The most common reason for the `MySQL server has gone away` error is that the server timed out and closed the connection. By default, the server closes the connection after 8 hours if nothing has happened. You can change the time limit by setting the `wait_timeout` variable when you start `mysqld`.

Another common reason to receive the `MySQL server has gone away` error is because you have issued a "close" on your MySQL connection and then tried to run a query on the closed connection.

If you have a script, you just have to issue the query again for the client to do an automatic reconnection.

You normally can get the following error codes in this case (which one you get is OS-dependent):

Error code	Description
CR_SERVER_GONE_ERROR	The client couldn't send a question to the server.
CR_SERVER_LOST	The client didn't get an error when writing to the server, but it didn't get a full answer (or any answer) to the question.

You will also get this error if someone has kills the running thread with `kill #threadid#`.

You can check that the MySQL hasn't died by executing `mysqladmin version` and examining the uptime. If the problem is that mysqld crashed you should concentrate one finding the reason for the crash. You should in this case start by checking if issuing the query again will kill MySQL again. See Section A.4.1 [Crashing], page 859.

You can also get these errors if you send a query to the server that is incorrect or too large. If `mysqld` gets a packet that is too large or out of order, it assumes that something has gone wrong with the client and closes the connection. If you need big queries (for example, if you are working with big `BLOB` columns), you can increase the query limit by starting `mysqld` with the `-O max_allowed_packet=#` option (default 1M). The extra memory is allocated on demand, so `mysqld` will allocate more memory only when you issue a big query or when `mysqld` must return a big result row!

You will also get a lost connection if you are sending a packet >= 16M if your client is older than 4.0.8 and your server is 4.0.8 and above, or the other way around.

If you want to make a bug report regarding this problem, be sure that you include the following information:

- Include information if MySQL died or not. (You can find this in the `hostname.err file`. See Section A.4.1 [Crashing], page 859.
- If a specific query kills `mysqld` and the involved tables where checked with `CHECK TABLE` before you did the query, can you do a test case for this? See Section E.1.6 [Reproduceable test case], page 1012.
- What is the value of the `wait_timeout` variable in the MySQL server ? `mysqladmin variables` gives you the value of this
- Have you tried to run `mysqld` with `--log` and check if the issued query appears in the log ?

See Section 1.6.1.2 [Asking questions], page 27.

A.2.3 `Can't connect to [local] MySQL server` Error

A MySQL client on Unix can connect to the `mysqld` server in two different ways: Unix sockets, which connect through a file in the file system (default '`/tmp/mysqld.sock`') or TCP/IP, which connects through a port number. Unix sockets are faster than TCP/IP but can only be used when connecting to a server on the same computer. Unix sockets are used if you don't specify a hostname or if you specify the special hostname `localhost`.

On Windows, if the `mysqld` server is running on 9x/Me, you can connect only via TCP/IP. If the server is running on NT/2000/XP and mysqld is started with `--enable-named-pipe`, you can also connect with named pipes. The name of the named pipe is MySQL. If you don't give a hostname when connecting to `mysqld`, a MySQL client will first try to connect

to the named pipe, and if this doesn't work it will connect to the TCP/IP port. You can force the use of named pipes on Windows by using `.` as the hostname.

The error (2002) `Can't connect to ...` normally means that there isn't a MySQL server running on the system or that you are using a wrong socket file or TCP/IP port when trying to connect to the `mysqld` server.

Start by checking (using `ps` or the task manager on Windows) that there is a process running named `mysqld` on your server! If there isn't any `mysqld` process, you should start one. See Section 2.4.2 [Starting server], page 107.

If a `mysqld` process is running, you can check the server by trying these different connections (the port number and socket pathname might be different in your setup, of course):

```
shell> mysqladmin version
shell> mysqladmin variables
shell> mysqladmin -h 'hostname' version variables
shell> mysqladmin -h 'hostname' --port=3306 version
shell> mysqladmin -h 'ip for your host' version
shell> mysqladmin --protocol=socket --socket=/tmp/mysql.sock version
```

Note the use of backquotes rather than forward quotes with the `hostname` command; these cause the output of `hostname` (that is, the current hostname) to be substituted into the `mysqladmin` command.

Here are some reasons the `Can't connect to local MySQL server` error might occur:

- `mysqld` is not running.
- You are running on a system that uses MIT-pthreads. If you are running on a system that doesn't have native threads, `mysqld` uses the MIT-pthreads package. See Section 2.2.3 [Which OS], page 73. However, not all MIT-pthreads versions support Unix sockets. On a system without sockets support you must always specify the hostname explicitly when connecting to the server. Try using this command to check the connection to the server:

  ```
  shell> mysqladmin -h 'hostname' version
  ```

- Someone has removed the Unix socket that `mysqld` uses (default '`/tmp/mysqld.sock`'). You might have a `cron` job that removes the MySQL socket (for example, a job that removes old files from the '`/tmp`' directory). You can always run `mysqladmin version` and check that the socket `mysqladmin` is trying to use really exists. The fix in this case is to change the `cron` job to not remove '`mysqld.sock`' or to place the socket somewhere else. See Section A.4.5 [Problems with mysql.sock], page 863.
- You have started the `mysqld` server with the `--socket=/path/to/socket` option. If you change the socket pathname for the server, you must also notify the MySQL clients about the new path. You can do this by providing the socket path as an argument to the client. See Section A.4.5 [Problems with mysql.sock], page 863.
- You are using Linux and one thread has died (core dumped). In this case you must kill the other `mysqld` threads (for example, with the `mysql_zap` script before you can start a new MySQL server. See Section A.4.1 [Crashing], page 859.
- You may not have read and write privilege to either the directory that holds the socket file or privilege to the socket file itself. In this case you have to either change the

privilege for the directory / file or restart `mysqld` so that it uses a directory that you can access.

If you get the error message `Can't connect to MySQL server on some_hostname`, you can try the following things to find out what the problem is:

- Check if the server is up by doing `telnet your-host-name tcp-ip-port-number` and press Enter a couple of times. If there is a MySQL server running on this port you should get a responses that includes the version number of the running MySQL server. If you get an error like `telnet: Unable to connect to remote host: Connection refused`, then there is no server running on the given port.
- Try connecting to the `mysqld` daemon on the local machine and check the TCP/IP port that `mysqld` it's configured to use (variable `port`) with `mysqladmin variables`.
- Check that your `mysqld` server is not started with the `--skip-networking` option.

A.2.4 `Client does not support authentication protocol` error

MySQL 4.1 uses an authentication protocal based on a password hashing algorithm that is incompatible with that used by older clients. If you upgrade the server to 4.1, attempts to connect to a it with an older client may fail with the following message:

```
shell> mysql
Client does not support authentication protocol requested
by server; consider upgrading MySQL client
```

To solve this problem you should do one of the following:

- Upgrade all client programs to use the 4.1.1 or newer client library.
- Use a user account with an old password when connecting from a pre 4.1 client.
- Reset the user that needs a pre-4.1 client to use an old password:

```
mysql> UPDATE user SET Password = OLD_PASSWORD('mypass')
    -> WHERE Host = 'some_host' AND User = 'some_user';
mysql> FLUSH PRIVILEGES;
```

- Tell the server to use the older password hashing algorithm:
  1. Start mysqld with `--old-passwords`.
  2. Set the password for all users that has a long password. You can find these users with:

```
SELECT * FROM mysql.user WHERE LEN(password) > 16;
```

For background on password hashing and authentication, see Section 4.3.11 [Password hashing], page 230.

A.2.5 `Host '...' is blocked` Error

If you get an error like this:

```
Host 'hostname' is blocked because of many connection errors.
Unblock with 'mysqladmin flush-hosts'
```

this means that `mysqld` has gotten a lot (`max_connect_errors`) of connect requests from the host `'hostname'` that have been interrupted in the middle. After `max_connect_errors`

failed requests, `mysqld` assumes that something is wrong (like an attack from a cracker), and blocks the site from further connections until someone executes the command `mysqladmin flush-hosts`.

By default, `mysqld` blocks a host after 10 connection errors. You can easily adjust this by starting the server like this:

```
shell> mysqld_safe -O max_connect_errors=10000 &
```

Note that if you get this error message for a given host, you should first check that there isn't anything wrong with TCP/IP connections from that host. If your TCP/IP connections aren't working, it won't do you any good to increase the value of the `max_connect_errors` variable!

A.2.6 `Too many connections` Error

If you get the error `Too many connections` when you try to connect to MySQL, this means that there is already `max_connections` clients connected to the `mysqld` server.

If you need more connections than the default (100), then you should restart `mysqld` with a bigger value for the `max_connections` variable.

Note that `mysqld` actually allows (`max_connections+1`) clients to connect. The last connection is reserved for a user with the `SUPER` privilege. By not giving this privilege to normal users (they shouldn't need this), an administrator with this privilege can log in and use `SHOW PROCESSLIST` to find out what could be wrong. See Section 4.6.8.6 [SHOW PROCESSLIST], page 301.

The maximum number of connects MySQL is depending on how good the thread library is on a given platform. Linux or Solaris should be able to support 500-1000 simultaneous connections, depending on how much RAM you have and what your clients are doing.

A.2.7 `Some non-transactional changed tables couldn't be rolled back` Error

If you get the error/warning: `Warning: Some non-transactional changed tables couldn't be rolled back` when trying to do a `ROLLBACK`, this means that some of the tables you used in the transaction didn't support transactions. These non-transactional tables will not be affected by the `ROLLBACK` statement.

The most typical case when this happens is when you have tried to create a table of a type that is not supported by your `mysqld` binary. If `mysqld` doesn't support a table type (or if the table type is disabled by a startup option) , it will instead create the table type with the table type that is most resembles to the one you requested, probably `MyISAM`.

You can check the table type for a table by doing:

`SHOW TABLE STATUS LIKE 'table_name'`. See Section 4.6.8.2 [SHOW TABLE STATUS], page 286.

You can check the extensions your `mysqld` binary supports by doing:

`show variables like 'have_%'`. See Section 4.6.8.4 [SHOW VARIABLES], page 290.

A.2.8 `Out of memory` Error

If you issue a query and get something like the following error:

```
mysql: Out of memory at line 42, 'malloc.c'
mysql: needed 8136 byte (8k), memory in use: 12481367 bytes (12189k)
ERROR 2008: MySQL client ran out of memory
```

note that the error refers to the MySQL client `mysql`. The reason for this error is simply that the client does not have enough memory to store the whole result.

To remedy the problem, first check that your query is correct. Is it reasonable that it should return so many rows? If so, you can use `mysql --quick`, which uses `mysql_use_result()` to retrieve the result set. This places less of a load on the client (but more on the server).

A.2.9 `Packet too large` Error

When a MySQL client or the `mysqld` server gets a packet bigger than `max_allowed_packet` bytes, it issues a `Packet too large` error and closes the connection.

In MySQL 3.23 the biggest possible packet is 16M (due to limits in the client/server protocol). In MySQL 4.0.1 and up, this is only limited by the amount on memory you have on your server (up to a theoretical maximum of 2G).

A communication packet is a single SQL statement sent to the MySQL server or a single row that is sent to the client.

When a MySQL client or the `mysqld` server gets a packet bigger than `max_allowed_packet` bytes, it issues a `Packet too large` error and closes the connection. With some clients, you may also get `Lost connection to MySQL server during query` error if the communication packet is too big.

Note that both the client and the server has it's own `max_allowed_packet` variable. If you want to handle big packets, you have to increase this variable both in the client and in the server.

It's safe to increase this variable as memory is only allocated when needed; this variable is more a precaution to catch wrong packets between the client/server and also to ensure that you don't accidentally use big packets so that you run out of memory.

If you are using the `mysql` client, you may specify a bigger buffer by starting the client with `mysql --set-variable=max_allowed_packet=8M`. Other clients have different methods to set this variable. Please note that `--set-variable` is deprecated since MySQL 4.0, just use `--max-allowed-packet=8M` instead.

You can use the option file to set `max_allowed_packet` to a larger size in `mysqld`. For example, if you are expecting to store the full length of a `MEDIUMBLOB` into a table, you'll need to start the server with the `set-variable=max_allowed_packet=16M` option.

You can also get strange problems with large packets if you are using big blobs, but you haven't given `mysqld` access to enough memory to handle the query. If you suspect this is the case, try adding `ulimit -d 256000` to the beginning of the `mysqld_safe` script and restart `mysqld`.

A.2.10 Communication Errors / Aborted Connection

Starting with MySQL 3.23.40 you only get the Aborted connection error of you start mysqld with --warnings.

If you find errors like the following in your error log.

```
010301 14:38:23  Aborted connection 854 to db: 'users' user: 'josh'
```

See Section 4.10.1 [Error log], page 350.

This means that something of the following has happened:

- The client program did not call mysql_close() before exit.
- The client had been sleeping more than wait_timeout or interactive_timeout without doing any requests. See Section 4.6.8.4 [wait_timeout], page 290. See Section 4.6.8.4 [interactive_timeout], page 290.
- The client program ended abruptly in the middle of the transfer.

When the above happens, the server variable Aborted_clients is incremented.

The server variable Aborted_connects is incremented when:

- When a connection packet doesn't contain the right information.
- When the user didn't have privileges to connect to a database.
- When a user uses a wrong password.
- When it takes more than connect_timeout seconds to get a connect package. See Section 4.6.8.4 [connect_timeout], page 290.

Note that the above could indicate that someone is trying to break into your database!

Other reasons for problems with Aborted clients / Aborted connections.

- Usage of Ethernet protocol with Linux, both half and full duplex. Many Linux Ethernet drivers have this bug. You should test for this bug by transferring a huge file via ftp between these two machines. If a transfer goes in burst-pause-burst-pause ... mode then you are experiencing a Linux duplex syndrome. The only solution is switching duplex mode for both your network card and Hub/Switch to either full duplex or to half duplex and testing the results to decide on the best setting.
- Some problem with the thread library that causes interrupts on reads.
- Badly configured TCP/IP.
- Faulty Ethernets or hubs or switches, cables ... This can be diagnosed properly only by replacing hardware.
- max_allowed_packet is too small or queries require more memory than you have allocated for mysqld. See Section A.2.9 [Packet too large], page 852.

A.2.11 The table is full Error

There are a couple of different cases when you can get this error:

- You are using an older MySQL version (before 3.23.0) when an in-memory temporary table becomes larger than tmp_table_size bytes. To avoid this problem, you can use the -O tmp_table_size=# option to make mysqld increase the temporary table

size or use the SQL option `BIG_TABLES` before you issue the problematic query. See Section 5.5.6 [`SET`], page 432.

You can also start `mysqld` with the `--big-tables` option. This is exactly the same as using `BIG_TABLES` for all queries.

In MySQL Version 3.23, in-memory temporary tables will automatically be converted to a disk-based `MyISAM` table after the table size gets bigger than `tmp_table_size`.

- You are using `InnoDB` tables and run out of room in the `InnoDB` tablespace. In this case the solution is to extend the `InnoDB` tablespace.
- You are using `ISAM` or `MyISAM` tables on an OS that only supports files of 2G in size and you have hit this limit for the datafile or index file.
- You are using `MyISAM` tables and the needed data or index size is bigger than what MySQL has allocated pointers for. (If you don't specify `MAX_ROWS` to `CREATE TABLE` MySQL will only allocate pointers to hold 4G of data).

  You can check the maximum data/index sizes by doing

  ```
  SHOW TABLE STATUS FROM database LIKE 'table_name';
  ```

  or using `myisamchk -dv database/table_name`.

  If this is the problem, you can fix it by doing something like:

  ```
  ALTER TABLE table_name MAX_ROWS=1000000000 AVG_ROW_LENGTH=nnn;
  ```

  You only have to specify `AVG_ROW_LENGTH` for tables with `BLOB/TEXT` fields as in this case MySQL can't optimise the space required based only on the number of rows.

A.2.12 `Can't create/write to file` Error

If you get an error for some queries of type:

```
Can't create/write to file '\\sqla3fe_0.ism'.
```

this means that MySQL can't create a temporary file for the result set in the given temporary directory. (The above error is a typical error message on Windows, and the Unix error message is similar.) The fix is to start `mysqld` with `--tmpdir=path` or to add to your option file:

```
[mysqld]
tmpdir=C:/temp
```

assuming that the '`c:\\temp`' directory exists. See Section 4.1.2 [Option files], page 203.

Check also the error code that you get with `perror`. One reason may also be a disk full error;

```
shell> perror 28
Error code  28:  No space left on device
```

A.2.13 `Commands out of sync` Error in Client

If you get `Commands out of sync; you can't run this command now` in your client code, you are calling client functions in the wrong order!

This can happen, for example, if you are using `mysql_use_result()` and try to execute a new query before you have called `mysql_free_result()`. It can also happen if you try

to execute two queries that return data without a `mysql_use_result()` or `mysql_store_result()` in between.

A.2.14 `Ignoring user` Error

If you get the following error:

`Found wrong password for user: 'some_user@some_host'; ignoring user`

this means that when `mysqld` was started or when it reloaded the permissions tables, it found an entry in the `user` table with an invalid password. As a result, the entry is simply ignored by the permission system.

Possible causes of and fixes for this problem:

- You may be running a new version of `mysqld` with an old `user` table. You can check this by executing `mysqlshow mysql user` to see if the password field is shorter than 16 characters. If so, you can correct this condition by running the `scripts/add_long_password` script.
- The user has an old password (8 characters long) and you didn't start `mysqld` with the `--old-protocol` option. Update the user in the `user` table with a new password or restart `mysqld` with `--old-protocol`.
- You have specified a password in the `user` table without using the `PASSWORD()` function. Use `mysql` to update the user in the `user` table with a new password. Make sure to use the `PASSWORD()` function:

```
mysql> UPDATE user SET password=PASSWORD('your password')
    ->             WHERE user='XXX';
```

A.2.15 `Table 'xxx' doesn't exist` Error

If you get the error `Table 'xxx' doesn't exist` or `Can't find file: 'xxx' (errno: 2)`, this means that no table exists in the current database with the name `xxx`.

Note that as MySQL uses directories and files to store databases and tables, the database and table names are **case-sensitive**! (On Windows the databases and tables names are not case-sensitive, but all references to a given table within a query must use the same case!)

You can check which tables you have in the current database with `SHOW TABLES`. See Section 4.6.8 [SHOW], page 284.

A.2.16 `Can't initialize character set xxx` error

If you get an error like:

```
MySQL Connection Failed: Can't initialize character set xxx
```

This means one of the following things:

- The character set is a multi-byte character set and you have no support for the character set in the client.

  In this case you need to recompile the client with `--with-charset=xxx` or with `--with-extra-charsets=xxx`. See Section 2.3.3 [configure options], page 91.

All standard MySQL binaries are compiled with `--with-extra-character-sets=complex` which will enable support for all multi-byte character sets. See Section 4.7.1 [Character sets], page 306.

- The character set is a simple character set which is not compiled into `mysqld` and the character set definition files are not in the place where the client expects to find them.

  In this case you need to:

  - Recompile the client with support for the character set. See Section 2.3.3 [configure options], page 91.
  - Specify to the client where the character set definition files are. For many clients you can do this with the `--character-sets-dir=path-to-charset-dir` option.
  - Copy the character definition files to the path where the client expects them to be.

A.2.17 File Not Found

If you get `ERROR '...' not found (errno: 23)`, `Can't open file: ... (errno: 24)`, or any other error with `errno` 23 or `errno` 24 from MySQL, it means that you haven't allocated enough file descriptors for MySQL. You can use the `perror` utility to get a description of what the error number means:

```
shell> perror 23
File table overflow
shell> perror 24
Too many open files
shell> perror 11
Resource temporarily unavailable
```

The problem here is that `mysqld` is trying to keep open too many files simultaneously. You can either tell `mysqld` not to open so many files at once or increase the number of file descriptors available to `mysqld`.

To tell `mysqld` to keep open fewer files at a time, you can make the table cache smaller by using the `-O table_cache=32` option to `mysqld_safe` (the default value is 64). Reducing the value of `max_connections` will also reduce the number of open files (the default value is 90).

To change the number of file descriptors available to `mysqld`, you can use the option `--open-files-limit=#` to `mysqld_safe` or `-O open-files-limit=#` to `mysqld`. See Section 4.6.8.4 [`open_files_limit`], page 290. The easiest way to do that is to add the option to your option file. See Section 4.1.2 [Option files], page 203. If you have an old `mysqld` version that doesn't support this, you can edit the `mysqld_safe` script. There is a commented-out line `ulimit -n 256` in the script. You can remove the `'#'` character to uncomment this line, and change the number 256 to affect the number of file descriptors available to `mysqld`.

`ulimit` (and `open-files-limit`) can increase the number of file descriptors, but only up to the limit imposed by the operating system. There is also a 'hard' limit that can only be overridden if you start `mysqld_safe` or `mysqld` as root (just remember that you need to also use the `--user=...` option in this case). If you need to increase the OS limit on the number of file descriptors available to each process, consult the documentation for your operating system.

Note that if you run the `tcsh` shell, `ulimit` will not work! `tcsh` will also report incorrect values when you ask for the current limits! In this case you should start `mysqld_safe` with `sh`!

A.3 Installation Related Issues

A.3.1 Problems When Linking with the MySQL Client Library

If you are linking your program and you get errors for unreferenced symbols that start with `mysql_`, like the following:

```
/tmp/ccFKsdPa.o: In function ‘main’:
/tmp/ccFKsdPa.o(.text+0xb): undefined reference to ‘mysql_init’
/tmp/ccFKsdPa.o(.text+0x31): undefined reference to ‘mysql_real_connect’
/tmp/ccFKsdPa.o(.text+0x57): undefined reference to ‘mysql_real_connect’
/tmp/ccFKsdPa.o(.text+0x69): undefined reference to ‘mysql_error’
/tmp/ccFKsdPa.o(.text+0x9a): undefined reference to ‘mysql_close’
```

you should be able to solve this by adding `-Lpath-to-the-mysql-library -lmysqlclient` **last** on your link line.

If you get `undefined reference` errors for the `uncompress` or `compress` function, add `-lz` **last** on your link line and try again!

If you get `undefined reference` errors for functions that should exist on your system, like `connect`, check the man page for the function in question, for which libraries you should add to the link line!

If you get `undefined reference` errors for functions that don't exist on your system, like the following:

```
mf_format.o(.text+0x201): undefined reference to ‘__lxstat’
```

it usually means that your library is compiled on a system that is not 100% compatible with yours. In this case you should download the latest MySQL source distribution and compile this yourself. See Section 2.3 [Installing source], page 88.

If you are trying to run a program and you then get errors for unreferenced symbols that start with `mysql_` or that the `mysqlclient` library can't be found, this means that your system can't find the share '`libmysqlclient.so`' library.

The fix for this is to tell your system to search after shared libraries where the library is located by one of the following methods:

- Add the path to the directory where you have '`libmysqlclient.so`' the `LD_LIBRARY_PATH` environment variable.
- Add the path to the directory where you have '`libmysqlclient.so`' the `LD_LIBRARY` environment variable.
- Copy '`libmysqlclient.so`' to some place that is searched by your system, like '`/lib`', and update the shared library information by executing `ldconfig`.

Another way to solve this problem is to link your program statically, with `-static`, or by removing the dynamic MySQL libraries before linking your code. In the second case you should be sure that no other programs are using the dynamic libraries!

A.3.2 How to Run MySQL As a Normal User

The MySQL server `mysqld` can be started and run by any user. In order to change `mysqld` to run as a Unix user `user_name`, you must do the following:

1. Stop the server if it's running (use `mysqladmin shutdown`).
2. Change the database directories and files so that `user_name` has privileges to read and write files in them (you may need to do this as the Unix `root` user):

   ```
   shell> chown -R user_name /path/to/mysql/datadir
   ```

   If directories or files within the MySQL data directory are symlinks, you'll also need to follow those links and change the directories and files they point to. `chown -R` may not follow symlinks for you.
3. Start the server as user `user_name`, or, if you are using MySQL Version 3.22 or later, start `mysqld` as the Unix `root` user and use the `--user=user_name` option. `mysqld` will switch to run as the Unix user `user_name` before accepting any connections.
4. To start the server as the given user name automatically at system startup time, add a `user` line that specifies the user name to the `[mysqld]` group of the '`/etc/my.cnf`' option file or the '`my.cnf`' option file in the server's data directory. For example:

   ```
   [mysqld]
   user=user_name
   ```

At this point, your `mysqld` process should be running fine and dandy as the Unix user `user_name`. One thing hasn't changed, though: the contents of the permissions tables. By default (right after running the permissions table install script `mysql_install_db`), the MySQL user `root` is the only user with permission to access the `mysql` database or to create or drop databases. Unless you have changed those permissions, they still hold. This shouldn't stop you from accessing MySQL as the MySQL `root` user when you're logged in as a Unix user other than `root`; just specify the `-u root` option to the client program.

Note that accessing MySQL as `root`, by supplying `-u root` on the command-line, has **nothing** to do with MySQL running as the Unix `root` user, or, indeed, as another Unix user. The access permissions and user names of MySQL are completely separate from Unix user names. The only connection with Unix user names is that if you don't provide a `-u` option when you invoke a client program, the client will try to connect using your Unix login name as your MySQL user name.

If your Unix box itself isn't secured, you should probably at least put a password on the MySQL `root` users in the access tables. Otherwise, any user with an account on that machine can run `mysql -u root db_name` and do whatever he likes.

A.3.3 Problems with File Permissions

If you have problems with file permissions, for example, if `mysql` issues the following error message when you create a table:

```
ERROR: Can't find file: 'path/with/filename.frm' (Errcode: 13)
```

then the environment variable `UMASK` might be set incorrectly when `mysqld` starts up. The default umask value is `0660`. You can change this behaviour by starting `mysqld_safe` as follows:

```
shell> UMASK=384  # = 600 in octal
shell> export UMASK
shell> /path/to/mysqld_safe &
```

By default MySQL will create database and `RAID` directories with permission type 0700. You can modify this behaviour by setting the `UMASK_DIR` variable. If you set this, new directories are created with the combined `UMASK` and `UMASK_DIR`. For example, if you want to give group access to all new directories, you can do:

```
shell> UMASK_DIR=504  # = 770 in octal
shell> export UMASK_DIR
shell> /path/to/mysqld_safe &
```

In MySQL Version 3.23.25 and above, MySQL assumes that the value for `UMASK` and `UMASK_DIR` is in octal if it starts with a zero.

See Appendix F [Environment variables], page 1019.

A.4 Administration Related Issues

A.4.1 What To Do If MySQL Keeps Crashing

All MySQL versions are tested on many platforms before they are released. This doesn't mean that there aren't any bugs in MySQL, but it means if there are bugs, they are very few and can be hard to find. If you have a problem, it will always help if you try to find out exactly what crashes your system, as you will have a much better chance of getting this fixed quickly.

First, you should try to find out whether the problem is that the `mysqld` daemon dies or whether your problem has to do with your client. You can check how long your `mysqld` server has been up by executing `mysqladmin version`. If `mysqld` has died, you may find the reason for this in the file '`mysql-data-directory/‘hostname‘.err`'. See Section 4.10.1 [Error log], page 350.

On some systems you can find in this file a stack trace of where `mysqld` died that you can resolve with `resolve_back_stack`. See Section E.1.4 [Using stack trace], page 1010. Note that the variable values written in the `.err` file may not always be 100 percent correct.

Many crashes of MySQL are caused by corrupted index files or datafiles. MySQL will update the data on disk, with the `write()` system call, after every SQL statement and before the client is notified about the result. (This is not true if you are running with `delay_key_write`, in which case only the data is written.) This means that the data is safe even if `mysqld` crashes, as the OS will ensure that the not flushed data is written to disk. You can force MySQL to sync everything to disk after every SQL command by starting `mysqld` with `--flush`.

The above means that normally you shouldn't get corrupted tables unless:

- Someone/something killed `mysqld` or the machine in the middle of an update.
- You have found a bug in `mysqld` that caused it to die in the middle of an update.
- Someone is manipulating the data/index files outside of **mysqld** without locking the table properly.

- If you are running many `mysqld` servers on the same data on a system that doesn't support good filesystem locks (normally handled by the `lockd` daemon) or if you are running multiple servers with `--skip-external-locking`
- You have a crashed index/datafile that contains very wrong data that got `mysqld` confused.
- You have found a bug in the data storage code. This isn't that likely, but it's at least possible. In this case you can try to change the file type to another storage engine by using `ALTER TABLE` on a repaired copy of the table!

Because it is very difficult to know why something is crashing, first try to check whether things that work for others crash for you. Please try the following things:

Take down the `mysqld` daemon with `mysqladmin shutdown`, run `myisamchk --silent --force */*.MYI` on all tables, and restart the `mysqld` daemon. This will ensure that you are running from a clean state. See Chapter 4 [MySQL Database Administration], page 195.

- Use `mysqld --log` and try to determine from the information in the log whether some specific query kills the server. About 95% of all bugs are related to a particular query! Normally this is one of the last queries in the log file just before MySQL restarted. See Section 4.10.2 [Query log], page 350. If you can repeatedly kill MySQL with one of the queries, even when you have checked all tables just before doing the query, then you have been able to locate the bug and should do a bug report for this! See Section 1.6.1.3 [Bug reports], page 27.
- Try to make a test case that we can use to reproduce the problem. See Section E.1.6 [Reproduceable test case], page 1012.
- Try running the included mysql-test test and the MySQL benchmarks. See Section 13.1.2 [MySQL test suite], page 832. They should test MySQL rather well. You can also add code to the benchmarks that simulates your application! The benchmarks can be found in the '`bench`' directory in the source distribution or, for a binary distribution, in the '`sql-bench`' directory under your MySQL installation directory.
- Try `fork_test.pl` and `fork2_test.pl`.
- If you configure MySQL for debugging, it will be much easier to gather information about possible errors if something goes wrong. Reconfigure MySQL with the `--with-debug` option or `--with-debug=full` to `configure` and then recompile. See Section E.1 [Debugging server], page 1007.
- Configuring MySQL for debugging causes a safe memory allocator to be included that can find some errors. It also provides a lot of output about what is happening.
- Have you applied the latest patches for your operating system?
- Use the `--skip-external-locking` option to `mysqld`. On some systems, the `lockd` lock manager does not work properly; the `--skip-external-locking` option tells `mysqld` not to use external locking. (This means that you cannot run 2 `mysqld` servers on the same data and that you must be careful if you use `myisamchk`, but it may be instructive to try the option as a test.)
- Have you tried `mysqladmin -u root processlist` when `mysqld` appears to be running but not responding? Sometimes `mysqld` is not comatose even though you might think so. The problem may be that all connections are in use, or there may be some internal

lock problem. `mysqladmin processlist` will usually be able to make a connection even in these cases, and can provide useful information about the current number of connections and their status.

- Run the command `mysqladmin -i 5 status` or `mysqladmin -i 5 -r status` or in a separate window to produce statistics while you run your other queries.
- Try the following:
  1. Start `mysqld` from `gdb` (or in another debugger). See Section E.1.3 [Using gdb on mysqld], page 1009.
  2. Run your test scripts.
  3. Print the backtrace and the local variables at the 3 lowest levels. In gdb you can do this with the following commands when `mysqld` has crashed inside gdb:

     ```
     backtrace
     info local
     up
     info local
     up
     info local
     ```

     With gdb you can also examine which threads exist with `info threads` and switch to a specific thread with `thread #`, where `#` is the thread ID.
- Try to simulate your application with a Perl script to force MySQL to crash or misbehave.
- Send a normal bug report. See Section 1.6.1.3 [Bug reports], page 27. Be even more detailed than usual. Because MySQL works for many people, it may be that the crash results from something that exists only on your computer (for example, an error that is related to your particular system libraries).
- If you have a problem with tables with dynamic-length rows and you are not using `BLOB/TEXT` columns (but only `VARCHAR` columns), you can try to change all `VARCHAR` to `CHAR` with `ALTER TABLE`. This will force MySQL to use fixed-size rows. Fixed-size rows take a little extra space, but are much more tolerant to corruption!

  The current dynamic row code has been in use at MySQL AB for at least 3 years without any problems, but by nature dynamic-length rows are more prone to errors, so it may be a good idea to try the above to see if it helps!

A.4.2 How to Reset a Forgotten Root Password

If you never set a `root` password for MySQL, then the server will not require a password at all for connecting as `root`. It is recommended to always set a password for each user. See Section 4.3.2 [Security], page 215.

If you have set a `root` password, but forgot what it was, you can set a new password with the following procedure:

1. Take down the `mysqld` server by sending a `kill` (not `kill -9`) to the `mysqld` server. The pid is stored in a '`.pid`' file, which is normally in the MySQL database directory:

   ```
   shell> kill `cat /mysql-data-directory/hostname.pid`
   ```

   You must be either the Unix `root` user or the same user `mysqld` runs as to do this.

2. Restart `mysqld` with the `--skip-grant-tables` option.
3. Set a new password with the `mysqladmin password` command:

```
shell> mysqladmin -u root password 'mynewpassword'
```

4. Now you can either stop `mysqld` and restart it normally, or just load the privilege tables with:

```
shell> mysqladmin -h hostname flush-privileges
```

5. After this, you should be able to connect using the new password.

Alternatively, you can set the new password using the `mysql` client:

1. Take down and restart `mysqld` with the `--skip-grant-tables` option as described above.
2. Connect to the `mysqld` server with:

```
shell> mysql -u root mysql
```

3. Issue the following commands in the `mysql` client:

```
mysql> UPDATE user SET Password=PASSWORD('mynewpassword')
    ->             WHERE User='root';
mysql> FLUSH PRIVILEGES;
```

4. After this, you should be able to connect using the new password.
5. You can now stop `mysqld` and restart it normally.

A.4.3 How MySQL Handles a Full Disk

When a disk-full condition occurs, MySQL does the following:

- It checks once every minute to see whether there is enough space to write the current row. If there is enough space, it continues as if nothing had happened.
- Every 6 minutes it writes an entry to the log file warning about the disk full condition.

To alleviate the problem, you can take the following actions:

- To continue, you only have to free enough disk space to insert all records.
- To abort the thread, you must send a `mysqladmin kill` to the thread. The thread will be aborted the next time it checks the disk (in 1 minute).
- Note that other threads may be waiting for the table that caused the disk full condition. If you have several "locked" threads, killing the one thread that is waiting on the disk-full condition will allow the other threads to continue.

Exceptions to the above behaveour is when you use `REPAIR` or `OPTIMIZE` or when the indexes are created in a batch after an `LOAD DATA INFILE` or after an `ALTER TABLE` statement.

All of the above commands may use big temporary files that left to themself would cause big problems for the rest of the system. If MySQL gets disk full while doing any of the above operations, it will remove the big temporary files and mark the table as crashed (except for `ALTER TABLE`, in which the old table will be left unchanged).

A.4.4 Where MySQL Stores Temporary Files

MySQL uses the value of the `TMPDIR` environment variable as the pathname of the directory in which to store temporary files. If you don't have `TMPDIR` set, MySQL uses the system default, which is normally '`/tmp`' or '`/usr/tmp`'. If the filesystem containing your temporary file directory is too small, you should edit `mysqld_safe` to set `TMPDIR` to point to a directory in a filesystem where you have enough space! You can also set the temporary directory using the `--tmpdir` option to `mysqld`.

MySQL creates all temporary files as hidden files. This ensures that the temporary files will be removed if `mysqld` is terminated. The disadvantage of using hidden files is that you will not see a big temporary file that fills up the filesystem in which the temporary file directory is located.

When sorting (`ORDER BY` or `GROUP BY`), MySQL normally uses one or two temporary files. The maximum disk-space needed is:

```
(length of what is sorted + sizeof(database pointer))
* number of matched rows
* 2
```

`sizeof(database pointer)` is usually 4, but may grow in the future for really big tables.

For some `SELECT` queries, MySQL also creates temporary SQL tables. These are not hidden and have names of the form '`SQL_*`'.

`ALTER TABLE` creates a temporary table in the same directory as the original table.

If you use MySQL 4.1 or later you can spread load between several physical disks by setting `--tmpdir` to a list of paths separated by colon `:` (semicolon `;` on Windows). They will be used in round-robin fashion. **Note:** These paths should end up on different **physical** disks, not different partitions of the same disk.

It is possible to set `tmpdir` to point to a memory-based filesystem, except if the MySQL server is a slave. If it is a slave, it needs some of its temporary files (for replication of temporary tables or of `LOAD DATA INFILE`) to survive a machine's reboot, so a memory-based `tmpdir` which is cleared when the machine reboots is not suitable; a disk-based `tmpdir` is necessary.

A.4.5 How to Protect or Change the MySQL Socket File '/tmp/mysql.sock'

If you have problems with the fact that anyone can delete the MySQL communication socket '`/tmp/mysql.sock`', you can, on most versions of Unix, protect your '`/tmp`' filesystem by setting the `sticky` bit on it. Log in as `root` and do the following:

```
shell> chmod +t /tmp
```

This will protect your '`/tmp`' filesystem so that files can be deleted only by their owners or the superuser (`root`).

You can check if the `sticky` bit is set by executing `ls -ld /tmp`. If the last permission bit is `t`, the bit is set.

You can change the place where MySQL uses / puts the socket file the following ways:

- Specify the path in a global or local option file. For example, put in `/etc/my.cnf`:

```
[client]
socket=path-for-socket-file

[mysqld]
socket=path-for-socket-file
```

See Section 4.1.2 [Option files], page 203.

- Specifying this on the command-line to `mysqld_safe` and most clients with the `--socket=path-for-socket-file` option.
- Specify the path to the socket in the `MYSQL_UNIX_PORT` environment variable.
- Defining the path with the `configure` option `--with-unix-socket-path=path-for-socket-file`. See Section 2.3.3 [configure options], page 91.

You can test that the socket works with this command:

```
shell> mysqladmin --socket=/path/to/socket version
```

A.4.6 Time Zone Problems

If you have a problem with `SELECT NOW()` returning values in GMT and not your local time, you have to set the `TZ` environment variable to your current time zone. This should be done for the environment in which the server runs, for example, in `mysqld_safe` or `mysql.server`. See Appendix F [Environment variables], page 1019.

A.5 Query Related Issues

A.5.1 Case-Sensitivity in Searches

By default, MySQL searches are case-insensitive (although there are some character sets that are never case-insensitive, such as `czech`). That means that if you search with `col_name LIKE 'a%'`, you will get all column values that start with `A` or `a`. If you want to make this search case-sensitive, use something like `INSTR(col_name, "A")=1` to check a prefix. Or use `STRCMP(col_name, "A") = 0` if the column value must be exactly `"A"`.

Simple comparison operations (`>=, >, = , < , <=`, sorting and grouping) are based on each character's "sort value". Characters with the same sort value (like E, e and é) are treated as the same character!

In older MySQL versions `LIKE` comparisons were done on the uppercase value of each character (E == e but E <> é). In newer MySQL versions `LIKE` works just like the other comparison operators.

If you want a column always to be treated in case-sensitive fashion, declare it as `BINARY`. See Section 6.5.3 [`CREATE TABLE`], page 564.

If you are using Chinese data in the so-called big5 encoding, you want to make all character columns `BINARY`. This works because the sorting order of big5 encoding characters is based on the order of ASCII codes.

A.5.2 Problems Using DATE Columns

The format of a DATE value is 'YYYY-MM-DD'. According to standard SQL, no other format is allowed. You should use this format in UPDATE expressions and in the WHERE clause of SELECT statements. For example:

```
mysql> SELECT * FROM tbl_name WHERE date >= '1997-05-05';
```

As a convenience, MySQL automatically converts a date to a number if the date is used in a numeric context (and vice versa). It is also smart enough to allow a "relaxed" string form when updating and in a WHERE clause that compares a date to a TIMESTAMP, DATE, or a DATETIME column. (Relaxed form means that any punctuation character may be used as the separator between parts. For example, '1998-08-15' and '1998#08#15' are equivalent.) MySQL can also convert a string containing no separators (such as '19980815'), provided it makes sense as a date.

The special date '0000-00-00' can be stored and retrieved as '0000-00-00'. When using a '0000-00-00' date through MyODBC, it will automatically be converted to NULL in MyODBC Version 2.50.12 and above, because ODBC can't handle this kind of date.

Because MySQL performs the conversions described above, the following statements work:

```
mysql> INSERT INTO tbl_name (idate) VALUES (19970505);
mysql> INSERT INTO tbl_name (idate) VALUES ('19970505');
mysql> INSERT INTO tbl_name (idate) VALUES ('97-05-05');
mysql> INSERT INTO tbl_name (idate) VALUES ('1997.05.05');
mysql> INSERT INTO tbl_name (idate) VALUES ('1997 05 05');
mysql> INSERT INTO tbl_name (idate) VALUES ('0000-00-00');

mysql> SELECT idate FROM tbl_name WHERE idate >= '1997-05-05';
mysql> SELECT idate FROM tbl_name WHERE idate >= 19970505;
mysql> SELECT MOD(idate,100) FROM tbl_name WHERE idate >= 19970505;
mysql> SELECT idate FROM tbl_name WHERE idate >= '19970505';
```

However, the following will not work:

```
mysql> SELECT idate FROM tbl_name WHERE STRCMP(idate,'19970505')=0;
```

STRCMP() is a string function, so it converts idate to a string and performs a string comparison. It does not convert '19970505' to a date and perform a date comparison.

Note that MySQL does very limited checking whether the date is correct. If you store an incorrect date, such as '1998-2-31', the wrong date will be stored.

Because MySQL packs dates for storage, it can't store any given date as it would not fit onto the result buffer. The rules for accepting a date are:

- If MySQL can store and retrieve a given date, the wrong date is accepted for DATE and DATETIME columns.
- All days values between 0-31 are accepted for any date. This makes it very convenient for web applications where you ask year, month and day in 3 different fields.
- The day or month field may be zero. This is convenient if you want to store a birthdate in a DATE column and you only know part of the date.

If the date cannot be converted to any reasonable value, a 0 is stored in the DATE field, which will be retrieved as 0000-00-00. This is both a speed and convenience issue as we

believe that the database's responsibility is to retrieve the same date you stored (even if the data was not logically correct in all cases). We think it is up to the application to check the dates, and not the server.

A.5.3 Problems with NULL Values

The concept of the NULL value is a common source of confusion for newcomers to SQL, who often think that NULL is the same thing as an empty string "". This is not the case! For example, the following statements are completely different:

```
mysql> INSERT INTO my_table (phone) VALUES (NULL);
mysql> INSERT INTO my_table (phone) VALUES ("");
```

Both statements insert a value into the phone column, but the first inserts a NULL value and the second inserts an empty string. The meaning of the first can be regarded as "phone number is not known" and the meaning of the second can be regarded as "she has no phone".

In SQL, the NULL value is always false in comparison to any other value, even NULL. An expression that contains NULL always produces a NULL value unless otherwise indicated in the documentation for the operators and functions involved in the expression. All columns in the following example return NULL:

```
mysql> SELECT NULL,1+NULL,CONCAT('Invisible',NULL);
```

If you want to search for column values that are NULL, you cannot use the =NULL test. The following statement returns no rows, because expr = NULL is FALSE, for any expression:

```
mysql> SELECT * FROM my_table WHERE phone = NULL;
```

To look for NULL values, you must use the IS NULL test. The following shows how to find the NULL phone number and the empty phone number:

```
mysql> SELECT * FROM my_table WHERE phone IS NULL;
mysql> SELECT * FROM my_table WHERE phone = "";
```

Note that you can add an index on a column that can have NULL values only if you are using MySQL Version 3.23.2 or newer and are using the MyISAM, InnoDB, or BDB table type. In earlier versions and with other table types, you must declare such columns NOT NULL. This also means you cannot then insert NULL into an indexed column.

When reading data with LOAD DATA INFILE, empty columns are updated with ''. If you want a NULL value in a column, you should use \N in the text file. The literal word 'NULL' may also be used under some circumstances. See Section 6.4.8 [LOAD DATA], page 555.

When using ORDER BY, NULL values are presented first, or last if you specify DESC to sort in descending order. Exception: In MySQL versions 4.0.2 through 4.0.10, NULL values sort first regardless of sort order.

When using GROUP BY, all NULL values are regarded as equal.

Aggregate (summary) functions such as COUNT(), MIN(), and SUM() ignore NULL values. The exception to this is COUNT(*), which counts rows and not individual column values. For example, the following statement would produce two counts. The first is a count of the number of rows in the table, and the second is a count of the number of non-NULL values in the age column:

```
mysql> SELECT COUNT(*), COUNT(age) FROM person;
```

To help with NULL handling, you can use the IS NULL and IS NOT NULL operators and the IFNULL() function.

For some column types, NULL values are handled specially. If you insert NULL into the first TIMESTAMP column of a table, the current date and time is inserted. If you insert NULL into an AUTO_INCREMENT column, the next number in the sequence is inserted.

A.5.4 Problems with alias

You can use an alias to refer to a column in the GROUP BY, ORDER BY, or in the HAVING part. Aliases can also be used to give columns better names:

```
SELECT SQRT(a*b) as rt FROM table_name GROUP BY rt HAVING rt > 0;
SELECT id,COUNT(*) AS cnt FROM table_name GROUP BY id HAVING cnt > 0;
SELECT id AS "Customer identity" FROM table_name;
```

Note that standard SQL doesn't allow you to refer to an alias in a WHERE clause. This is because when the WHERE code is executed the column value may not yet be determined. For example, the following query is **illegal**:

```
SELECT id,COUNT(*) AS cnt FROM table_name WHERE cnt > 0 GROUP BY id;
```

The WHERE statement is executed to determine which rows should be included in the GROUP BY part while HAVING is used to decide which rows from the result set should be used.

A.5.5 Deleting Rows from Related Tables

As MySQL doesn't support subqueries (prior to Version 4.1), nor the use of more than one table in the DELETE statement (prior to Version 4.0), you should use the following approach to delete rows from 2 related tables:

1. SELECT the rows based on some WHERE condition in the main table.
2. DELETE the rows in the main table based on the same condition.
3. DELETE FROM related_table WHERE related_column IN (selected_rows).

If the total number of characters in the query with related_column is more than 1,048,576 (the default value of max_allowed_packet, you should split it into smaller parts and execute multiple DELETE statements. You will probably get the fastest DELETE by only deleting 100-1000 related_column ids per query if the related_column is an index. If the related_column isn't an index, the speed is independent of the number of arguments in the IN clause.

A.5.6 Solving Problems with No Matching Rows

If you have a complicated query that has many tables and that doesn't return any rows, you should use the following procedure to find out what is wrong with your query:

1. Test the query with EXPLAIN and check if you can find something that is obviously wrong. See Section 5.2.1 [EXPLAIN], page 399.
2. Select only those fields that are used in the WHERE clause.

3. Remove one table at a time from the query until it returns some rows. If the tables are big, it's a good idea to use `LIMIT 10` with the query.
4. Do a `SELECT` for the column that should have matched a row against the table that was last removed from the query.
5. If you are comparing `FLOAT` or `DOUBLE` columns with numbers that have decimals, you can't use `'='`. This problem is common in most computer languages because floating-point values are not exact values. In most cases, changing the `FLOAT` to a `DOUBLE` will fix this. See Section A.5.7 [Problems with float], page 868.
6. If you still can't figure out what's wrong, create a minimal test that can be run with `mysql test < query.sql` that shows your problems. You can create a test file with `mysqldump --quick database tables > query.sql`. Open the file in an editor, remove some insert lines (if there are too many of these), and add your select statement at the end of the file.

   Test that you still have your problem by doing:

   ```
   shell> mysqladmin create test2
   shell> mysql test2 < query.sql
   ```

   Post the test file using `mysqlbug` to the general MySQL mailing list. See Section 1.6.1.1 [Mailing-list], page 25.

A.5.7 Problems with Floating-Point Comparison

floating-point numbers cause confusion sometimes, because these numbers are not stored as exact values inside computer architecture. What one can see on the screen usually is not the exact value of the number.

Field types `FLOAT`, `DOUBLE` and `DECIMAL` are such.

```
CREATE TABLE t1 (i INT, d1 DECIMAL(9,2), d2 DECIMAL(9,2));
INSERT INTO t1 VALUES (1, 101.40, 21.40), (1, -80.00, 0.00),
(2, 0.00, 0.00), (2, -13.20, 0.00), (2, 59.60, 46.40),
(2, 30.40, 30.40), (3, 37.00, 7.40), (3, -29.60, 0.00),
(4, 60.00, 15.40), (4, -10.60, 0.00), (4, -34.00, 0.00),
(5, 33.00, 0.00), (5, -25.80, 0.00), (5, 0.00, 7.20),
(6, 0.00, 0.00), (6, -51.40, 0.00);

mysql> SELECT i, SUM(d1) AS a, SUM(d2) AS b
    -> FROM t1 GROUP BY i HAVING a <> b;
+------+--------+-------+
| i    | a      | b     |
+------+--------+-------+
|    1 |  21.40 | 21.40 |
|    2 |  76.80 | 76.80 |
|    3 |   7.40 |  7.40 |
|    4 |  15.40 | 15.40 |
|    5 |   7.20 |  7.20 |
|    6 | -51.40 |  0.00 |
+------+--------+-------+
```

The result is correct. Although the first five records look like they shouldn't pass the comparison test, they may do so because the difference between the numbers show up around tenth decimal, or so depending on computer architecture.

The problem cannot be solved by using ROUND() (or similar function), because the result is still a floating-point number. Example:

```
mysql> SELECT i, ROUND(SUM(d1), 2) AS a, ROUND(SUM(d2), 2) AS b
    -> FROM t1 GROUP BY i HAVING a <> b;
+------+--------+-------+
| i    | a      | b     |
+------+--------+-------+
|    1 |  21.40 | 21.40 |
|    2 |  76.80 | 76.80 |
|    3 |   7.40 |  7.40 |
|    4 |  15.40 | 15.40 |
|    5 |   7.20 |  7.20 |
|    6 | -51.40 |  0.00 |
+------+--------+-------+
```

This is what the numbers in column 'a' look like:

```
mysql> SELECT i, ROUND(SUM(d1), 2)*1.0000000000000000 AS a,
    -> ROUND(SUM(d2), 2) AS b FROM t1 GROUP BY i HAVING a <> b;
+------+----------------------+-------+
| i    | a                    | b     |
+------+----------------------+-------+
|    1 |  21.3999999999999986 | 21.40 |
|    2 |  76.7999999999999972 | 76.80 |
|    3 |   7.4000000000000004 |  7.40 |
|    4 |  15.4000000000000004 | 15.40 |
|    5 |   7.2000000000000002 |  7.20 |
|    6 | -51.3999999999999986 |  0.00 |
+------+----------------------+-------+
```

Depending on the computer architecture you may or may not see similar results. Each CPU may evaluate floating-point numbers differently. For example in some machines you may get 'right' results by multiplying both arguments with 1, an example follows.

WARNING: NEVER TRUST THIS METHOD IN YOUR APPLICATION, THIS IS AN EXAMPLE OF A WRONG METHOD!!!

```
mysql> SELECT i, ROUND(SUM(d1), 2)*1 AS a, ROUND(SUM(d2), 2)*1 AS b
    -> FROM t1 GROUP BY i HAVING a <> b;
+------+--------+------+
| i    | a      | b    |
+------+--------+------+
|    6 | -51.40 | 0.00 |
+------+--------+------+
```

The reason why the above example seems to be working is that on the particular machine where the test was done, the CPU floating-point arithmetics happens to round the numbers to same, but there is no rule that any CPU should do so, so it cannot be trusted.

The correct way to do floating-point number comparison is to first decide on what is the wanted tolerance between the numbers and then do the comparison against the tolerance number. For example, if we agree on that floating-point numbers should be regarded the same, if they are same with precision of one of ten thousand (0.0001), the comparison should be done like this:

```
mysql> SELECT i, SUM(d1) AS a, SUM(d2) AS b FROM t1
    -> GROUP BY i HAVING ABS(a - b) > 0.0001;
+------+--------+------+
| i    | a      | b    |
+------+--------+------+
|    6 | -51.40 | 0.00 |
+------+--------+------+
1 row in set (0.00 sec)
```

And vice versa, if we wanted to get rows where the numbers are the same, the test would be:

```
mysql> SELECT i, SUM(d1) AS a, SUM(d2) AS b FROM t1
    -> GROUP BY i HAVING ABS(a - b) < 0.0001;
+------+-------+-------+
| i    | a     | b     |
+------+-------+-------+
|    1 | 21.40 | 21.40 |
|    2 | 76.80 | 76.80 |
|    3 |  7.40 |  7.40 |
|    4 | 15.40 | 15.40 |
|    5 |  7.20 |  7.20 |
+------+-------+-------+
```

A.6 Optimiser Related Issues

MySQL uses a cost based optimiser to find out the best way to resolve a query. In many cases MySQL can calculate the best possible query plan but in some cases MySQL doesn't have enough information about the data at hand and have to do some 'educated' guesses about the data.

This manual section is intended for the cases when MySQL doesn't get it right.

The tools one has available to help MySQL do the 'right' things are:

- `EXPLAIN`. See Section 5.2.1 [`EXPLAIN`], page 399.
- `ANALYZE TABLE`. See Section 4.6.2 [`ANALYZE TABLE`], page 281.
- `USE INDEX`, `FORCE INDEX` and `IGNORE INDEX`. See Section 6.4.1 [SELECT], page 530.
- Global and table level `STRAIGHT JOIN`. See Section 6.4.1 [SELECT], page 530.
- Setting thread specific variables. See Section 4.6.8.4 [SHOW VARIABLES], page 290.

A.6.1 How to avoid table scan,,,

`EXPLAIN` will show `ALL` in the `type` column when MySQL uses a table scan to resolve a query. This happens usually when:

- The table is so small that it's faster to do a table scan than a key lookup. This is a common case for tables with < 10 rows and a short row length.
- There is no usable restrictions in the `ON` or `WHERE` clause for indexed columns.
- You are comparing indexed columns with constants and MySQL has calculated (based on the index tree) that the constants covers a too big part of the table and a table scan would be faster. See Section 5.2.4 [Where optimisations], page 407.
- You are using a key with low cardinality (= many matching rows) through another column. MySQL will in this case assume that by using the key it will probably do a lot of key lookups and in this case the table scan would be faster.

What you can do to avoid a 'wrong' table scan for big tables are:

- Use `ANALYZE TABLE` for the scanned table to update key distributions. See Section 4.6.2 [ANALYZE TABLE], page 281.
- Use `FORCE INDEX` for the scanned table to tell MySQL that table scans are very expensive compared to use one of the given index. See Section 6.4.1 [SELECT], page 530.

```
SELECT * FROM t1,t2 force index(index_for_column) WHERE t1.column=t2.column;
```

- Start `mysqld` with `--max-seeks-for-key=1000` or do `SET MAX_SEEKS_FOR_KEY=1000` to tell the optimiser that for no key scan will cause more than 1000 key seeks.

A.7 Table Definition Related Issues

A.7.1 Problems with `ALTER TABLE`.

`ALTER TABLE` changes a table to the current character set. If you get a duplicate key error during `ALTER TABLE`, then the cause is either that the new character sets maps two keys to the same value or that the table is corrupted, in which case you should run `REPAIR TABLE` on the table.

If `ALTER TABLE` dies with an error like this:

```
Error on rename of './database/name.frm' to './database/B-a.frm' (Errcode: 17)
```

the problem may be that MySQL has crashed in a previous `ALTER TABLE` and there is an old table named '`A-something`' or '`B-something`' lying around. In this case, go to the MySQL data directory and delete all files that have names starting with `A-` or `B-`. (You may want to move them elsewhere instead of deleting them.)

`ALTER TABLE` works the following way:

- Create a new table named '`A-xxx`' with the requested changes.
- All rows from the old table are copied to '`A-xxx`'.
- The old table is renamed '`B-xxx`'.
- '`A-xxx`' is renamed to your old table name.
- '`B-xxx`' is deleted.

If something goes wrong with the renaming operation, MySQL tries to undo the changes. If something goes seriously wrong (this shouldn't happen, of course), MySQL may leave the old table as '`B-xxx`', but a simple rename on the system level should get your data back.

A.7.2 How To Change the Order of Columns in a Table

The whole point of SQL is to abstract the application from the data storage format. You should always specify the order in which you wish to retrieve your data. For example:

```
SELECT col_name1, col_name2, col_name3 FROM tbl_name;
```

will return columns in the order `col_name1`, `col_name2`, `col_name3`, whereas:

```
SELECT col_name1, col_name3, col_name2 FROM tbl_name;
```

will return columns in the order `col_name1`, `col_name3`, `col_name2`.

If you want to change the order of columns anyway, you can do it as follows:

1. Create a new table with the columns in the right order.
2. Execute `INSERT INTO new_table SELECT fields-in-new_table-order FROM old_table`.
3. Drop or rename `old_table`.
4. `ALTER TABLE new_table RENAME old_table`.

In an application, you should **never** use `SELECT *` and retrieve the columns based on their position, because the order and position in which columns are returned will not remain the same if you add, move, or delete columns. A simple change to your database structure would then cause your application to fail. Of course `SELECT *` is quite suitable for testing queries.

A.7.3 TEMPORARY TABLE problems

The following are a list of the limitations with `TEMPORARY TABLES`.

- A temporary table can only be of type `HEAP`, `ISAM`, `MyISAM`, `MERGE`, or `InnoDB`.
- You can't use temporary tables more than once in the same query. For example, the following doesn't work.

  ```
  mysql> SELECT * FROM temporary_table, temporary_table AS t2;
  ```

- You can't use `RENAME` on a `TEMPORARY` table. Note that `ALTER TABLE org_name RENAME new_name` works!

Appendix B Contributed Programs

Many users of MySQL have contributed *very* useful support tools and add-ons.

A list of some software available from the MySQL website (or any mirror) is shown here.

You can also visit our online listing of MySQL-related software at `http://www.mysql.com/portal/software/`. The community facilities there also allow for your input!

If you want to build MySQL support for the Perl `DBI/DBD` interface, you should fetch the `Data-Dumper`, `DBI`, and `DBD-mysql` files and install them. See Section 2.7 [Perl support], page 152.

Note: The programs listed here can be freely downloaded and used. They are copyrighted by their respective owners. Please see individual product documentation for more details on licensing and terms. MySQL AB assumes no liability for the correctness of the information in this chapter or for the proper operation of the programs listed herein.

B.1 APIs

- Perl Modules
  - `http://www.mysql.com/Downloads/Contrib/KAMXbase1.2.tar.gz` Convert between '`.dbf`' files and MySQL tables. Perl module written by Pratap Pereira `pereira@ee.eng.ohio-state.edu`, extended by Kevin A. McGrail `kmcgrail@digital1.peregrinehw.com`. This converter can handle MEMO fields.
  - `http://www.mysql.com/Downloads/Contrib/HandySQL-1.1.tar.gz` HandySQL is a MySQL access module. It offers a C interface embedded in Perl and is approximately 20% faster than regular DBI.
- OLEDB
  - `http://www.mysql.com/Downloads/Win32/MyOLEDB3.exe` MyOLEDB 3.0 installation package from SWSoft.
  - `http://www.mysql.com/Downloads/Win32/mysql-oledb-3.0.0.zip` Source for MyOLEDB 3.0.
  - `http://www.mysql.com/Downloads/Win32/MySamples.zip` Examples and documentation for MyOLEDB.
  - `http://www.mysql.com/Downloads/Win32/MyOLEDB.chm` Help files for MyOLEDB.
  - `http://www.mysql.com/Downloads/Win32/libmyodbc.zip` Static MyODBC library used for build MyOLEDB. Based on MyODBC code.
- C++
  - `http://www.mysql.com/Downloads/Contrib/mysql-c++-0.02.tar.gz` MySQL C++ wrapper library. By Roland Haenel, `rh@ginster.net`.
  - `http://www.mysql.com/Downloads/Contrib/MyDAO.tar.gz` MySQL C++ API. By Satish `spitfire@pn3.vsnl.net.in`. Inspired by Roland Haenel's C++ API and Ed Carp's MyC library.

  - http://www.mysql.com/products/mysql++/ MySQL C++ API (more than just a wrapper library). Originally by kevina@clark.net. Now maintained by Sinisa at MySQL AB.
  - http://nelsonjr.homepage.com/NJrAPI/ A C++ database independent library that supports MySQL.
- Delphi
  - http://www.mysql.com/Downloads/Contrib/DelphiMySQL2.zip Delphi interface to libmysql.dll, by bsilva@umesd.k12.or.us.
  - http://www.mysql.com/Downloads/Contrib/Udmysql.pas A wrapper for libmysql.dll for usage in Delphi. By Reiner Sombrowsky.
  - http://www.fichtner.net/delphi/mysql.delphi.phtml A Delphi Interface to MySQL, with source code. By Matthias Fichtner.
  - http://www.productivity.org/projects/tmysql/ TmySQL, a library to use MySQL with Delphi.
  - https://sourceforge.net/projects/zeoslib/ Zeos Library is a set of delphi native datasets and database components for MySQL, PostgreSQL, Interbase, MS SQL, Oracle, and DB2. Also it includes development tools such as Database Explorer and Database Designer.
  - http://www.mysql.com/Downloads/Contrib/JdmMysqlDriver-0.1.0.tar.gz A VisualWorks 3.0 Smalltalk driver for MySQL. By joshmiller@earthlink.net.
  - http://www.mysql.com/Downloads/Contrib/Db.py Python module with caching. By gandalf@rosmail.com.
  - http://www.mysql.com/Downloads/Contrib/MySQLmodule-1.4.tar.gz Python interface for MySQL. By Joseph Skinner joe@earthlight.co.nz. Modified by Joerg Senekowitsch senekow@ibm.net.
  - http://www.mysql.com/Downloads/Contrib/mysqltcl-1.53.tar.gz Tcl interface for MySQL. Based on 'msqltcl-1.50.tar.gz'. For version 2.0 and more info, see http://www.xdobry.de/mysqltcl/.
  - http://www.mysql.com/Downloads/Contrib/MyC-0.1.tar.gz A Visual Basic-like API, by Ed Carp.
  - http://www.mysql.com/Downloads/Contrib/Vdb-dflts-2.1.tar.gz This is a new version of a set of library utilities intended to provide a generic interface to SQL database engines such that your application becomes a 3-tiered application. The advantage is that you can easily switch between and move to other database engines by implementing one file for the new backend without making any changes to your applications. By damian@cablenet.net.
  - http://www.mysql.com/Downloads/Contrib/DbFramework-1.10.tar.gz DbFramework is a collection of classes for manipulating MySQL databases. The classes are loosely based on the CDIF Data Model Subject Area. By Paul Sharpe paul@miraclefish.com.
  - http://www.mysql.com/Downloads/Contrib/pike-mysql-1.4.tar.gz MySQL module for pike. For use with the Roxen web server.
  - http://www.mysql.com/Downloads/Contrib/squile.tar.gz Module for guile that allows guile to interact with SQL databases. By Hal Roberts.

- `http://www.mysql.com/Downloads/Contrib/stk-mysql.tar.gz` Interface for Stk. Stk is the Tk widgets with Scheme underneath instead of Tcl. By Terry Jones.
- `http://www.mysql.com/Downloads/Contrib/eiffel-wrapper-1.0.tar.gz` Eiffel wrapper by Michael Ravits.
- `http://www.mysql.com/Downloads/Contrib/SQLmy0.06.tgz` FlagShip Replaceable Database Driver (RDD) for MySQL. By Alejandro Fernandez Herrero. The Flagship RDD homepage is at `http://www.fship.com/rdds.html`.
- `http://www.mysql.com/Downloads/Contrib/mydsn-1.0.zip` Binary and source for `mydsn.dll`. mydsn should be used to build and remove the DSN registry file for the MyODBC driver in Coldfusion applications. By Miguel Angel Solórzano.
- `http://www.mysql.com/Downloads/Contrib/MySQL-ADA95_API.zip` An ADA95 interface to the MySQL API. By Francois Fabien.
- `http://www.mysql.com/Downloads/Contrib/MyTool-DLL_for_VB_and_MySQL.zip` A DLL with MySQL C API for Visual Basic. By Ken Menzel `kenm@icarz.com`.
- `http://www.mysql.com/Downloads/Contrib/MYSQLX.EXE` MySQL ActiveX Object for directly accessing your MySQL servers from IIS/ASP, VB, VC++ skipping the slower ODBC methods. Fully updatable, multi-threaded with full support for all MySQL fieldtypes (version 2001.1.1). By SciBit `http://www.scibit.com/`.
- `http://www.fastflow.it/mylua/` MyLUA home page; how to use the LUA language to write MySQL `PROCEDURE` that can be loaded runtime.
  - `http://www.mysql.com/Downloads/Contrib/lua-4.0.tar.gz` LUA 4.0
  - `http://www.mysql.com/Downloads/Contrib/mylua-3.23.32.1.tar.gz` Patch for MySQL 3.23.32 to use LUA 4.0. By Cristian Giussani.
- `http://www.mysql.com/Downloads/Contrib/patched_myodbc.zip` Patch (for Omniform 4.0 support) to the MyODBC driver. By Thomas Thaele `tthaele@papenmeier.de`

B.2 Converters

- `http://www.mysql.com/Downloads/Contrib/mssql2mysql.txt` Converter from MS-SQL to MySQL. By Michael Kofler. The mssql2mysql home page is at `http://www.kofler.cc/mysql/mssql2mysql.html`.
- `http://www.mysql.com/Downloads/Contrib/dbf2mysql-1.14.tar.gz` Convert between '`.dbf`' files and MySQL tables. By Maarten Boekhold (`boekhold@cindy.et.tudelft.nl`), William Volkman, and Michael Widenius. This converter includes rudimentary read-only support for MEMO fields.
- `http://www.mysql.com/Downloads/Contrib/dbf2mysql-1.13.tgz` Convert between '`.dbf`' files and MySQL tables. By Maarten Boekhold, `boekhold@cindy.et.tudelft.nl`, and Michael Widenius. This converter can't handle MEMO fields.

- `http://www.mysql.com/Downloads/Contrib/dbf2mysql.zip` Convert between FoxPro '`.dbf`' files and MySQL tables on Windows. By Alexander Eltsyn, `ae@nica.ru` or `ae@usa.net`.
- `http://www.mysql.com/Downloads/Contrib/dbf2sql.zip` Short and simple prg that can help you transport your data from foxpro table into MySQL table. By Danko Josic.
- `http://www.mysql.com/Downloads/Contrib/dump2h-1.20.gz` Convert from `mysqldump` output to a C header file. By Harry Brueckner, `brueckner@mail.respublica.de`.
- `http://www.mysql.com/Downloads/Contrib/exportsql.txt` A script that is similar to `access_to_mysql.txt`, except that this one is fully configurable, has better type conversion (including detection of `TIMESTAMP` fields), provides warnings and suggestions while converting, quotes **all** special characters in text and binary data, and so on. It will also convert to `mSQL` v1 and v2, and is free of charge for anyone. See `http://www.cynergi.net/exportsql/` for the latest version. By Pedro Freire, `support@cynergi.net`. Note: Doesn't work with Access 2.0!
- `http://www.mysql.com/Downloads/Contrib/access_to_mysql.txt` Paste this function into an Access module of a database that has the tables you want to export. See also `exportsql`. By Brian Andrews. Note: Doesn't work with Access2!
- `http://www.mysql.com/Downloads/Contrib/importsql.txt` A script that does the exact reverse of `exportsql.txt`. That is, it imports data from MySQL into an Access database via ODBC. This is very handy when combined with exportsql, because it lets you use Access for all DB design and administration, and synchronise with your actual MySQL server either way. Free of charge. See `http://www.netdive.com/freebies/importsql/` for any updates. Created by Laurent Bossavit of NetDIVE. **Note**: doesn't work with Access 2.0!
- `http://www.mysql.com/Downloads/Contrib/mdb2sql.bas` Converter from Access97 to MySQL by Moshe Gurvich.
- `http://www.mysql.com/Downloads/Contrib/msql2mysqlWrapper-1.0.tgz` A C wrapper from `mSQL` to MySQL. By `alfred@sb.net`
- `http://www.mysql.com/Downloads/Contrib/sqlconv.pl` A simple script that can be used to copy fields from one MySQL table to another in bulk. Basically, you can run `mysqldump` and pipe it to the `sqlconv.pl` script. The script will parse through the `mysqldump` output and will rearrange the fields so they can be inserted into a new table. An example is when you want to create a new table for a different site you are working on, but the table is just a bit different (that is - fields in different order, etc.). By Steve Shreeve.
- `http://www.mysql.com/Downloads/Contrib/oracledump` Perl program to convert Oracle databases to MySQL. Has same output format as mysqldump. By Johan Andersson.
- `http://www.mysql.com/Downloads/Contrib/excel2mysql` Perl program to import Excel spreadsheets into a MySQL database. By Stephen Hurd `shurd@sk.sympatico.ca`
- `http://www.mysql.com/Downloads/Contrib/T2S_100.ZIP`. Windows program to convert text files to MySQL databases. By Asaf Azulay.

B.3 Utilities

- `http://worldcommunity.com/opensource/utilities/mysql_backup.html` MySQL Backup is a backup script for MySQL. By Peter F. Brown.
- `http://www.mysql.com/Downloads/Contrib/mysql_watchdog.pl` Monitor the MySQL daemon for possible lockups. By Yermo Lamers, `yml@yml.com`.
- `http://www.mysql.com/Downloads/Contrib/mysql_structure_dumper.tar.gz`
- `http://www.mysql.com/Downloads/Contrib/mysql_structure_dumper.tgz` Prints the structure of every table in a database. By Thomas Wana.
- `http://www.mysql.com/Downloads/Contrib/mysqlsync`. A Perl script to keep remote copies of a MySQL database in sync with a central master copy. By Mark Jeftovic. `markjr@easydns.com`.
- `http://www.mysql.com/Downloads/Contrib/MySQLTutor-0.2.tar.gz`. MySQLTutor. A MySQL tutorial for beginners.
- `http://www.mysql.com/Downloads/Contrib/MySQLDB.zip`
- `http://www.mysql.com/Downloads/Contrib/MySQLDB-readme.html`. A COM library for MySQL by Alok Singh.
- `http://www.mysql.com/Downloads/Contrib/mysql_replicate.pl` Perl program that handles replication. By `elble@icculus.nsg.nwu.edu`
- `http://www.mysql.com/Downloads/Contrib/dbcheck` Perl script that takes a backup of tables before running isamchk on them. By Elizabeth.
- `http://www.mysql.com/Downloads/Contrib/mybackup`.
- `http://www.mswanson.com/mybackup` (mybackup home page) Wrapper for mysqldump to backup all databases. By Marc Swanson.
- `http://www.mysql.com/Downloads/Contrib/mdu.pl.gz` Prints the storage usage of a MySQL database.

Appendix C Credits

This appendix lists the developers, contributors, and supporters that have helped to make MySQL what it is today.

C.1 Developers at MySQL AB

These are the developers that are or have been employed by `MySQL AB` to work on the `MySQL` database software, roughly in the order they started to work with us. Following each developer is a small list of the tasks that the developer is responsible for, or the accomplishments they have made. All developers are involved in support.

Michael (Monty) Widenius

- Lead developer and main author of the MySQL server (`mysqld`).
- New functions for the string library.
- Most of the `mysys` library.
- The `ISAM` and `MyISAM` libraries (B-tree index file handlers with index compression and different record formats).
- The `HEAP` library. A memory table system with our superior full dynamic hashing. In use since 1981 and published around 1984.
- The `replace` program (take a look at it, it's **COOL**!).
- `MyODBC`, the ODBC driver for Windows95.
- Fixing bugs in MIT-pthreads to get it to work for MySQL Server. And also Unireg, a curses-based application tool with many utilities.
- Porting of `mSQL` tools like `msqlperl`, `DBD/DBI`, and `DB2mysql`.
- Most of `crash-me` and the foundation for the MySQL benchmarks.

David Axmark

- Initial main writer of the **Reference Manual**, including enhancements to `texi2html`.
- Automatic web site updating from the manual.
- Initial Autoconf, Automake, and Libtool support.
- Licensing.
- Parts of all the text files. (Nowadays only the '`README`' is left. The rest ended up in the manual.)
- Lots of testing of new features.
- Our in-house Free Software legal expert.
- Mailing list maintainer (who never has the time to do it right...).
- Our original portability code (more than 10 years old now). Nowadays only some parts of `mysys` are left.
- Someone for Monty to call in the middle of the night when he just got that new feature to work.
- Chief "Open Sourcerer" (MySQL community relations).

Jani Tolonen

- `mysqlimport`
- A lot of extensions to the command-line clients.
- `PROCEDURE ANALYSE()`

Sinisa Milivojevic

- Compression (with `zlib`) in the client/server protocol.
- Perfect hashing for the lexical analyser phase.
- Multi-row `INSERT`
- `mysqldump` -e option
- `LOAD DATA LOCAL INFILE`
- `SQL_CALC_FOUND_ROWS SELECT` option
- `--max-user-connections=...` option
- `net_read` and `net_write_timeout`
- `GRANT/REVOKE` and `SHOW GRANTS FOR`
- New client/server protocol for 4.0
- `UNION` in 4.0
- Multi-table `DELETE/UPDATE`
- Derived tables in 4.1
- User resources management
- Initial developer of the `MySQL++` C++ API and the `MySQLGUI` client.

Tonu Samuel (past developer)

- VIO interface (the foundation for the encrypted client/server protocol).
- MySQL Filesystem (a way to use MySQL databases as files and directories).
- The `CASE` expression.
- The `MD5()` and `COALESCE()` functions.
- `RAID` support for `MyISAM` tables.

Sasha Pachev

- Initial implementation of replication (up to version 4.0).
- `SHOW CREATE TABLE`.
- `mysql-bench`

Matt Wagner

- MySQL test suite.
- Webmaster (until 2002).
- Coordinator of development.

Miguel Solorzano

- Win32 development and release builds.
- Windows NT server code.
- WinMySQLAdmin

Timothy Smith (past developer)

- Dynamic character sets support.
- configure, RPMs and other parts of the build system.
- Initial developer of `libmysqld`, the embedded server.

Sergei Golubchik

- Full-text search.
- Added keys to the `MERGE` library.

Jeremy Cole

- Proofreading and editing this fine manual.
- `ALTER TABLE ... ORDER BY ...`.
- `UPDATE ... ORDER BY ...`.
- `DELETE ... ORDER BY ...`.

Indrek Siitan

- Designing/programming of our web interface.
- Author of our newsletter management system.

Jorge del Conde

- `MySQLCC` (`MySQL Control Center`)
- Win32 development
- Initial implementation of the website portals.

Venu Anuganti

- Connector/ODBC (MyODBC) 3.51
- New client/server protocol for 4.1 (for prepared statements).
-

Arjen Lentz

- Maintainer of the MySQL Reference Manual.
- Preparing the O'Reilly printed edition of the manual.

Alexander (Bar) Barkov, Alexey (Holyfoot) Botchkov, and Ramil Kalimullin

- Spatial data (GIS) and R-Trees implementation for 4.1
- Unicode and character sets for 4.1; documentation for same

Oleksandr (Sanja) Byelkin

- Query cache in 4.0
- Implementation of subqueries (4.1).

Aleksey (Walrus) Kishkin and Alexey (Ranger) Stroganov

- Benchmarks design and analysis.
- Maintenance of the MySQL test suite.

Zak Greant

- Open Source advocate, MySQL community relations.

Carsten Pedersen

- The MySQL Certification program.

Lenz Grimmer
- Production (build and release) engineering.

Peter Zaitsev
- `SHA1()`, `AES_ENCRYPT()` and `AES_DECRYPT()` functions.
- Debugging, cleaning up various features.

Alexander (Salle) Keremidarski
- Support.
- Debugging.

Per-Erik Martin
- Lead developer for stored procedures (5.0) and triggers.

Jim Winstead
- Lead web developer.

Mark Matthews
- Connector/J driver (Java).

Peter Gulutzan

SQL-99, SQL:2003 standards compliance.
- Documentation of existing MySQL code/algorithms.
- Character set documentation.

Guilhem Bichot
- Replication, from `MySQL` version 4.0.
- Fixed handling of exponents for `DECIMAL`.
- Author of `mysql_tableinfo`.

Antony T. Curtis
- Porting of the MySQL Database software to OS/2.

C.2 Contributors to MySQL

While `MySQL AB` owns all copyrights in the `MySQL server` and the `MySQL manual`, we wish to recognise those who have made contributions of one kind or another to the `MySQL distribution`. Contributors are listed here, in somewhat random order:

Gianmassimo Vigazzola `qwerg@mbox.vol.it` or `qwerg@tin.it`
The initial port to Win32/NT.

Per Eric Olsson
For more or less constructive criticism and real testing of the dynamic record format.

Irena Pancirov `irena@mail.yacc.it`
Win32 port with Borland compiler. `mysqlshutdown.exe` and `mysqlwatch.exe`

David J. Hughes
For the effort to make a shareware SQL database. At TcX, the predecessor of MySQL AB, we started with `mSQL`, but found that it couldn't satisfy

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

Patrick Lynch
: For helping us acquire `http://www.mysql.com/`.

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

Igor Romanenko `igor@frog.kiev.ua`
: `mysqldump` (previously `msqldump`, but ported and enhanced by Monty).

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

Tim Bunce
: Author of `mysqlhotcopy`.

Zarko Mocnik `zarko.mocnik@dem.si`
: Sorting for Slovenian language.

"TAMITO" `tommy@valley.ne.jp`
: The `_MB` character set macros and the ujis and sjis character sets.

Joshua Chamas `joshua@chamas.com`
: Base for concurrent insert, extended date syntax, debugging on NT, and answering on the MySQL mailing list.

Yves Carlier `Yves.Carlier@rug.ac.be`
: `mysqlaccess`, a program to show the access rights for a user.

Rhys Jones `rhys@wales.com` (And GWE Technologies Limited)
: For one of the early JDBC drivers.

Dr Xiaokun Kelvin ZHU `X.Zhu@brad.ac.uk`
: Further development of one of the early JDBC drivers and other MySQL-related Java tools.

James Cooper `pixel@organic.com`
: For setting up a searchable mailing list archive at his site.

Rick Mehalick `Rick_Mehalick@i-o.com`
: For `xmysql`, a graphical X client for MySQL Server.

Doug Sisk `sisk@wix.com`
: For providing RPM packages of MySQL for Red Hat Linux.

Diemand Alexander V. `axeld@vial.ethz.ch`
: For providing RPM packages of MySQL for Red Hat Linux-Alpha.

Antoni Pamies Olive `toni@readysoft.es`
: For providing RPM versions of a lot of MySQL clients for Intel and SPARC.

Jay Bloodworth `jay@pathways.sde.state.sc.us`
: For providing RPM versions for MySQL Version 3.21.

David Sacerdote `davids@secnet.com`
: Ideas for secure checking of DNS hostnames.

Wei-Jou Chen `jou@nematic.ieo.nctu.edu.tw`
: Some support for Chinese(BIG5) characters.

Wei He `hewei@mail.ied.ac.cn`
: A lot of functionality for the Chinese(GBK) character set.

Jan Pazdziora `adelton@fi.muni.cz`
: Czech sorting order.

Zeev Suraski `bourbon@netvision.net.il`
: `FROM_UNIXTIME()` time formatting, `ENCRYPT()` functions, and `bison` advisor. Active mailing list member.

Luuk de Boer `luuk@wxs.nl`
: Ported (and extended) the benchmark suite to `DBI/DBD`. Have been of great help with `crash-me` and running benchmarks. Some new date functions. The `mysql_setpermissions` script.

Alexis Mikhailov `root@medinf.chuvashia.su`
: User-definable functions (UDFs); `CREATE FUNCTION` and `DROP FUNCTION`.

Andreas F. Bobak `bobak@relog.ch`
: The `AGGREGATE` extension to UDF functions.

Ross Wakelin `R.Wakelin@march.co.uk`
: Help to set up InstallShield for MySQL-Win32.

Jethro Wright III `jetman@li.net`
: The '`libmysql.dll`' library.

James Pereria `jpereira@iafrica.com`
: Mysqlmanager, a Win32 GUI tool for administrating MySQL Server.

Curt Sampson `cjs@portal.ca`
: Porting of MIT-pthreads to NetBSD/Alpha and NetBSD 1.3/i386.

Martin Ramsch `m.ramsch@computer.org`
: Examples in the MySQL Tutorial.

Steve Harvey
: For making `mysqlaccess` more secure.

Konark IA-64 Centre of Persistent Systems Private Limited
: `http://www.pspl.co.in/konark/`. Help with the Win64 port of the MySQL server.

Albert Chin-A-Young.
: Configure updates for Tru64, large file support and better TCP wrappers support.

John Birrell
: Emulation of `pthread_mutex()` for OS/2.

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

Jocelyn Fournier
: Excellent spotting and reporting innumerable bugs (especially in the MySQL 4.1 subquery code).

Marc Liyanage
: Maintaining the Mac OS X packages and providing invaluable feedback on how to create Mac OS X PKGs.

Robert Rutherford
: Providing invaluable information and feedback about the QNX port.

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

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

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

Daniel Koch `dkoch@amcity.com`
: Irix setup.

Luuk de Boer `luuk@wxs.nl`
: Benchmark questions.

Tim Sailer `tps@users.buoy.com`
: `DBD-mysql` questions.

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: SCO-related questions.

Richard Mehalick `RM186061@shellus.com`
: `xmysql`-related questions and basic installation questions.

Zeev Suraski `bourbon@netvision.net.il`
: Apache module configuration questions (log & auth), PHP-related questions, SQL syntax-related questions and other general questions.

Francesc Guasch `frankie@citel.upc.es`
: General questions.

Jonathan J Smith `jsmith@wtp.net`
: Questions pertaining to OS-specifics with Linux, SQL syntax, and other things that might need some work.

David Sklar `sklar@student.net`
: Using MySQL from PHP and Perl.

Alistair MacDonald `A.MacDonald@uel.ac.uk`
: Not yet specified, but is flexible and can handle Linux and maybe HP-UX. Will try to get user to use `mysqlbug`.

John Lyon `jlyon@imag.net`
: Questions about installing MySQL on Linux systems, using either '`.rpm`' files or compiling from source.

Lorvid Ltd. `lorvid@WOLFENET.com`
: Simple billing/license/support/copyright issues.

Patrick Sherrill `patrick@coconet.com`
: ODBC and VisualC++ interface questions.

Randy Harmon `rjharmon@uptimecomputers.com`
: `DBD`, Linux, some SQL syntax questions.

C.3 Documenters and translators

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

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

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

Michael J. Miller Jr. `mke@terrapin.turbolift.com`
: For the first MySQL manual. And a lot of spelling/language fixes for the FAQ (that turned into the MySQL manual a long time ago).

Yan Cailin
: First translator of the MySQL Reference Manual into simplified Chinese in early 2000 on which the Big5 and HK coded (`http://mysql.hitstar.com/`) versions were based. Personal home page at linuxdb.yeah.net (`http://linuxdb.yeah.net`).

Jay Flaherty `fty@mediapulse.com`
: Big parts of the Perl `DBI/DBD` section in the manual.

Paul Southworth `pauls@etext.org`, Ray Loyzaga `yar@cs.su.oz.au`
: Proof-reading of the Reference Manual.

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: French error messages.

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Peter Feher
: Hungarian error messages.

Roberto M. Serqueira
: Portuguese error messages.

Carsten H. Pedersen
: Danish error messages.

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

C.4 Libraries used by and included with MySQL

The following is a list of the creators of the libraries we have included with the MySQL server source to make it easy to compile and install MySQL. We are very thankfully to all individuals that have created these and it has made our life much easier.

Fred Fish
: For his excellent C debugging and trace library. Monty has made a number of smaller improvements to the library (speed and additional options).

Richard A. O'Keefe
: For his public domain string library.

Henry Spencer
: For his regex library, used in `WHERE column REGEXP regexp`.

Chris Provenzano
: Portable user level pthreads. From the copyright: This product includes software developed by Chris Provenzano, the University of California, Berkeley,

and contributors. We are currently using version 1_60_beta6 patched by Monty (see '`mit-pthreads/Changes-mysql`').

Jean-loup Gailly and Mark Adler
: For the zlib library (used on MySQL on windows).

Bjorn Benson
: For his safe_malloc (memory checker) package which is used in when you configure MySQL with `--debug`.

Free Software Foundation
: The `readline` library (used by the `mysql` command line client).

The NetBSD fondation
: The `libedit` package (optionally used by the `mysql` command line client).

C.5 Packages that support MySQL

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

We can't list every possible package here becasue the list would then be way to hard to maintain. For other packages, please refer to the software portal at `http://www.mysql.com/portal/software`.

Tim Bunce, Alligator Descartes
: For the `DBD` (Perl) interface.

Andreas Koenig `a.koenig@mind.de`
: For the Perl interface for MySQL Server.

Jochen Wiedmann `wiedmann@neckar-alb.de`
: For maintaining the Perl `DBD::mysql` module.

Eugene Chan `eugene@acenet.com.sg`
: For porting PHP for MySQL Server.

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

Giovanni Maruzzelli `maruzz@matrice.it`
: For porting iODBC (Unix ODBC).

Xavier Leroy `Xavier.Leroy@inria.fr`
: The author of LinuxThreads (used by the MySQL Server on Linux).

C.6 Tools that was used to create MySQL

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

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

Free Software Foundation & The XEmacs development team
: For a really great editor/environment used by almost everybody at MySQL AB.

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

Dorothea Lütkehaus and Andreas Zeller
: For `DDD` (The Data Display Debugger) which is an excellent graphical frontend to `gdb`).

C.7 Supporters to MySQL

While `MySQL AB` owns all copyrights in the `MySQL server` and the `MySQL manual`, we wish to recognise the following companies, which helped us finance the development of the `MySQL server`, such as by paying us for developing a new feature or giving us hardware for development of the `MySQL server`.

VA Linux / Andover.net
: Funded replication.

NuSphere
: Editing of the MySQL manual.

Stork Design studio
: The MySQL web site in use between 1998-2000.

Intel
: Contributed to development on Windows and Linux platforms.

Compaq
: Contributed to Development on Linux/Alpha.

SWSoft
: Development on the embedded `mysqld` version.

FutureQuest
: `--skip-show-database`

Appendix D MySQL Change History

This appendix lists the changes from version to version in the MySQL source code.

We are now working actively on MySQL 4.1 & 5.0 and will only provide critical bug fixes for MySQL 4.0 and MySQL 3.23. We update this section as we add new features, so that everybody can follow the development.

Our TODO section contains what further plans we have for 4.1 & 5.0. See Section 1.8 [TODO], page 49.

Note that we tend to update the manual at the same time we make changes to MySQL. If you find a version listed here that you can't find on the MySQL download page (`http://www.mysql.com/downloads/`), this means that the version has not yet been released!

The date mentioned with a release version is the date of the last BitKeeper ChangeSet that this particular release has been based on, not the date when the packages have been made available. The binaries are usually made available a few days after the date of the tagged ChangeSet - building and testing all packages takes some time.

D.1 Changes in release 5.0.0 (Development)

For the time being, version 5.0 is only available in source code. See Section 2.3.4 [Installing source tree], page 94.

The following changelog shows what has already been done in the 5.0 tree:

- Basic support for stored procedures (SQL-99 style).
- Added `SELECT INTO list_of_vars`, which can be of mixed, that is, global and local type.
- Deprecated the update log (no longer supported). It is fully replaced by the binary log.
- User variable names are now case insensitive: if you do `SET @a=10;` then `SELECT @A;` will now return `10`. Of course, the content of the variable is still case sensitive; only the name of this variable is case insensitive.

D.2 Changes in release 4.1.x (Alpha)

Version 4.1 of the MySQL server includes many enhancements and new features. Binaries for this version are available for download at `http://www.mysql.com/downloads/mysql-4.1.html`.

- Subqueries and derived tables (unnamed views). See Section 6.4.2 [Subqueries], page 537.
- `INSERT ... ON DUPLICATE KEY UPDATE ...` syntax. This allows you to `UPDATE` an existing row if the insert would cause a duplicate value in a `PRIMARY` or `UNIQUE` key. (`REPLACE` allows you to overwrite an existing row, which is something entirely different.) See Section 6.4.3 [INSERT], page 546.
- A newly designed `GROUP_CONCAT()` aggregate function. See Section 6.3.7 [Group by functions and modifiers], page 524.
- Extensive Unicode (UTF8) support.

- Character sets can be defined per column, table, and database.
- New key cache for MyISAM tables with a lot of tunable parameters. You can have multiple key caches, preload index into caches for batches...
- `BTREE` index on `HEAP` tables.
- Support for OpenGIS spatial types (geographical data). See Chapter 10 [Spatial extensions in MySQL], page 687.
- `SHOW WARNINGS` shows warnings for the last command. See Section 4.6.8.9 [SHOW WARNINGS], page 303.
- Faster binary protocol with prepared statements and parameter binding. See Section 11.1.4 [C API Prepared statements], page 765.
- Multi-line queries: You can now issue several queries at once and then read the results in one go. See Section 11.1.8 [C API multiple queries], page 792.
- Create Table: `CREATE [TEMPORARY] TABLE [IF NOT EXISTS] table2 LIKE table1`.
- Server based `HELP command` that can be used in the `mysql` command line client (and other clients) to get help for SQL commands.

For a full list of changes, please refer to the changelog sections for each individual 4.1.x release.

D.2.1 Changes in release 4.1.1 (to be released soon)

Functionality added or changed:

- Added client command `mysql_set_server_option()` to allow one to set/reset the multiple statement handling in the server.
- Renamed connect option flag `CLIENT_MULTI_QUERIES` to `CLIENT_MULTI_STATEMENTS`. (Old option will work for a while).
- Require `DEFAULT` before table and database default character set. This enables us to use `ALTER TABLE table_name ... CHARACTER SET=...` to change the character set for all `CHAR/VARCHAR/TEXT` columns in a table.
- `MATCH ... AGAINST( ... WITH QUERY EXPANSION)` and command-line option `ft_query_expansion_limit` were added.
- Unused `ft_max_word_len_for_sort` command-line option was removed.
- Full-text search now support multi-byte character sets, and Unicode (UTF-8, but not UCS-2 yet).
- Phrase search in `MATCH ... AGAINST ( ... IN BOOLEAN MODE)` does not match partial words anymore.
- Added new aggregate function `BIT_XOR()` for bitwise XOR operations.
- Replication over SSL now works.
- The `START SLAVE` statement now supports an `UNTIL` clause for specifying that the slave SQL thread should be started but run only until it reaches a given position in the master's binlogs or in the slave's relay logs.
- Create warnings also for simple (one row) `INSERT`. Before you had to set `SQL_WARNING=1` for this to generate warnings.

- Added `delimiter` (`\d`) command to the `mysql` command-line client for changing the statement delimiter (terminator). The default delimiter is semicolon.
- `CHAR`, `VARCHAR`, and `TEXT` columns now have lengths measured in characters rather than bytes. Similarly, index values on such columns are measured in characters, not bytes. The character size depends on the column's character set. This means, for example, that a `CHAR(n)` column for a multi-byte character set will take more storage than before.
- The `DATABASE()` function now returns `NULL` rather than the empty string if there is no database selected.
- Added option `--sql-mode=NO_AUTO_VALUE_ON_ZERO` to suppress usual behaviour of generating the next sequence number when zero is stored in an `AUTO_INCREMENT` column. With this mode enabled, only `NULL` generates a sequence number.
- **Warning: Incompatible change!** Client authentication now is based on 41-byte passwords in the `user` table, not 45-byte passwords as in 4.1.0. Any 45-byte passwords created for 4.1.0 must be reset after running the `mysql_fix_privilege_tables` script.
- **Warning: Incompatible change!** Renamed `mysql_prepare_result()` to `mysql_get_metadata()` as the old name was confusing.
- Added command `DROP USER 'username'@'hostname'`.
- The interface to aggregated UDF functions has changed a bit. One must now declare a `clear` function for each aggregate function.
- `CONCAT_WS()` no longer skips empty strings.
- Added new functions `UTC_DATE()`, `UTC_TIME()`, and `UTC_TIMESTAMP()`.
- Added new functions `DATE()`, `TIME()`, `TIMESTAMP()`, `WEEKOFYEAR()`, `MICROSECOND()`, `ADDTIME()`, `SUBTIME()`, `DATEDIFF()`, `TIMEDIFF()`, `MAKEDATE()`, `MAKETIME()`, and `TIMEDIFF()`.
- Added new syntax for `ADDDATE()` and `SUBDATE()`. They now allow a numeric second argument representing the number of days to be added to or subtracted from the first date argument.
- Added new `type` values `DAY_MICROSECOND`, `HOUR_MICROSECOND`, `MINUTE_MICROSECOND`, `SECOND_MICROSECOND`, and `MICROSECOND` for `DATE_ADD()`, `DATE_SUB()`, and `EXTRACT()`.
- Added new `%f` microseconds format specifier for `DATE_FORMAT()` and `TIME_FORMAT()`.
- Enabled that all queries in which at least one `SELECT` does not use indices properly get into slow query log when long log format is used.
- It is now possible to create `MERGE` tables from `MyISAM` tables in different databases. Formerly, all the `MyISAM` tables had to be in the same database, and the `MERGE` table had to be created in that database as well.
- Added new functions `COMPRESS()`, `UNCOMPRESS()`, and `UNCOMPRESSED_LENGTH()`.
- When doing `SET sql_mode='mode'` for a complex mode (like `ANSI`), we now update the `sql_mode` variable to include all the individual options implied by the complex mode.
- Added the OLAP (On-Line Analytical Processing) function `ROLLUP`, which provides summary rows for each `GROUP BY` level.
- Added `SQLSTATE` codes for all server errors.

- Added client API functions `mysql_sqlstate()` and `mysql_stmt_sqlstate()` that return the SQLSTATE error code for the last error.
- `TIME` columns with hours > 24 (days) were returned incorrectly to the client.
- `ANALYZE`, `OPTIMIZE`, `REPAIR`, `FLUSH` (and its equivalents invoked from `mysqladmin`) commands are now stored in the binary log (hence are replicated to the slave), except `FLUSH LOGS`, `FLUSH MASTER`, `FLUSH SLAVE`, `FLUSH TABLES WITH READ LOCK`, and unless the optional `NO_WRITE_TO_BINLOG` keyword (or its alias `LOCAL`) was used. For a syntax example, see Section 4.6.4 [`FLUSH`], page 282.
- New global variable `RELAY_LOG_PURGE` to enable or disable automatic relay log purging.
- `LOAD DATA` now produces warnings that can be fetched with `SHOW WARNINGS`.
- Added support for syntax `CREATE TABLE table2 (LIKE table1)` that creates an empty table `table2` with a definition that is exactly the same as `table1`, including any indexes.
- `CREATE TABLE table_name (...) TYPE=storage_engine` now generates a warning if the named storage engine is not available. The table is still created as a `MyISAM` table, as before.
- Most subqueries are now much faster than before.
- Added alias `PURGE BINARY LOGS` for `PURGE MASTER LOGS`.
- `PURGE LOGS` syntax is disabled (it had been added in version 4.1.0). It is now `PURGE MASTER LOGS` or `PURGE BINARY LOGS`.
- Added alias `SHOW BDB LOGS` for `SHOW LOGS`.
- Added alias `SHOW MASTER LOGS` (which had been deleted in version 4.1.0) to `SHOW BINARY LOGS`.
- Added a column `Slave_IO_State` (the state of the slave I/O thread) and a column `Seconds_behind_master` (the number of seconds by which the slave is late compared to the master) to the output of `SHOW SLAVE STATUS`.

Bugs fixed:

- Fixed a bug in privilege handling that made connections from certain IP addresses to get wrong database-level privileges. (More precisely: The connection got the database privileges of the previous successful authentication from one of those IP addresses, even if the IP address user name and database name were different). (Bug #1636)
- Error handling functions were not called properly when one got an error from `[CREATE | REPLACE| INSERT] ... SELECT`.
- `HASH`, `BTREE`, `RTREE`, `ERRORS` and `WARNINGS` are not reserved words anymore. (Bug #724)
- Fix for bug in `ROLLUP` when all tables were `const` tables. (Bug #714)
- `--lower-case-table-names=1` now also makes aliases case insensitive. (Bug #534)
- Fixed a bug in `UNION` which prohibited that `NULL` values are inserted in result set where first `SELECT` contains `NOT NULL` columns
- Fixed name resolution of fields of reduced subqueries in unions. (Bug #745)
- Fixed memory overrun in subqueries in select list with `WHERE` clause bigger than outer query `WHERE` clause. (Bug #726)

- Fixed a bug that caused `MyISAM` tables with `FULLTEXT` indexes created in 4.0.x to be unreadable in 4.1.x.
- Fixed a data loss bug in `REPAIR TABLE ... USE_FRM` when used with tables that contained `TIMESTAMP` fields and were created in 4.0.x.
- Fixed reduced subquery processing in `ORDER BY/GROUP BY` clauses. (Bug #442)
- Fixed name resolving of outer fields of subquery in `INSERT/REPLACE` statements. (Bug #446)
- Fixed bug in marking fields of reduced subqueries. (Bug #679)
- Fixed a bug that made `CREATE FULLTEXT INDEX` syntax illegal.
- Fixed a crash when a `SELECT` that required a temporary table (marked by `Using temporary` in `EXPLAIN` output) was used as a derived table in `EXPLAIN` command. (Bug #251)
- Fixed a rare table corruption bug in `DELETE` from a big table with a **new** (created by MySQL-4.1) fulltext index.
- `LAST_INSERT_ID()` now returns 0 if the last `INSERT` statement didn't insert any rows.
- Fixed missing last character in function output. (Bug #447)
- Fixed a rare replication bug when a transaction spanned two or more relay logs, and the slave was stopped while executing the part of the transaction that was in the second or later relay log. Then replication would resume at the beginning of the second or later relay log, which was wrong. (It should resume at `BEGIN`, in the first relay log.) (Bug #53)
- `CONNECTION_ID()` is now properly replicated. (Bug #177)
- The new `PASSWORD()` function in 4.1 is now properly replicated. (Bug #344)
- Fixed bug with doubly freed memory.
- Fixed crashing bug in `UNION` operations that involved temporary tables.
- Fixed a crashing bug in `DERIVED TABLES` when `EXPLAIN` is used on a `DERIVED TABLES` with a join.
- Fixed a crashing bug in `DELETE` with `ORDER BY` and `LIMIT` caused by an uninitialized array of reference pointers.
- Fixed a bug in `USER()` function caused by an error in the size of the allocated string.
- Fixed a crashing bug when attempting to create a table with a spatial (GIS) column type with a storage engine that does not support spatial types.
- Fixed a crashing bug in `UNION` caused by the empty select list and a non-existent field being used in some of the sub-selects.
- Fixed a replication bug when the master is 3.23 and the slave 4.0: The slave lost the replicated temporary tables if `FLUSH LOGS` was issued on the master. (Bug #254)
- Fixed a security bug: A server compiled without SSL support still allowed connections by users that had the `REQUIRE SSL` option specified for their accounts.
- When an undefined user variable was used in a updating query on the master (like `INSERT INTO t VALUES(@a)` where `@a` had never been set by this connection before), then the slave could replicate the query wrongly if a previous transaction on the master used a user variable of the same name. (Bug #1331)

D.2.2 Changes in release 4.1.0 (03 Apr 2003: Alpha)

Functionality added or changed:

- New more secure client authentication based on 45-byte passwords in the `user` table.
- New `CRC32()` function to compute cyclic redundancy check value.
- On Windows, we are now using shared memory to communicate between server and client when they are running on the same machine and you are connecting to `localhost`.
- `REPAIR` of `MyISAM` tables now uses less temporary disk space when sorting char columns.
- `DATE/DATETIME` checking is now a bit stricter to support the ability to automatically distinguish between date, datetime, and time with microseconds. For example, dates of type `YYYYMMDD HHMMDD` are no longer supported; you must either have separators between each `DATE/TIME` part or not at all.
- Server side help for all MySQL functions. One can now type `help week` in the `mysql` client and get help for the `week()` function.
- Added new C API client function: `mysql_get_server_version()`.
- Fixed bug in `libmysqlclient` that fetched field defaults.
- Fixed bug in '`mysql.cc`' client when skipping comments
- Added `record_in_range()` method to `MERGE` tables to be able to choose the right index when there are many to choose from.
- Replication now works with `RAND()` and user variables `@var`.
- Allow one to change mode for `ANSI_QUOTES` on the fly.
- `EXPLAIN SELECT` now can be killed. See Section 4.6.7 [KILL], page 284.
- `REPAIR TABLE` now can be killed. See Section 4.6.7 [KILL], page 284.
- Allow one to specify empty key lists for `USE|IGNORE|FORCE INDEX`.
- `DROP TEMPORARY TABLE` now only drops temporary tables and doesn't end transactions.
- Added a support for `UNION` in derived tables.
- `TIMESTAMP` is now returned as a string of type `'YYYY-MM-DD HH:MM:SS'` and different timestamp lengths are not supported.

  This change was necessary for SQL standards compliance. In a future version, a further change will be made (backward compatible with this change), allowing the timestamp length to indicate the desired number of digits of fractions of a second.
- New faster client/server protocol which supports prepared statements, bound parameters, and bound result columns, binary transfer of data, warnings.
- Added database and real table name (in case of alias) to the `MYSQL_FIELD` structure.
- Multi-line queries: You can now issue several queries at once and then read the results in one go.
- In `CREATE TABLE foo (a INT not null primary key)` the `PRIMARY` word is now optional.
- In `CREATE TABLE` the attribute `SERIAL` is now an alias for `BIGINT NOT NULL AUTO_INCREMENT UNIQUE`.

- `SELECT ... FROM DUAL` is an alias for `SELECT ...`. (To be compatible with some other databases).
- If one creates a too long `CHAR/VARCHAR` it's now automatically changed to `TEXT` or `BLOB`; One will get a warning in this case.
- One can specify the different `BLOB/TEXT` types with the syntax `BLOB(length)` and `TEXT(length)`. MySQL will automatically change it to one of the internal `BLOB/TEXT` types.
- `CHAR BYTE` is an alias for `CHAR BINARY`.
- `VARCHARACTER` is an alias for `VARCHAR`.
- New operators `integer MOD integer` and `integer DIV integer`.
- `SERIAL DEFAULT VALUE` added as an alias for `AUTO_INCREMENT`.
- `TRUE` and `FALSE` added as alias for 1 and 0, respectively.
- Aliases are now forced in derived tables, as per SQL-99.
- Fixed `SELECT .. LIMIT 0` to return proper row count for `SQL_CALC_FOUND_ROWS`.
- One can specify many temporary directories to be used in a round-robin fashion with: `--tmpdir=dirname1:dirname2:dirname3`.
- Subqueries: `SELECT * from t1 where t1.a=(SELECT t2.b FROM t2)`.
- Derived tables:

```
SELECT a.col1, b.col2
       FROM (SELECT MAX(col1) AS col1 FROM root_table) a,
       other_table b
       WHERE a.col1=b.col1;
```

- Character sets to be defined per column, table and database.
- Unicode (UTF8) support.
- New `CONVERT(... USING ...)` syntax for converting string values between character sets.
- `BTREE` index on `HEAP` tables.
- Faster embedded server (new internal communication protocol).
- One can add a comment per column in `CREATE TABLE`.
- `SHOW FULL COLUMNS FROM table_name` shows column comments.
- `ALTER DATABASE`.
- Support for GIS (Geometrical data). See Chapter 10 [Spatial extensions in MySQL], page 687.
- `SHOW [COUNT(*)] WARNINGS` shows warnings from the last command.
- One can specify a column type for a colum in `CREATE TABLE ... SELECT` by defining the column in the `CREATE` part.

```
CREATE TABLE foo (a tinyint not null) SELECT b+1 AS 'a' FROM bar;
```

- `expr SOUNDS LIKE expr` same as `SOUNDEX(expr)=SOUNDEX(expr)`.
- `VARIANCE(expr)` returns the variance of `expr`
- One can create a table from the existing table using `CREATE [TEMPORARY] TABLE [IF NOT EXISTS] table (LIKE table)`. The table can be either normal or temporary.

- New options `--reconnect` and `disable-reconnect` for the `mysql` client, to reconnect automatically or not if the connection is lost.
- `START SLAVE` (`STOP SLAVE`) no longer returns an error if the slave is already started (stopped); it returns a warning instead.
- `SLAVE START` and `SLAVE STOP` are no longer accepted by the query parser; use `START SLAVE` and `STOP SLAVE` instead.

D.3 Changes in release 4.0.x (Production)

Version 4.0 of the MySQL server includes many enhancements and new features:

- The `InnoDB` table type is now included in the standard binaries, adding transactions, row-level locking, and foreign keys. See Section 7.5 [InnoDB], page 606.
- A query cache, offering vastly increased performance for many applications. By caching complete result sets, later identical queries can return instantly. See Section 6.9 [Query Cache], page 589.
- Improved full-text indexing with boolean mode, truncation, and phrase searching. See Section 6.8 [Fulltext Search], page 584.
- Enhanced `MERGE` tables, now supporting `INSERT` statements and `AUTO_INCREMENT`. See Section 7.2 [MERGE], page 601.
- `UNION` syntax in `SELECT`. See Section 6.4.1.2 [UNION], page 537.
- Multi-table `DELETE` statements. See Section 6.4.5 [DELETE], page 552.
- `libmysqld`, the embedded server library. See Section 11.1.15 [libmysqld], page 800.
- Additional `GRANT` privilege options for even tighter control and security. See Section 4.4.1 [GRANT], page 239.
- Management of user resources in the `GRANT` system, particularly useful for ISPs and other hosting providers. See Section 4.4.7 [User resources], page 249.
- Dynamic server variables, allowing configuration changes without having to take down the server. See Section 5.5.6 [SET OPTION], page 432.
- Improved replication code and features. See Section 4.11 [Replication], page 355.
- Numerous new functions and options.
- Changes to existing code for enhanced performance and reliability.

For a full list of changes, please refer to the changelog sections for each individual 4.0.x release.

D.3.1 Changes in release 4.0.17 (not released yet)

Functionality added or changed:

- Changed default service name for mysqld on windows from MySql to MySQL. (Should not affect usage as service names are case insensitive).
- When you install mysqld as service on Windows systems, mysqld will read the configure options on the option files tagged with the service name. (Except when service name is 'MySQL').

Bugs fixed:

- Fixed optimizer bug, introduced in 4.0.16, when REF access plan was preferred to more efficient RANGE on another column.
- Fixed problem when installing MySQL as a service with `mysqld --install mysql --defaults-file=path-to-file`.
- Fixed an incorrect result from a query that uses only const tables (e.g. one-row tables) and non-constant expression (e.g. `RAND()`). (Bug #1271)
- Fixed bug when the optimiser did not take `SQL_CALC_FOUND_ROWS` into account if `LIMIT` clause was present. (Bug #1274)
- `mysqlbinlog` now asks for a password at console when the `-p/--password` option is used with no argument. This is how the other clients (`mysqladmin`, `mysqldump`..) already behave. Note that one now has to use `mysqlbinlog -p<my_password>`; `mysqlbinlog -p <my_password>` will not work anymore (in other words, put no space after `-p`). (Bug #1595)
- Bug accidentally introduced in 4.0.16: in 4.0.16 the slave SQL thread deleted its replicated temporary tables when `STOP SLAVE` was issued.
- In a "chain" replication setup `A->B->C`, if 2 sessions on A updated temporary tables of the same name at the same time, the binlog of `B` became wrong and hence `C` was confused. (Bug #1686)
- In a "chain" replication setup `A->B->C`, if `STOP SLAVE` was issued on `B` while it was replicating a temporary table from `A`, then when `START SLAVE` was issued on `B`, the binlog of `B` became wrong and hence `C` was confused. (Bug #1240)

D.3.2 Changes in release 4.0.16 (17 Oct 2003)

Functionality added or changed:

- Write memory allocation information to error log when doing `mysqladmin debug`. This only works on system that support the `mallinfo()` call (like newer Linux systems).
- Added the following new server variables to allow more precise memory allocation: `range_alloc_block_size`, `query_alloc_block_size`, `query_prealloc_size`, `transaction_alloc_block_size`, and `transaction_prealloc_size`.
- `mysqlbinlog` now reads options files. To make this work one must now specify `--read-from-remote-server` when reading binary logs from a MySQL server. (Note that using a remote server is deprecated and may disappear in future `mysqlbinlog` versions).
- Block `SIGPIPE` also for non-threaded programs. The blocking is moved from `mysql_init()` to `mysql_server_init()`, which is automatically called on the first call to `mysql_init()`.
- Added `--libs_r` and `--include` options to `mysql_config`.
- New `‘>` prompt for `mysql`. This prompt is similar to the `’>` and `">` prompts, but indicates that an identifier quoted with backticks was begun on an earlier line and the closing backtick has not yet been seen.
- Updated `mysql_install_db` to be able to use the local machine's IP address instead of the host name when building the initial grant tables if `skip-name-resolve` has been

specified in `my.cnf`. Using this option can be helpful on FreeBSD to avoid thread-safety problems with the FreeBSD resolver libraries. (Thanks to Jeremy Zawodny for the patch)

- A documentation change: added a note that when backing up a slave, one needs to backup the '`master.info`' and '`relay-log.info`' files, and the '`SQL-LOAD*`' files (which are in the '`slave-load-tmpdir`' directory, which defaults to '`tmpdir`' if unset). All these files will be needed when the slave resumes replication after you restore the slave's data.

Bugs fixed:

- Fixed a spurious error `ERROR 14: Can't change size of file (Errcode: 2)` on Windows in `DELETE FROM myisamtable` without `WHERE` clause or `TRUNCATE TABLE myisamtable`. (Bug #1397)
- Fixed a bug that resulted in `thr_alarm queue is full` warnings after increasing the variable `max_connections` (with `SET GLOBAL`). (Bug #1435)
- Made `LOCK TABLES` to work when `Lock_tables_priv` is granted on the database level and `Select_priv` is granted on the table level.
- Fixed crash of `FLUSH QUERY CACHE` on queries which use same table several times (Bug #988).
- Fixed core dump bug when setting an enum system variable (like `SQL_WARNINGS`) to `NULL`.
- Extended default timeout in clients on windows from 30 seconds to 1 year. (The timeout that was added in MySQL 4.0.15 was way too short).
- More "out of memory" checking in range optimiser.
- Fixed and documented problem when setting and using a user variable in the same `SELECT` statement. (Bug #1194).
- Fixed bug in overrun check for blobs with compressed tables (bug introduced in 4.0.14). This caused MySQL to regard some correct tables with blobs to be corrupted. (Bug #770, Bug #1304, and maybe Bug #1295)
- `SHOW GRANTS` showed `USAGE` instead of real privileges for column grants when no table grants was given.
- When it wanted to copy a database from the master, `LOAD DATA FROM MASTER` dropped the corresponding database on the slave, thus dropping tables which may not have a counterpart on the master, or tables which may be excluded from replication using `replicate-*-table` rules. Now `LOAD DATA FROM MASTER` does not drop the database anymore, it drops only the tables which have a counterpart on the master and which match the `replicate-*-table` rules. `replicate-*-db` rules can still be used to include/exclude a database as a whole from `LOAD DATA FROM MASTER`. A database will also be included/excluded as a whole if there are some rules like `replicate-wild-do-table=db1.%` or `replicate-wild-ignore-table=db1.%`, like it's already the case for `CREATE DATABASE` and `DROP DATABASE` in replication. (Bug #1248)
- `mysqlbinlog` crashed (segmentation fault) when used with the `-h, --host` option. (Bug #1258)
- `mysqlbinlog` crashed (segmentation fault) when used on binlog containing only final events for `LOAD DATA`. (Bug #1340)

- Fixed compilation problem when compiling with OpenSSL 0.9.7 with disabled old DES support (If `OPENSSL_DISABLE_OLD_DES_SUPPORT` option was enabled).
- Slave no longer can delete temporary files for `LOAD DATA` ('`SQL_LOAD-*`') belonging to other instances if these instances use the same temporary directory. (Bug #1357)
- If `LOAD DATA INFILE` failed for a small file, the master forgot to write a marker (a `Delete_file` event) in its binary log, so the slave could not delete 2 files ('`SQL_LOAD*.info`' and '`SQL_LOAD*.data`' from its `tmpdir`. (Bug #1391)
- On Windows, the slave forgot to delete a `SQL_LOAD*.info` file from '`tmpdir`' after successfully replicating a `LOAD DATA INFILE` command. (Bug #1392)
- When a connection terminates, MySQL writes `DROP TEMPORARY TABLE` statements to the binary log for all temporary tables which the connection had not explicitely dropped. MySQL forgot to backquote the database and table names in the statement. (Bug #1345)
- On some 64-bit machines (some HP-UX and Solaris machines), a slave installed with the 64-bit MySQL binary could not connect to its master (it connected to itself instead). (Bug #1256, #1381)
- Code introduced in MySQL 4.0.15 for the slave to detect that the master had died while writing a transaction to its binlog, reported an error in a legal situation (when the slave I/O thread was stopped while copying a transaction to the relay log, the slave SQL thread would later pretend that it found an unfinished transaction). (Bug #1475)

D.3.3 Changes in release 4.0.15 (03 Sep 2003)

Functionality added or changed:

- `mysqldump` now correctly quotes all identifiers when communicating with the server. This assures that during the dump process, `mysqldump` will never send queries to the server that result in a syntax error. This problem is **not** related to the `mysqldump` program's output, which was not changed. (Bug #1148)
- Change result set metadata information so that `MIN()` and `MAX()` report that they can return `NULL` (this is true because an empty set will return `NULL`). (Bug #324)
- Produce an error message on Windows if a second `mysqld` server is started on the same TCP/IP port as an already running `mysqld` server.
- The `mysqld` server variables `wait_timeout`, `net_read_timeout` and `net_write_timeout` now work on Windows.
- Added option `--sql-mode=NO_DIR_IN_CREATE` to make it possible for slaves to ignore `INDEX DIRECTORY` and `DATA DIRECTORY` options given to `CREATE TABLE`. When this is mode is on, `SHOW CREATE TABLE` will not show the given directories.
- `SHOW CREATE TABLE` now shows the `INDEX DIRECTORY` and `DATA DIRECTORY` options, if they were specified when the table was created.
- The `open_files_limit` server variable now shows the real open files limit.
- `MATCH ... AGAINST()` in natural language mode now treats words that are present in more than 2,000,000 rows as stopwords.

- The Mac OS X installation disk images now include an additional '`MySQLStartupItem.pkg`' package that enables the automatic startup of MySQL on system bootup. See Section 2.1.3 [Mac OS X installation], page 66.
- Most of the documentation included in the binary tarball distributions (`.tar.gz`) has been moved into a subdirectory `docs`. See Section 2.2.5 [Installation layouts], page 77.
- The manual is now included as an additional `info` file in the binary distributions. (Bug #1019)
- The binary distributions now include the embedded server library (`libmysqld.a`) by default. Due to a linking problem with non-gcc compilers, it was not included in all packages of the initial 4.0.15 release. The affected packages were rebuilt and released as 4.0.15a. See Section 1.5.1.2 [Nutshell Embedded MySQL], page 22.
- MySQL can now use range optimisation for `BETWEEN` with non-constant limits. (Bug #991)
- Replication error messages now include the default database, so that users can check which database the failing query was run for.
- A documentation change: Added a paragraph about how the `binlog-do-db` and `binlog-ignore-db` options are tested against the database on the master (see Section 4.10.4 [Binary log], page 351), and a paragraph about how `replicate-do-db`, `replicate-do-table` and analogous options are tested against the database and tables on the slave (see Section 4.11.6 [Replication Options], page 369).
- Now the slave does not replicate `SET PASSWORD` if it is configured to exclude the `mysql` database from replication (using for example `replicate-wild-ignore-table=mysql.%`). This was already the case for `GRANT` and `REVOKE` since version 4.0.13 (though there was Bug #980 in 4.0.13 & 4.0.14, which has been fixed in 4.0.15).
- Rewrote the information shown in the `State` column of `SHOW PROCESSLIST` for replication threads and for `MASTER_POS_WAIT()` and added the most common states for these threads to the documentation, see Section 4.11.3 [Replication Implementation Details], page 357.
- Added a test in replication to detect the case where the master died in the middle of writing a transaction to the binlog; such unfinished transactions now trigger an error message on the slave.
- A `GRANT` command that creates an anonymous user (that is, an account with an empty username) no longer requires `FLUSH PRIVILEGES` for the account to be recognized by the server. (Bug #473)
- `CHANGE MASTER` now flushes '`relay-log.info`'. Previously this was deferred to the next run of `START SLAVE`, so if `mysqld` was shutdown on the slave after `CHANGE MASTER` without having run `START SLAVE`, the relay log's name and position were lost. At restart they were reloaded from '`relay-log.info`', thus reverting to their old (incorrect) values from before `CHANGE MASTER` and leading to error messages (as the old relay log did not exist any more) and the slave threads refusing to start. (Bug #858)

Bugs fixed:

- Fixed buffer overflow in password handling which could potentially be exploited by MySQL users with `ALTER` privilege on the `mysql.user` table to execute random code

or to gain shell access with the UID of the mysqld process (thanks to Jedi/Sector One for spotting and reporting this bug).

- Fixed server crash on `FORCE INDEX` in a query that contained "Range checked for each record" in the `EXPLAIN` output. (Bug #1172)
- Fixed table/column grant handling - proper sort order (from most specific to less specific, see Section 4.3.10 [Request access], page 228) was not honored. (Bug #928)
- Fixed rare bug in MYISAM introduced in 4.0.3 where the index file header was not updated directly after an `UPDATE` of split dynamic rows. The symptom was that the table had a corrupted delete-link if mysqld was shut down or the table was checked directly after the update.
- Fixed `Can't unlock file` error when running `myisamchk --sort-index` on Windows. (Bug #1119)
- Fixed possible deadlock when changing `key_buffer_size` while the key cache was actively used. (Bug #1088)
- Fixed overflow bug in `MyISAM` and `ISAM` when a row is updated in a table with a large number of columns and at least one `BLOB/TEXT` column.
- Fixed incorrect result when doing `UNION` and `LIMIT #,#` when one didn't use braces around the `SELECT` parts.
- Fixed incorrect result when doing `UNION` and `ORDER BY .. LIMIT #` when one didn't use braces around the `SELECT` parts.
- Fixed problem with `SELECT SQL_CALC_FOUND_ROWS ... UNION ALL ... LIMIT #` where `FOUND_ROWS()` returned incorrect number of rows.
- Fixed unlikely stack bug when having a BIG expression of type `1+1-1+1-1...` in certain combinations. (Bug #871)
- Fixed the bug that sometimes prevented a table with a `FULLTEXT` index from being marked as "analyzed".
- Fixed MySQL so that the field length (in C API) for the second column in `SHOW CREATE TABLE` is always larger than the data length. The only known application that was affected by the old behaviour was Borland dbExpress, which truncated the output from the command. (Bug #1064)
- Fixed crash in comparisons of strings using the `tis620` character set. (Bug #1116)
- Fixed `ISAM` bug in `MAX()` optimisation.
- `myisamchk --sort-records=N` no longer marks table as crashed if sorting failed because of an inappropriate key. (Bug #892)
- Fixed a minor bug in `MyISAM` compressed table handling that sometimes made it impossible to repair compressed table in "Repair by sort" mode. "Repair with keycache" (`myisamchk --safe-recover`) worked, though. (Bug #1015)
- Fixed bug in propagating the version number to the manual included in the distribution files. (Bug #1020)
- Fixed key sorting problem (a `PRIMARY` key declared for a column that is not explicitly marked `NOT NULL` was sorted after a `UNIQUE` key for a `NOT NULL` column).
- Fixed the result of `INTERVAL` when applied to a `DATE` value. (Bug #792)
- Fixed compiling of the embedded server library in the RPM spec file. (Bug #959)

- Added some missing files to the RPM spec file and fixed some RPM building errors that occured on Red Hat Linux 9. (Bug #998)
- Fixed incorrect `XOR` evaluation in `WHERE` clause. (Bug #992)
- Fixed bug with processing in query cache merged tables constructed from more then 255 tables. (Bug #930)
- Fixed incorrect results from outer join query (e.g. `LEFT JOIN`) when `ON` condition is always false, and range search in used. (Bug #926)
- Fixed a bug causing incorrect results from `MATCH ... AGAINST()` in some joins. (Bug #942)
- `MERGE` tables do not ignore "Using index" (from `EXPLAIN` output) anymore.
- Fixed a bug that prevented an empty table from being marked as "analyzed". (Bug #937)
- Fixed `myisamchk --sort-records` crash when used on compressed table.
- Fixed slow (as compared to 3.23) `ALTER TABLE` and related commands such as `CREATE INDEX`. (Bug #712)
- Fixed segmentation fault resulting from `LOAD DATA FROM MASTER` when the master was running without the `--log-bin` option. (Bug #934)
- Fixed a security bug: A server compiled without SSL support still allowed connections by users that had the `REQUIRE SSL` option specified for their accounts.
- Fixed a random bug: Sometimes the slave would replicate `GRANT` or `REVOKE` queries even if it was configured to exclude the `mysql` database from replication (for example, using `replicate-wild-ignore-table=mysql.%`). (Bug #980)
- The `Last_errno` and `Last_error` fields in the output of `SHOW SLAVE STATUS` are now cleared by `CHANGE MASTER` and when the slave SQL thread starts. (Bug #986)
- A documentation mistake: It said that `RESET SLAVE` does not change connection information (master host, port, user, and password), whereas it does. The statement resets these to the startup options (`master-host` etc) if there were some. (Bug #985)
- `SHOW SLAVE STATUS` now shows correct information (master host, port, user, and password) after `RESET SLAVE` (that is, it shows the new values, which are copied from the startup options if there were some). (Bug #985)
- Disabled propagation of the original master's log position for events because this caused unexpected values for `Exec_master_log_pos` and problems with `MASTER_POS_WAIT()` in A->B->C replication setup. (Bug #1086)
- Fixed a segfault in `mysqlbinlog` when `--position=x` was used with `x` being between a `Create_file` event and its fellow `Append_block`, `Exec_load` or `Delete_file` events. (Bug #1091)
- `mysqlbinlog` printed superfluous warnings when using `--database`, which caused syntax errors when piped to `mysql`. (Bug #1092)
- Made `mysqlbinlog --database` filter `LOAD DATA INFILE` too (previously, it filtered all queries except `LOAD DATA INFILE`). (Bug #1093)
- `mysqlbinlog` in some cases forgot to put a leading `'#'` in front of the original `LOAD DATA INFILE` (this command is displayed only for information, not to be run; it is later

reworked to `LOAD DATA LOCAL` with a different filename, for execution by `mysql`). (Bug #1096)

- `binlog-do-db` and `binlog-ignore-db` incorrectly filtered `LOAD DATA INFILE` (it was half-written to the binary log). This resulted in a corrupted binary log, which could cause the slave to stop with an error. (Bug #1100)
- When, in a transaction, a transactional table (such as an `InnoDB` table) was updated, and later in the same transaction a non-transactional table (such as a `MyISAM` table) was updated using the updated content of the transactional table (with `INSERT ... SELECT` for example), the queries were written to the binary log in an incorrect order. (Bug #873)
- When, in a transaction, `INSERT ... SELECT` updated a non-transactional table, and `ROLLBACK` was issued, no error was returned to the client. Now the client is warned that some changes could not be rolled back, as this was already the case for normal `INSERT`. (Bug #1113)
- Fixed a potential bug: When `STOP SLAVE` was run while the slave SQL thread was in the middle of a transaction, and then `CHANGE MASTER` was used to point the slave to some non-transactional statement, the slave SQL thread could get confused (because it would still think, from the past, that it was in a transaction).

D.3.4 Changes in release 4.0.14 (18 Jul 2003)

Functionality added or changed:

- `InnoDB` now supports indexing a prefix of a column. This means, in particular, that `BLOB` and `TEXT` columns can be indexed in `InnoDB` tables, which was not possible before.
- A documentation change: Function `INTERVAL(NULL, ...)` returns `-1`.
- Enabled `INSERT` from `SELECT` when the table into which the records are inserted is also a table listed in the `SELECT`.
- Allow `CREATE TABLE` and `INSERT` from any `UNION`.
- The `SQL_CALC_FOUND_ROWS` option now always returns the total number of rows for any `UNION`.
- Removed `--table` option from `mysqlbinlog` to avoid repeating `mysqldump` functionality.
- Changed optimiser slightly to prefer index lookups over full table scans in some boundary cases.
- Added thread-specific `max_seeks_for_key` variable that can be used to force the optimiser to use keys instead of table scans even if the cardinality of the index is low.
- Added optimisation that converts `LEFT JOIN` to normal join in some cases.
- A documentation change: added a paragraph about failover in replication (how to use a surviving slave as the new master, how to resume to the original setup). See Section 4.11.9 [Replication FAQ], page 386.
- A documentation change: added warning notes about safe use of the `CHANGE MASTER` command. See Section 4.11.8.1 [CHANGE MASTER TO], page 378.
- MySQL now issues a warning (not an error, as in 4.0.13) when it opens a table that was created with MySQL 4.1.

- Added `--nice` option to `mysqld_safe` to allow setting the niceness of the `mysqld` process. (Thanks to Christian Hammers for providing the initial patch.) (Bug #627)
- Added `--read-only` option to cause `mysqld` to allow no updates except from slave threads or from users with the `SUPER` privilege. (Original patch from Markus Benning).
- `SHOW BINLOG EVENTS FROM x` where `x` is less than 4 now silently converts `x` to 4 instead of printing an error. The same change was done for `CHANGE MASTER TO MASTER_LOG_POS=x` and `CHANGE MASTER TO RELAY_LOG_POS=x`.
- `mysqld` now only adds an interrupt handler for the `SIGINT` signal if you start it with the new `--gdb` option. This is because some MySQL users encountered strange problems when they accidentally sent `SIGINT` to `mysqld` threads.
- `RESET SLAVE` now clears the `Last_errno` and `Last_error` fields in the output of `SHOW SLAVE STATUS`.
- Added `max_relay_log_size` variable; the relay log will be rotated automatically when its size exceeds `max_relay_log_size`. But if `max_relay_log_size` is 0 (the default), `max_binlog_size` will be used (as in older versions). `max_binlog_size` still applies to binary logs in any case.
- `FLUSH LOGS` now rotates relay logs in addition to the other types of logs it already rotated.

Bugs fixed:

- Comparison/sorting for `latin1_de` character set was rewritten. The old algorithm could not handle cases like `"sä" > "ßa"`. See Section 4.7.1.1 [German character set], page 307. In rare cases it resulted in table corruption.
- Fixed a problem with the password prompt on Windows. (Bug #683)
- `ALTER TABLE ... UNION=(...)` for `MERGE` table is now allowed even if some underlying `MyISAM` tables are read-only. (Bug #702)
- Fixed a problem with `CREATE TABLE t1 SELECT x'41'`. (Bug #801)
- Removed some incorrect lock warnings from the error log.
- Fixed memory overrun when doing `REPAIR` on a table with a multi-part auto_increment key where one part was a packed `CHAR`.
- Fixed a probable race condition in the replication code that could potentially lead to `INSERT` statements not being replicated in the event of a `FLUSH LOGS` command or when the binary log exceeds `max_binlog_size`. (Bug #791)
- Fixed a crashing bug in `INTERVAL` and `GROUP BY` or `DISTINCT`. (Bug #807)
- Fixed bug in `mysqlhotcopy` so it actually aborts for unsuccessful table copying operations. Fixed another bug so that it succeeds when there are thousands of tables to copy. (Bug #812)
- Fixed problem with `mysqlhotcopy` failing to read options from option files. (Bug #808)
- Fixed bugs in optimiser that sometimes prevented MySQL from using `FULLTEXT` indexes even though it was possible (for example, in `SELECT * FROM t1 WHERE MATCH a,b AGAINST("index") > 0`).
- Fixed a bug with "table is full" in `UNION` operations.
- Fixed a security problem that enabled users with no privileges to obtain information on the list of existing databases by using `SHOW TABLES` and similar commands.

- Fixed a stack problem on UnixWare/OpenUnix.
- Fixed a configuration problem on UnixWare/OpenUNIX and OpenServer.
- Fixed a stack overflow problem in password verification.
- Fixed a problem with `max_user_connections`.
- `HANDLER` without an index now works properly when a table has deleted rows. (Bug #787)
- Fixed a bug with `LOAD DATA` in `mysqlbinlog`. (Bug #670)
- Fixed that `SET CHARACTER SET DEFAULT` works. (Bug #462)
- Fixed `MERGE` table behaviour in `ORDER BY ... DESC` queries. (Bug #515)
- Fixed server crash on `PURGE MASTER LOGS` or `SHOW MASTER LOGS` when the binary log is off. (Bug #733)
- Fixed password-checking problem on Windows. (Bug #464)
- Fixed the bug in comparison of a `DATETIME` column and an integer constant. (Bug #504)
- Fixed remote mode of `mysqlbinlog`. (Bug #672)
- Fixed `ERROR 1105: Unknown error` that occurred for some `SELECT` queries, where a column that was declared as `NOT NULL` was compared with an expression that took `NULL` value.
- Changed timeout in `mysql_real_connect()` to use `poll()` instead of `select()` to work around problem with many open files in the client.
- Fixed incorrect results from `MATCH ... AGAINST` used with a `LEFT JOIN` query.
- Fixed a bug that limited the maximum value for `mysqld` variables to 4294967295 when they are specified on the command line.
- Fixed a bug that sometimes caused spurious "Access denied" errors in `HANDLER ... READ` statements, when a table is referenced via an alias.
- Fixed portability problem with `safe_malloc`, which caused MySQL to give "Freeing wrong aligned pointer" errors on SCO 3.2.
- `ALTER TABLE ... ENABLE/DISABLE KEYS` could cause a core dump when done after an `INSERT DELAYED` statement on the same table.
- Fixed problem with conversion of localtime to GMT where some times resulted in different (but correct) timestamps. Now MySQL should use the smallest possible timestamp value in this case. (Bug #316)
- Very small query cache sizes could crash `mysqld`. (Bug #549)
- Fixed a bug (accidentally introduced by us but present only in version 4.0.13) that made `INSERT ... SELECT` into an `AUTO_INCREMENT` column not replicate well. This bug is in the master, not in the slave. (Bug #490)
- Fixed a bug: When an `INSERT ... SELECT` statement inserted rows into a non-transactional table, but failed at some point (for example, due to a "Duplicate key" error), the query was not written to the binlog. Now it is written to the binlog, with its error code, as all other queries are. About the `slave-skip-errors` option for how to handle partially completed queries in the slave, see Section 4.11.6 [Replication Options], page 369. (Bug #491)

- `SET FOREIGN_KEY_CHECKS=0` was not replicated properly. The fix probably will not be backported to 3.23.
- On a slave, `LOAD DATA INFILE` which had no `IGNORE` or `REPLACE` clause on the master, was replicated with `IGNORE`. While this is not a problem if the master and slave data are identical (a `LOAD` that produces no duplicate conflicts on the master will produce none on the slave anyway), which is true in normal operation, it is better for debugging not to silently add the `IGNORE`. That way, you can get an error message on the slave and discover that for some reason, the data on master and slave are different and investigate why. (Bug #571)
- On a slave, `LOAD DATA INFILE` printed an incomplete "Duplicate entry '%-.64s' for key %d"' message (the key name and value were not mentioned) in case of duplicate conflict (which does not happen in normal operation). (Bug #573)
- When using a slave compiled with `--debug`, `CHANGE MASTER TO RELAY_LOG_POS` could cause a debug assertion failure. (Bug #576)
- When doing a `LOCK TABLES WRITE` on an `InnoDB` table, commit could not happen, if the query was not written to the binary log (for example, if `--log-bin` was not used, or `binlog-ignore-db` was used). (Bug #578)
- If a 3.23 master had open temporary tables that had been replicated to a 4.0 slave, and the binlog got rotated, these temporary tables were immediately dropped by the slave (which caused problems if the master used them subsequently). This bug had been fixed in 4.0.13, but in a manner which caused an unlikely inconvenience: if the 3.23 master died brutally (power failure), without having enough time to automatically write `DROP TABLE` statements to its binlog, then the 4.0.13 slave would not notice the temporary tables have to be dropped, until the slave `mysqld` server is restarted. This minor inconvenience is fixed in 3.23.57 and 4.0.14 (meaning the master must be upgraded to 3.23.57 and the slave to 4.0.14 to remove the inconvenience). (Bug #254)
- If `MASTER_POS_WAIT()` was waiting, and the slave was idle, and the slave SQL thread terminated, `MASTER_POS_WAIT()` would wait forever. Now when the slave SQL thread terminates, `MASTER_POS_WAIT()` immediately returns `NULL` ("slave stopped"). (Bug #651)
- After `RESET SLAVE; START SLAVE;`, the `Relay_log_space` value displayed by `SHOW SLAVE STATUS` was too big by four bytes. (Bug #763)
- If a query was ignored on the slave (because of `replicate-ignore-table` and other similar rules), the slave still checked if the query got the same error code (0, no error) as on the master. So if the master had an error on the query (for example, "Duplicate entry" in a multiple-row insert), then the slave stopped and warned that the error codes didn't match. (Bug #797)

D.3.5 Changes in release 4.0.13 (16 May 2003)

Functionality added or changed:

- `PRIMARY KEY` now implies `NOT NULL`. (Bug #390)
- The Windows binary packages are now compiled with `--enable-local-infile` to match the Unix build configuration.

- Removed timing of tests from `mysql-test-run`. `time` does not accept all required parameters on many platforms (for example, QNX) and timing the tests is not really required (it's not a benchmark anyway).
- `SHOW MASTER STATUS` and `SHOW SLAVE STATUS` required the `SUPER` privilege; now they accept `REPLICATION CLIENT` as well. (Bug #343)
- Added multi-threaded MyISAM repair optimisation and `myisam_repair_threads` variable to enable it. See Section 4.6.8.4 [`myisam_repair_threads`], page 290.
- Added `innodb_max_dirty_pages_pct` variable which controls amount of dirty pages allowed in `InnoDB` buffer pool.
- `CURRENT_USER()` and `Access denied` error messages now report the hostname exactly as it was specified in the `GRANT` command.
- Removed benchmark results from the source and binary distributions. They are still available in the BK source tree, though.
- `InnoDB` tables now support `ANALYZE TABLE`.
- MySQL now issues an error when it opens a table that was created with MySQL 4.1.
- Option `--new` now changes binary items (`0xFFDF`) to be treated as binary strings instead of numbers by default. This fixes some problems with character sets where it's convenient to input the string as a binary item. After this change you have to convert the binary string to `INTEGER` with a `CAST` if you want to compare two binary items with each other and know which one is bigger than the other. `SELECT CAST(0xfeff AS UNSIGNED) < CAST(0xff AS UNSIGNED)`. This will be the default behaviour in MySQL 4.1. (Bug #152)
- Enabled `delayed_insert_timeout` on Linux (most modern glibc libraries have a fixed `pthread_cond_timedwait`). (Bug #211)
- Don't create more insert delayed threads than given by `max_insert_delayed_threads`. (Bug #211)
- Changed `UPDATE ... LIMIT` to also count accepted, but not changed rows.
- Tuned optimiser to favour clustered index over table scan.
- `BIT_AND()` and `BIT_OR()` now return an unsigned 64 bit value.
- Added warnings to error log of why a secure connection failed (when running with `--log-warnings`).
- Deprecated options `--skip-symlink` and `--use-symbolic-links` and replaced these with `--symbolic-links`.
- The default option for `innodb_flush_log_at_trx_commit` was changed from 0 to 1 to make `InnoDB` tables ACID by default. See Section 7.5.3 [`InnoDB` start], page 607.
- Added a feature to `SHOW KEYS` to display keys that are disabled by `ALTER TABLE DISABLE KEYS` command.
- When using a non-existing table type with `CREATE TABLE`, first try if the default table type exists before falling back to `MyISAM`.
- Added `MEMORY` as an alias for `HEAP`.
- Renamed function `rnd` to `my_rnd` as the name was too generic and is an exported symbol in `libmysqlclient` (thanks to Dennis Haney for the initial patch).

- Portability fix: renamed '`include/dbug.h`' to '`include/my_debug.h`'.
- `mysqldump` no longer silently deletes the binlogs when called with `--master-data` or `--first-slave`; while this behaviour was convenient for some users, others may suffer from it. Now one has to explicitely ask for this deletion with the new `--delete-master-logs` option.
- If the slave is configured (using for example `replicate-wild-ignore-table=mysql.%`) to exclude `mysql.user`, `mysql.host`, `mysql.db`, `mysql.tables_priv` and `mysql.columns_priv` from replication, then `GRANT` and `REVOKE` will not be replicated.

Bugs fixed:

- Logged `Access denied` error message had wrong `Using password` value. (Bug #398)
- Fixed bug with `NATURAL LEFT JOIN`, `NATURAL RIGHT JOIN` and `RIGHT JOIN` when using many joined tables. The problem was that the `JOIN` method was not always associated with the tables surrounding the `JOIN` method. If you have a query that uses many `RIGHT JOIN` or `NATURAL ... JOINS` you should check that they work as you expected after upgrading MySQL to this version. (Bug #291)
- `mysql` command line client no longer looks for `\*` commands inside backtick-quoted strings.
- Fixed `Unknown error` when using `UPDATE ... LIMIT`. (Bug #373)
- Fixed problem with ANSI mode and `GROUP BY` with constants. (Bug #387)
- Fixed bug with `UNION` and `OUTER JOIN`. (Bug #386)
- Fixed bug if one used a multi-table `UPDATE` and the query required a temporary table bigger than `tmp_table_size`. (Bug #286)
- Run `mysql_install_db` with the `-IN-RPM` option for the Mac OS X installation to not fail on systems with improperly configured hostname configurations.
- `LOAD DATA INFILE` will now read `000000` as a zero date instead as `"2000-00-00"`.
- Fixed bug that caused `DELETE FROM table WHERE const_expression` always to delete the whole table (even if expression result was false). (Bug #355)
- Fixed core dump bug when using `FORMAT('nan',#)`. (Bug #284)
- Fixed name resolution bug with `HAVING ... COUNT(DISTINCT ...)`.
- Fixed wrong result from truncation operator (`*`) in `MATCH ... AGAINST()` in some complex joins.
- Fixed a crash in `REPAIR ... USE_FRM` command, when used on read-only, nonexisting table or a table with a crashed index file.
- Fixed a crashing bug in mysql monitor program. It occurred if program was started with `--no-defaults`, with a prompt that contained hostname and connection to non-existing db was requested
- Fixed problem when comparing a key for a multi-byte-character set. (Bug #152)
- Fixed bug in `LEFT`, `RIGHT` and `MID` when used with multi-byte character sets and some `GROUP BY` queries. (Bug #314)
- Fix problem with `ORDER BY` being discarded for some `DISTINCT` queries. (Bug #275)

- Fixed that `SET SQL_BIG_SELECTS=1` works as documented (This corrects a new bug introduced in 4.0)
- Fixed some serious bugs in `UPDATE ... ORDER BY`. (Bug #241)
- Fixed unlikely problem in optimising `WHERE` clause with constant expression like in `WHERE 1 AND (a=1 AND b=1)`.
- Fixed that `SET SQL_BIG_SELECTS=1` works again.
- Introduced proper backtick quoting for db.table in `SHOW GRANTS`.
- `FULLTEXT` index stopped working after `ALTER TABLE` that converts `TEXT` field to `CHAR`. (Bug #283)
- Fixed a security problem with `SELECT` and wildcarded select list, when user only had partial column `SELECT` privileges on the table.
- Mark a MyISAM table as "analyzed" only when all the keys are indeed analyzed.
- Only ignore world-writeable '`my.cnf`' files that are regular files (and not, for example, named pipes or character devices).
- Fixed few smaller issues with `SET PASSWORD`.
- Fixed error message which contained deprecated text.
- Fixed a bug with two `NATURAL JOIN`s in the query.
- `SUM()` didn't return `NULL` when there was no rows in result or when all values was `NULL`.
- On Unix symbolic links handling was not enabled by default and there was no way to turn this on.
- Added missing dashes to parameter `--open-files-limit` in `mysqld_safe`. (Bug #264)
- Fixed wrong hostname for TCP/IP connections displayed in `SHOW PROCESSLIST`.
- Fixed a bug with `NAN` in `FORMAT(...)` function ...
- Fixed a bug with improperly cached database privileges.
- Fixed a bug in `ALTER TABLE ENABLE / DISABLE KEYS` which failed to force a refresh of table data in the cache.
- Fixed bugs in replication of `LOAD DATA INFILE` for custom parameters (`ENCLOSED`, `TERMINATED` and so on) and temporary tables. (Bug #183, Bug #222)
- Fixed a replication bug when the master is 3.23 and the slave 4.0: the slave lost the replicated temporary tables if `FLUSH LOGS` was issued on the master. (Bug #254)
- Fixed a bug when doing `LOAD DATA INFILE IGNORE`: When reading the binary log, `mysqlbinlog` and the replication code read `REPLACE` instead of `IGNORE`. This could make the slave's table become different from the master's table. (Bug #218)
- Fixed a deadlock when `relay_log_space_limit` was set to a too small value. (Bug #79)
- Fixed a bug in HAVING clause when an alias is used from the **select list**.
- Fixed overflow bug in `MyISAM` when a row is inserted into a table with a large number of columns and at least one `BLOB/TEXT` column. Bug was caused by incorrect calculation of the needed buffer to pack data.
- Fixed a bug when `SELECT` **@nonexistent_variable** caused the error in client - server protocol due to net_printf() being sent to the client twice.

- Fixed a bug in setting `SQL_BIG_SELECTS` option.
- Fixed a bug in `SHOW PROCESSLIST` which only displayed a localhost in the `"Host"` column. This was caused by a glitch that only used current thread information instead of information from the linked list of threads.
- Removed unnecessary Mac OS X helper files from server RPM. (Bug #144)
- Allow optimisation of multiple-table update for `InnoDB` tables as well.
- Fixed a bug in multiple-table updates that caused some rows to be updated several times.
- Fixed a bug in `mysqldump` when it was called with `--master-data`: the `CHANGE MASTER TO` commands appended to the SQL dump had wrong coordinates. (Bug #159)
- Fixed a bug when an updating query using `USER()` was replicated on the slave; this caused segfault on the slave. (Bug #178). `USER()` is still badly replicated on the slave (it is replicated to `""`).

D.3.6 Changes in release 4.0.12 (15 Mar 2003: Production)

Functionality added or changed:

- `mysqld` no longer reads options from world-writeable config files.
- Integer values between 9223372036854775807 and 9999999999999999999 are now regarded as unsigned longlongs, not as floats. This makes these values work similar to values between 10000000000000000000 and 18446744073709551615.
- `SHOW PROCESSLIST` will now include the client TCP port after the hostname to make it easier to know from which client the request originated.

Bugs fixed:

- Fixed `mysqld` crash on extremely small values of `sort_buffer` variable.
- `INSERT INTO u SELECT ... FROM t` was written too late to the binary log if t was very frequently updated during the execution of this query. This could cause a problem with `mysqlbinlog` or replication. The master must be upgraded, not the slave. (Bug #136)
- Fixed checking of random part of `WHERE` clause. (Bug #142)
- Fixed a bug with multiple-table updates with `InnoDB` tables. This bug occurred as, in many cases, `InnoDB` tables can not be updated "on the fly," but offsets to the records have to be stored in a temporary table.
- Added missing file `mysql_secure_installation` to the `server` RPM subpackage. (Bug #141)
- Fixed MySQL (and `myisamchk`) crash on artificially corrupted `.MYI` files.
- Don't allow `BACKUP TABLE` to overwrite existing files.
- Fixed a bug with multi-table `UPDATE` statements when user had all privileges on the database where tables are located and there were any entries in `tables_priv` table, that is, `grant_option` was true.
- Fixed a bug that allowed a user with table or column grants on some table, `TRUNCATE` any table in the same database.

- Fixed deadlock when doing `LOCK TABLE` followed by `DROP TABLE` in the same thread. In this case one could still kill the thread with `KILL`.
- `LOAD DATA LOCAL INFILE` was not properly written to the binary log (hence not properly replicated). (Bug #82)
- `RAND()` entries were not read correctly by `mysqlbinlog` from the binary log which caused problems when restoring a table that was inserted with `RAND()`. `INSERT INTO t1 VALUES(RAND())`. In replication this worked ok.
- `SET SQL_LOG_BIN=0` was ignored for `INSERT DELAYED` queries. (Bug #104)
- `SHOW SLAVE STATUS` reported too old positions (columns `Relay_Master_Log_File` and `Exec_master_log_pos`) for the last executed statement from the master, if this statement was the `COMMIT` of a transaction. The master must be upgraded for that, not the slave. (Bug #52)
- `LOAD DATA INFILE` was not replicated by the slave if `replicate_*_table` was set on the slave. (Bug #86)
- After `RESET SLAVE`, the coordinates displayed by `SHOW SLAVE STATUS` looked un-reset (though they were, but only internally). (Bug #70)
- Fixed query cache invalidation on `LOAD DATA`.
- Fixed memory leak on `ANALYZE` procedure with error.
- Fixed a bug in handling `CHAR(0)` columns that could cause wrong results from the query.
- Fixed rare bug with wrong initialisation of `AUTO_INCREMENT` column, as a secondary column in a multi-column key (see Section 3.6.9 [`AUTO_INCREMENT` on secondary column in a multi-column key], page 189), when data was inserted with `INSERT ... SELECT` or `LOAD DATA` into an empty table.
- On Windows, `STOP SLAVE` didn't stop the slave until the slave got one new command from the master (this bug has been fixed for MySQL 4.0.11 by releasing updated 4.0.11a Windows packages, which include this individual fix on top of the 4.0.11 sources). (Bug #69)
- Fixed a crash when no database was selected and `LOAD DATA` command was issued with full table name specified, including database prefix.
- Fixed a crash when shutting down replication on some platforms (for example, Mac OS X).
- Fixed a portability bug with `pthread_attr_getstacksize` on HP-UX 10.20 (Patch was also included in 4.0.11a sources).
- Fixed the `bigint` test to not fail on some platforms (for example, HP-UX and Tru64) due to different return values of the `atof()` function.
- Fixed the `rpl_rotate_logs` test to not fail on certain platforms (e.g. Mac OS X) due to a too long file name (changed `slave-master-info.opt` to `.slave-mi`).

D.3.7 Changes in release 4.0.11 (20 Feb 2003)

Functionality added or changed:

- `NULL` is now sorted **LAST** if you use `ORDER BY ... DESC` (as it was before MySQL 4.0.2). This change was required to comply with the SQL-99 standard. (The original change was made because we thought that SQL-99 required `NULL` to be always sorted at the same position, but this was incorrect).
- Added `START TRANSACTION` (SQL-99 syntax) as alias for `BEGIN`. This is recommended to use instead of `BEGIN` to start a transaction.
- Added `OLD_PASSWORD()` as a synonym for `PASSWORD()`.
- Allow keyword `ALL` in group functions.
- Added support for some new `INNER JOIN` and `JOIN` syntaxes. For example, `SELECT * FROM t1 INNER JOIN t2` didn't work before.
- Novell NetWare 6.0 porting effort completed, Novell patches merged into the main source tree.

Bugs fixed:

- Fixed problem with multiple-table delete and `InnoDB` tables.
- Fixed a problem with `BLOB NOT NULL` columns used with `IS NULL`.
- Re-added missing pre- and post(un)install scripts to the Linux RPM packages (they were missing after the renaming of the server subpackage).
- Fixed that table locks are not released with multi-table updates and deletes with `InnoDB` storage engine.
- Fixed bug in updating `BLOB` columns with long strings.
- Fixed integer-wraparound when giving big integer (>= 10 digits) to function that requires an unsigned argument, like `CREATE TABLE (...) AUTO_INCREMENT=#`.
- `MIN(key_column)` could in some cases return `NULL` on a column with `NULL` and other values.
- `MIN(key_column)` and `MAX(key_column)` could in some cases return wrong values when used in `OUTER JOIN`.
- `MIN(key_column)` and `MAX(key_column)` could return wrong values if one of the tables was empty.
- Fixed rare crash in compressed MyISAM tables with blobs.
- Fixed bug in using aggregate functions as argument for `INTERVAL`, `CASE`, `FIELD`, `CONCAT_WS`, `ELT` and `MAKE_SET` functions.
- When running with `--lower-case-table-names` (default on Windows) and you had tables or databases with mixed case on disk, then executing `SHOW TABLE STATUS` followed with `DROP DATABASE` or `DROP TABLE` could fail with `Errcode 13`.

D.3.8 Changes in release 4.0.10 (29 Jan 2003)

Functionality added or changed:

- Added option `--log-error[=file_name]` to `mysqld_safe` and `mysqld`. This option will force all error messages to be put in a log file if the option `--console` is not given. On Windows `--log-error` is enabled as default, with a default name of `host_name.err` if the name is not specified.

- Changed some things from `Warning:` to `Note:` in the log files.
- The mysqld server should now compile on NetWare.
- Added optimisation that if one does `GROUP BY ... ORDER BY NULL` then result is not sorted.
- New `--ft-stopword-file` command-line option for `mysqld` to replace/disable the built-in stopword list that is used in full-text searches. See Section 4.6.8.4 [`ft_stopword_file`], page 290.
- Changed default stack size from 64K to 192K; This fixes a core dump problem on Red Hat 8.0 and other systems with a `glibc` that requires a stack size larger than 128K for `gethostbyaddr()` to resolve a hostname. You can fix this for earlier MySQL versions by starting `mysqld` with `--thread-stack=192K`.
- Added `mysql_waitpid` to the binary distribution and the `MySQL-client` RPM subpackage (required for `mysql-test-run`).
- Renamed the main `MySQL` RPM package to `MySQL-server`. When updating from an older version, `MySQL-server.rpm` will simply replace `MySQL.rpm`.
- If a slave is configured with `replicate_wild_do_table=db.%` or `replicate_wild_ignore_table=db.%`, these rules will be applied to `CREATE/DROP DATABASE`, too.
- Added timeout value for `MASTER_POS_WAIT()`.

Bugs fixed:

- Fixed initialisation of the random seed for newly created threads to give a better `rand()` distribution from the first call.
- Fixed a bug that caused `mysqld` to hang when a table was opened with the `HANDLER` command and then dropped without being closed.
- Fixed bug in logging to binary log (which affects replication) a query that inserts a `NULL` in an `auto_increment` field and also uses `LAST_INSERT_ID()`.
- Fixed an unlikely bug that could cause a memory overrun when using `ORDER BY constant_expression`.
- Fixed a table corruption in `myisamchk`'s parallel repair mode.
- Fixed bug in query cache invalidation on simple table renaming.
- Fixed bug in `mysqladmin --relative`.
- On some 64 bit systems, `show status` reported a strange number for `Open_files` and `Open_streams`.
- Fixed wrong number of columns in `EXPLAIN` on empty table.
- Fixed bug in `LEFT JOIN` that caused zero rows to be returned in the case the `WHERE` condition was evaluated as `FALSE` after reading const tables. (Unlikely condition).
- `FLUSH PRIVILEGES` didn't correctly flush table/column privileges when `mysql.tables_priv` is empty.
- Fixed bug in replication when using `LOAD DATA INFILE` one a file that updated and auto_increment field with `NULL` or `0`. This bug only affected MySQL 4.0 masters (not slaves or MySQL 3.23 masters). **NOTE**: If you have a slave that has replicated a file with generated auto_increment fields then the slave data is corrupted and you should reinitialise the affected tables from the master.

- Fixed possible memory overrun when sending a blob > 16M to the client.
- Fixed wrong error message when setting a `NOT NULL` field to an expression that returned `NULL`.
- Fixed core dump bug in `str LIKE "%other_str%"` where `str` or `other_str` contained characters >= 128.
- Fixed bug: When executing on master `LOAD DATA` and `InnoDB` failed with `table full` error the binary log was corrupted.

D.3.9 Changes in release 4.0.9 (09 Jan 2003)

Functionality added or changed:

- `OPTIMIZE TABLE` will for MyISAM tables treat all `NULL` values as different when calculating cardinality. This helps in optimising joins between tables where one of the tables has a lot of `NULL` values in a indexed column:

```
SELECT * from t1,t2 where t1.a=t2.key_with_a_lot_of_null;
```

- Added join operator `FORCE INDEX (key_list)`. This acts likes `USE INDEX (key_list)` but with the addition that a table scan is assumed to be VERY expensive. One bad thing with this is that it makes `FORCE` a reserved word.
- Reset internal row buffer in MyISAM after each query. This will reduce memory in the case you have a lot of big blobs in a table.

Bugs fixed:

- A security patch in 4.0.8 causes the mysqld server to die if the remote hostname can't be resolved. This is now fixed.
- Fixed crash when replication big `LOAD DATA INFILE` statement that caused log rotation.

D.3.10 Changes in release 4.0.8 (07 Jan 2003)

Functionality added or changed:

- Default `max_packet_length` for libmysqld.c is now 1024*1024*1024.
- One can now specify `max_allowed_packet` in a file ready by `mysql_options(MYSQL_READ_DEFAULT_FILE)`. for clients.
- When sending a too big packet to the server with the not compressed protocol, the client now gets an error message instead of a lost connection.
- We now send big queries/result rows in bigger hunks, which should give a small speed improvement.
- Fixed some bugs with the compressed protocol for rows > 16M.
- `InnoDB` tables now also support `ON UPDATE CASCADE` in `FOREIGN KEY` constraints. See the `InnoDB` section in the manual for the `InnoDB` changelog.

Bugs fixed:

- Fixed bug in `ALTER TABLE` with BDB tables.
- Fixed core dump bug in `QUOTE()` function.

- Fixed a bug in handling communication packets bigger than 16M. Unfortunately this required a protocol change; If you upgrade the server to 4.0.8 and above and have clients that uses packets >= 255*255*255 bytes (=16581375) you must also upgrade your clients to at least 4.0.8. If you don't upgrade, the clients will hang when sending a big packet.
- Fixed bug when sending blobs longer than 16M to client.
- Fixed bug in `GROUP BY` when used on BLOB column with `NULL` values.
- Fixed a bug in handling `NULL` values in `CASE` ... WHEN ...

D.3.11 Changes in release 4.0.7 (20 Dec 2002)

Functionality added or changed:

- `mysqlbug` now also reports the compiler version used for building the binaries (if the compiler supports the option `--version`).

Bugs fixed:

- Fixed compilation problems on OpenUnix and HPUX 10.20.
- Fixed some optimisation problems when compiling MySQL with `-DBIG_TABLES` on a 32 bit system.
- `mysql_drop_db()` didn't check permissions properly so anyone could drop another users database. `DROP DATABASE` is checked properly.

D.3.12 Changes in release 4.0.6 (14 Dec 2002: Gamma)

Functionality added or changed:

- Added syntax support for `CHARACTER SET xxx` and `CHARSET=xxx` table options (to be able to read table dumps from 4.1).
- Fixed replication bug that caused the slave to loose its position in some cases when the replication log was rotated.
- Fixed that a slave will restart from the start of a transaction if it's killed in the middle of one.
- Moved the manual pages from '`man`' to '`man/man1`' in the binary distributions.
- The default type returned by `IFNULL(A,B)` is now set to be the more 'general' of the types of `A` and `B`. (The order is `STRING`, `REAL` or `INTEGER`).
- Moved the `mysql.server` startup script in the RPM packages from '`/etc/rc.d/init.d/mysql`' to '`/etc/init.d/mysql`' (which almost all current Linux distributions support for LSB compliance).
- Added `Qcache_lowmem_prunes` status variable (number of queries that were deleted from cache because of low memory).
- Fixed `mysqlcheck` so it can deal with table names containing dashes.
- Bulk insert optimisation (see Section 4.6.8.4 [`bulk_insert_buffer_size`], page 290) is no longer used when inserting small (less than 100) number of rows.
- Optimisation added for queries like `SELECT ... FROM merge_table WHERE indexed_column=constant_expr`.

- Added functions `LOCALTIME` and `LOCALTIMESTAMP` as synonyms for `NOW()`.
- `CEIL` is now an alias for `CEILING`.
- The `CURRENT_USER()` function can be used to get a `user@host` value as it was matched in the `GRANT` system. See Section 6.3.6.2 [`CURRENT_USER()`], page 515.
- Fixed `CHECK` constraints to be compatible with SQL-99. This made `CHECK` a reserved word. (Checking of `CHECK` constraints is still not implemented).
- Added `CAST(... as CHAR)`.
- Added PostgreSQL compatible `LIMIT` syntax: `SELECT ... LIMIT row_count OFFSET offset`
- `mysql_change_user()` will now reset the connection to the state of a fresh connect (Ie, `ROLLBACK` any active transaction, close all temporary tables, reset all user variables etc..)
- `CHANGE MASTER` and `RESET SLAVE` now require that slave threads be both already stopped; these commands will return an error if at least one of these two threads is running.

Bugs fixed:

- Fixed number of found rows returned in `multi table updates`
- Make `--lower-case-table-names` default on Mac OS X as the default file system (HFS+) is case insensitive. See Section 6.1.3 [Name case sensitivity], page 445.
- Transactions in `AUTOCOMMIT=0` mode didn't rotate binary log.
- A fix for the bug in a `SELECT` with joined tables with `ORDER BY` and `LIMIT` clause when filesort had to be used. In that case `LIMIT` was applied to filesort of one of the tables, although it could not be. This fix also solved problems with `LEFT JOIN`.
- `mysql_server_init()` now makes a copy of all arguments. This fixes a problem when using the embedded server in C# program.
- Fixed buffer overrun in `libmysqlclient` library that allowed a malicious `MySQL` server to crash the client application.
- Fixed security-related bug in `mysql_change_user()` handling. All users are strongly recommended to upgrade to version 4.0.6.
- Fixed bug that prevented `--chroot` command-line option of `mysqld` from working.
- Fixed bug in phrase operator `"..."` in boolean full-text search.
- Fixed bug that caused `OPTIMIZE TABLE` to corrupt the table under some rare circumstances.
- Part rewrite of multi-table-update to optimise it, make it safer and more bug free.
- `LOCK TABLES` now works together with multi-table-update and multi-table-delete.
- `--replicate-do=xxx` didn't work for `UPDATE` commands. (Bug introduced in 4.0.0)
- Fixed shutdown problem on Mac OS X.
- Major `InnoDB` bugs in `REPLACE, AUTO_INCREMENT, INSERT INTO ... SELECT ...` were fixed. See the `InnoDB` changelog in the `InnoDB` section of the manual.
- `RESET SLAVE` caused a crash if the slave threads were running.

D.3.13 Changes in release 4.0.5 (13 Nov 2002)

Functionality added or changed:

- Port number was added to host name (if it is known) in `SHOW PROCESSLIST` command
- Changed handling of last argument in `WEEK()` so that one can get week number according to the ISO 8601 specification. (Old code should still work).
- Fixed that `INSERT DELAYED` threads doesn't hang on `Waiting for INSERT` when one sends a `SIGHUP` to mysqld.
- Change that `AND` works according to SQL-99 when it comes to `NULL` handling. In practice, this only affects queries where you do something like `WHERE ... NOT (NULL AND 0)`.
- `mysqld` will now resolve `basedir` to its full path (with `realpath()`). This enables one to use relative symlinks to the MySQL installation directory. This will however cause `show variables` to report different directories on systems where there is a symbolic link in the path.
- Fixed that MySQL will not use index scan on index disabled with `IGNORE INDEX` or `USE INDEX`. to be ignored.
- Added `--use-frm` option to `mysqlcheck`. When used with `REPAIR`, it gets the table structure from the `.frm` file, so the table can be repaired even if the `.MYI` header is corrupted.
- Fixed bug in `MAX()` optimisation when used with `JOIN` and `ON` expressions.
- Added support for reading of MySQL 4.1 table definition files.
- `BETWEEN` behaviour changed (see Section 6.3.1.2 [Comparison Operators], page 475). Now `datetime_col BETWEEN timestamp AND timestamp` should work as expected.
- One can create `TEMPORARY MERGE` tables now.
- `DELETE FROM myisam_table` now shrinks not only the '`.MYD`' file but also the '`.MYI`' file.
- When one uses the `--open-files-limit=#` option to `mysqld_safe` it's now passed on to `mysqld`.
- Changed output from `EXPLAIN` from `'where used'` to `'Using where'` to make it more in line with other output.
- Removed variable `safe_show_database` as it was no longer used.
- Updated source tree to be built using `automake 1.5` and `libtool 1.4`.
- Fixed an inadvertently changed option (`--ignore-space`) back to the original `--ignore-spaces` in `mysqlclient`. (Both syntaxes will work).
- Don't require `UPDATE` privilege when using `REPLACE`.
- Added support for `DROP TEMPORARY TABLE ...`, to be used to make replication safer.
- When transactions are enabled, all commands that update temporary tables inside a `BEGIN/COMMIT` are now stored in the binary log on `COMMIT` and not stored if one does `ROLLBACK`. This fixes some problems with non-transactional temporary tables used inside transactions.

- Allow braces in joins in all positions. Formerly, things like `SELECT * FROM (t2 LEFT JOIN t3 USING (a)), t1` worked, but not `SELECT * FROM t1, (t2 LEFT JOIN t3 USING (a))`. Note that braces are simply removed, they do not change the way the join is executed.
- `InnoDB` now supports also isolation levels `READ UNCOMMITTED` and `READ COMMITTED`. For a detailed `InnoDB` changelog, see Section 7.5.16 [InnoDB change history], page 638 in this manual.

Bugs fixed:

- Fixed bug in `MAX()` optimisation when used with `JOIN` and `ON` expressions.
- Fixed that `INSERT DELAY` threads don't hang on `Waiting for INSERT` when one sends a `SIGHUP` to `mysqld`.
- Fixed that MySQL will not use an index scan on an index that has been disabled with `IGNORE INDEX` or `USE INDEX`.
- Corrected test for `root` user in `mysqld_safe`.
- Fixed error message issued when storage engine cannot do `CHECK` or `REPAIR`.
- Fixed rare core dump problem in complicated `GROUP BY` queries that didn't return any result.
- Fixed `mysqlshow` to work properly with wildcarded database names and with database names that contain underscores.
- Portability fixes to get MySQL to compile cleanly with Sun Forte 5.0.
- Fixed `MyISAM` crash when using dynamic-row tables with huge numbers of packed fields.
- Fixed query cache behaviour with `BDB` transactions.
- Fixed possible floating point exception in `MATCH` relevance calculations.
- Fixed bug in full-text search `IN BOOLEAN MODE` that made `MATCH` to return incorrect relevance value in some complex joins.
- Fixed a bug that limited `MyISAM` key length to a value slightly less that 500. It is exactly 500 now.
- Fixed that `GROUP BY` on columns that may have a `NULL` value doesn't always use disk based temporary tables.
- The filename argument for the `--des-key-file` argument to `mysqld` is interpreted relative to the data directory if given as a relative pathname.
- Removed a condition that temp table with index on column that can be `NULL` has to be `MyISAM`. This was okay for 3.23, but not needed in 4.*. This resulted in slowdown in many queries since 4.0.2.
- Small code improvement in multi-table updates.
- Fixed a newly introduced bug that caused `ORDER BY ... LIMIT row_count` to not return all rows.
- Fixed a bug in multi-table deletes when outer join is used on an empty table, which gets first to be deleted.
- Fixed a bug in multi-table updates when a single table is updated.
- Fixed bug that caused `REPAIR TABLE` and `myisamchk` to corrupt `FULLTEXT` indexes.

- Fixed bug with caching the `mysql` grant table database. Now queries in this database are not cached in the query cache.
- Small fix in `mysqld_safe` for some shells.
- Give error if a `MyISAM MERGE` table has more than 2 ^ 32 rows and MySQL was not compiled with `-DBIG_TABLES`.
- Fixed some `ORDER BY ... DESC` problems with `InnoDB` tables.

D.3.14 Changes in release 4.0.4 (29 Sep 2002)

- Fixed bug where `GRANT/REVOKE` failed if hostname was given in non-matching case.
- Don't give warning in `LOAD DATA INFILE` when setting a `timestamp` to a string value of `'0'`.
- Fixed bug in `myisamchk -R` mode.
- Fixed bug that caused `mysqld` to crash on `REVOKE`.
- Fixed bug in `ORDER BY` when there is a constant in the `SELECT` statement.
- One didn't get an error message if `mysqld` couldn't open the privilege tables.
- `SET PASSWORD FOR ...` closed the connection in case of errors (bug from 4.0.3).
- Increased max possible `max_allowed_packet` in `mysqld` to 1 GB.
- Fixed bug when doing a multi-line `INSERT` on a table with an `AUTO_INCREMENT` key which was not in the first part of the key.
- Changed `LOAD DATA INFILE` to not recreate index if the table had rows from before.
- Fixed overrun bug when calling `AES_DECRYPT()` with incorrect arguments.
- `--skip-ssl` can now be used to disable SSL in the MySQL clients, even if one is using other SSL options in an option file or previously on the command line.
- Fixed bug in `MATCH ... AGAINST( ... IN BOOLEAN MODE)` used with `ORDER BY`.
- Added `LOCK TABLES` and `CREATE TEMPORARY TABLES` privilege on the database level. One must run the `mysql_fix_privilege_tables` script on old installations to activate these.
- In `SHOW TABLE ... STATUS`, compressed tables sometimes showed up as `dynamic`.
- `SELECT @@[global|session].var_name` didn't report `global | session` in the result column name.
- Fixed problem in replication that `FLUSH LOGS` in a circular replication setup created an infinite number of binary log files. Now a `rotate-binary-log` command in the binary log will not cause slaves to rotate logs.
- Removed `STOP EVENT` from binary log when doing `FLUSH LOGS`.
- Disable the use of `SHOW NEW MASTER FOR SLAVE` as this needs to be completely reworked in a future release.
- Fixed a bug with constant expression (for example, field of a one-row table, or field from a table, referenced by a `UNIQUE` key) appeared in `ORDER BY` part of `SELECT DISTINCT`.
- `--log-binary=a.b.c` now properly strips off `.b.c`.
- `FLUSH LOGS` removed numerical extension for all future update logs.

- `GRANT ... REQUIRE` didn't store the SSL information in the `mysql.user` table if SSL was not enabled in the server.
- `GRANT ... REQUIRE NONE` can now be used to remove SSL information.
- `AND` is now optional between `REQUIRE` options.
- `REQUIRE` option was not properly saved, which could cause strange output in `SHOW GRANTS`.
- Fixed that `mysqld --help` reports correct values for `--datadir` and `--bind-address`.
- Fixed that one can drop UDFs that didn't exist when `mysqld` was started.
- Fixed core dump problem with `SHOW VARIABLES` on some 64 bit systems (like Solaris sparc).
- Fixed a bug in `my_getopt()`; `--set-variable` syntax didn't work for those options that didn't have a valid variable in the `my_option` struct. This affected at least the `default-table-type` option.
- Fixed a bug from 4.0.2 that caused `REPAIR TABLE` and `myisamchk --recover` to fail on tables with duplicates in a unique key.
- Fixed a bug from 4.0.3 in calculating the default datatype for some functions. This affected queries of type `CREATE TABLE table_name SELECT expression(),...`
- Fixed bug in queries of type `SELECT * FROM table-list GROUP BY ...` and `SELECT DISTINCT * FROM ...`.
- Fixed bug with the `--slow-log` when logging an administrator command (like `FLUSH TABLES`).
- Fixed a bug that `OPTIMIZE` of locked and modified table, reported table corruption.
- Fixed a bug in `my_getopt()` in handling of special prefixes (`--skip-`, `--enable-`). `--skip-external-locking` didn't work and the bug may have affected other similar options.
- Fixed bug in checking for output file name of the `tee` option.
- Added some more optimisation to use index for `SELECT ... FROM many_tables .. ORDER BY key limit #`
- Fixed problem in `SHOW OPEN TABLES` when a user didn't have access permissions to one of the opened tables.

D.3.15 Changes in release 4.0.3 (26 Aug 2002: Beta)

- Fixed problem with types of user variables. (Bug #551)
- Fixed problem with `configure ... --localstatedir=...`.
- Cleaned up `mysql.server` script.
- Fixed a bug in `mysqladmin shutdown` when pid file was modified while `mysqladmin` was still waiting for the previous one to disappear. This could happen during a very quick restart and caused `mysqladmin` to hang until `shutdown_timeout` seconds had passed.
- Don't increment warnings when setting `AUTO_INCREMENT` columns to `NULL` in `LOAD DATA INFILE`.

- Fixed all boolean type variables/options to work with the old syntax, for example, all of these work: `--lower-case-table-names`, `--lower-case-table-names=1`, `-O lower-case-table-names=1`, `--set-variable=lower-case-table-names=1`
- Fixed shutdown problem (SIGTERM signal handling) on Solaris. (Bug from 4.0.2).
- `SHOW MASTER STATUS` now returns an empty set if binary log is not enabled.
- `SHOW SLAVE STATUS` now returns an empty set if slave is not initialised.
- Don't update MyISAM index file on update if not strictly necessary.
- Fixed bug in `SELECT DISTINCT ... FROM many_tables ORDER BY not-used-column`.
- Fixed a bug with `BIGINT` values and quoted strings.
- Added `QUOTE()` function that performs SQL quoting to produce values that can be used as data values in queries.
- Changed variable `DELAY_KEY_WRITE` to an enum to allow one set `DELAY_KEY_WRITE` for all tables without taking down the server.
- Changed behaviour of `IF(condition,column,NULL)` so that it returns the value of the column type.
- Made `safe_mysqld` a symlink to `mysqld_safe` in binary distribution.
- Fixed security bug when having an empty database name in the `user.db` table.
- Fixed some problems with `CREATE TABLE ... SELECT function()`.
- `mysqld` now has the option `--temp-pool` enabled by default as this gives better performance with some operating systems.
- Fixed problem with too many allocated alarms on slave when connecting to master many times (normally not a very critical error).
- Fixed hang in `CHANGE MASTER TO` if the slave thread died very quickly.
- Big cleanup in replication code (less logging, better error messages, etc..)
- If the `--code-file` option is specified, the server calls `setrlimit()` to set the maximum allowed core file size to unlimited, so core files can be generated.
- Fixed bug in query cache after temporary table creation.
- Added `--count=N` (`-c`) option to `mysqladmin`, to make the program do only `N` iterations. To be used with `--sleep` (`-i`). Useful in scripts.
- Fixed bug in multi-table `UPDATE`: when updating a table, `do_select()` became confused about reading records from a cache.
- Fixed bug in multi-table `UPDATE` when several fields were referenced from a single table
- Fixed bug in truncating nonexisting table.
- Fixed bug in `REVOKE` that caused user resources to be randomly set.
- Fixed bug in `GRANT` for the new `CREATE TEMPORARY TABLE` privilege.
- Fixed bug in multi-table `DELETE` when tables are re-ordered in the table initialisation method and ref_lengths are of different sizes.
- Fixed two bugs in `SELECT DISTINCT` with large tables.
- Fixed bug in query cache initialisation with very small query cache size.
- Allow `DEFAULT` with `INSERT` statement.

- The startup parameters `myisam_max_sort_file_size` and `myisam_max_extra_sort_file_size` are now given in bytes, not megabytes.
- External system locking of `MyISAM/ISAM` files is now turned off by default. One can turn this on with `--external-locking`. (For most users this is never needed).
- Fixed core dump bug with `INSERT ... SET db_name.table_name.colname=''`.
- Fixed client hangup bug when using some SQL commands with wrong syntax.
- Fixed a timing bug in `DROP DATABASE`
- New `SET [GLOBAL | SESSION]` syntax to change thread-specific and global server variables at runtime.
- Added variable `slave_compressed_protocol`.
- Renamed variable `query_cache_startup_type` to `query_cache_type`, `myisam_bulk_insert_tree_size` to `bulk_insert_buffer_size`, `record_buffer` to `read_buffer_size` and `record_rnd_buffer` to `read_rnd_buffer_size`.
- Renamed some SQL variables, but old names will still work until 5.0. See Section 2.5.2 [Upgrading-from-3.23], page 113.
- Renamed `--skip-locking` to `--skip-external-locking`.
- Removed unused variable `query_buffer_size`.
- Fixed a bug that made the pager option in the `mysql` client non-functional.
- Added full `AUTO_INCREMENT` support to `MERGE` tables.
- Extended `LOG()` function to accept an optional arbitrary base parameter. See Section 6.3.3.2 [Mathematical functions], page 493.
- Added `LOG2()` function (useful for finding out how many bits a number would require for storage).
- Added `LN()` natural logarithm function for compatibility with other databases. It is synonymous with `LOG(X)`.

D.3.16 Changes in release 4.0.2 (01 Jul 2002)

- Cleaned up `NULL` handling for default values in `DESCRIBE table_name`.
- Fixed `truncate()` to round up negative values to the nearest integer.
- Changed `--chroot=path` option to execute `chroot()` immediately after all options have been parsed.
- Don't allow database names that contain '\'.
- `lower_case_table_names` now also affects database names.
- Added `XOR` operator (logical and bitwise `XOR`) with `^` as a synonym for bitwise `XOR`.
- Added function `IS_FREE_LOCK("lock_name")`. Based on code contributed by Hartmut Holzgraefe `hartmut@six.de`.
- Removed `mysql_ssl_clear()` from C API, as it was not needed.
- `DECIMAL` and `NUMERIC` types can now read exponential numbers.
- Added `SHA1()` function to calculate 160 bit hash value as described in RFC 3174 (Secure Hash Algorithm). This function can be considered a cryptographically more secure equivalent of `MD5()`. See Section 6.3.6.2 [Miscellaneous functions], page 515.

- Added `AES_ENCRYPT()` and `AES_DECRYPT()` functions to perform encryption according to AES standard (Rijndael). See Section 6.3.6.2 [Miscellaneous functions], page 515.
- Added `--single-transaction` option to `mysqldump`, allowing a consistent dump of `InnoDB` tables. See Section 4.9.6 [mysqldump], page 339.
- Fixed bug in `innodb_log_group_home_dir` in `SHOW VARIABLES`.
- Fixed a bug in optimiser with merge tables when non-unique values are used in summing up (causing crashes).
- Fixed a bug in optimiser when a range specified makes index grouping impossible (causing crashes).
- Fixed a rare bug when `FULLTEXT` index is present and no tables are used.
- Added privileges `CREATE TEMPORARY TABLES`, `EXECUTE`, `LOCK TABLES`, `REPLICATION CLIENT`, `REPLICATION SLAVE`, `SHOW DATABASES` and `SUPER`. To use these, you must have run the `mysql_fix_privilege_tables` script after upgrading.
- Fixed query cache align data bug.
- Fixed mutex bug in replication when reading from master fails.
- Added missing mutex in `TRUNCATE TABLE`; This fixes some core dump/hangup problems when using `TRUNCATE TABLE`.
- Fixed bug in multi-table `DELETE` when optimiser uses only indices.
- Fixed that `ALTER TABLE table_name RENAME new_table_name` is as fast as `RENAME TABLE`.
- Fixed bug in `GROUP BY` with two or more fields, where at least one field can contain `NULL` values.
- Use `Turbo Boyer-Moore` algorithm to speed up `LIKE "%keyword%"` searches.
- Fixed bug in `DROP DATABASE` with symlink.
- Fixed crash in `REPAIR ... USE_FRM`.
- Fixed bug in `EXPLAIN` with `LIMIT offset != 0`.
- Fixed bug in phrase operator `"..."` in boolean full-text search.
- Fixed bug that caused duplicated rows when using truncation operator `*` in boolean full-text search.
- Fixed bug in truncation operator of boolean full-text search (wrong results when there are only `+word*`s in the query).
- Fixed bug in boolean full-text search that caused a crash when an identical `MATCH` expression that did not use an index appeared twice.
- Query cache is now automatically disabled in `mysqldump`.
- Fixed problem on Windows 98 that made sending of results very slow.
- Boolean full-text search weighting scheme changed to something more reasonable.
- Fixed bug in boolean full-text search that caused MySQL to ignore queries of `ft_min_word_len` characters.
- Boolean full-text search now supports “phrase searches”.
- New configure option `--without-query-cache`.
- Memory allocation strategy for “root memory” changed. Block size now grows with number of allocated blocks.

- `INET_NTOA()` now returns `NULL` if you give it an argument that is too large (greater than the value corresponding to `255.255.255.255`).
- Fix `SQL_CALC_FOUND_ROWS` to work with `UNION`s. It will work only if the first `SELECT` has this option and if there is global `LIMIT` for the entire statement. For the moment, this requires using parentheses for individual `SELECT` queries within the statement.
- Fixed bug in `SQL_CALC_FOUND_ROWS` and `LIMIT`.
- Don't give an error for `CREATE TABLE ...(... VARCHAR(0))`.
- Fixed `SIGINT` and `SIGQUIT` problems in '`mysql.cc`' on Linux with some `glibc` versions.
- Fixed bug in '`convert.cc`', which is caused by having an incorrect `net_store_length()` linked in the `CONVERT::store()` method.
- `DOUBLE` and `FLOAT` columns now honor the `UNSIGNED` flag on storage.
- `InnoDB` now retains foreign key constraints through `ALTER TABLE` and `CREATE/DROP INDEX`.
- `InnoDB` now allows foreign key constraints to be added through the `ALTER TABLE` syntax.
- `InnoDB` tables can now be set to automatically grow in size (autoextend).
- Added `--ignore-lines=n` option to `mysqlimport`. This has the same effect as the `IGNORE n LINES` clause for `LOAD DATA`.
- Fixed bug in `UNION` with last offset being transposed to total result set.
- `REPAIR ... USE_FRM` added.
- Fixed that `DEFAULT_SELECT_LIMIT` is always imposed on `UNION` result set.
- Fixed that some `SELECT` options can appear only in the first `SELECT`.
- Fixed bug with `LIMIT` with `UNION`, where last select is in the braces.
- Fixed that full-text works fine with `UNION` operations.
- Fixed bug with indexless boolean full-text search.
- Fixed bug that sometimes appeared when full-text search was used with "const" tables.
- Fixed incorrect error value when doing a `SELECT` with an empty `HEAP` table.
- Use `ORDER BY column DESC` now sorts `NULL` values first. (In other words, `NULL` values sort first in all cases, whether or not `DESC` is specified.) This is changed back in 4.0.10.
- Fixed bug in `WHERE key_name='constant' ORDER BY key_name DESC`.
- Fixed bug in `SELECT DISTINCT ... ORDER BY DESC` optimisation.
- Fixed bug in `... HAVING 'GROUP_FUNCTION'(xxx) IS [NOT] NULL`.
- Fixed bug in truncation operator for boolean full-text search.
- Allow value of `--user=#` option for `mysqld` to be specified as a numeric user ID.
- Fixed a bug where `SQL_CALC_ROWS` returned an incorrect value when used with one table and `ORDER BY` and with `InnoDB` tables.
- Fixed that `SELECT 0 LIMIT 0` doesn't hang thread.
- Fixed some problems with `USE/IGNORE INDEX` when using many keys with the same start column.
- Don't use table scan with `BerkeleyDB` and `InnoDB` tables when we can use an index that covers the whole row.

- Optimised `InnoDB` sort-buffer handling to take less memory.
- Fixed bug in multi-table `DELETE` and `InnoDB` tables.
- Fixed problem with `TRUNCATE` and `InnoDB` tables that produced the error `Can't execute the given command because you have active locked tables or an active transaction`.
- Added `NO_UNSIGNED_SUBTRACTION` to the set of flags that may be specified with the `--sql-mode` option for `mysqld`. It disables unsigned arithmetic rules when it comes to subtraction. (This will make MySQL 4.0 behave more like 3.23 with `UNSIGNED` columns).
- The result returned for all bit functions (`|`, `<<`, ...) is now of type `unsigned integer`.
- Added detection of `nan` values in `MyISAM` to make it possible to repair tables with `nan` in float or double columns.
- Fixed new bug in `myisamchk` where it didn't correctly update number of "parts" in the `MyISAM` index file.
- Changed to use `autoconf` 2.52 (from `autoconf` 2.13).
- Fixed optimisation problem where the MySQL Server was in "preparing" state for a long time when selecting from an empty table which had contained a lot of rows.
- Fixed bug in complicated join with `const` tables. This fix also improves performance a bit when referring to another table from a `const` table.
- First pre-version of multi-table `UPDATE` statement.
- Fixed bug in multi-table `DELETE`.
- Fixed bug in `SELECT CONCAT(argument_list) ... GROUP BY 1`.
- `INSERT ... SELECT` did a full rollback in case of an error. Fixed so that we only roll back the last statement in the current transaction.
- Fixed bug with empty expression for boolean full-text search.
- Fixed core dump bug in updating full-text key from/to `NULL`.
- ODBC compatibility: Added `BIT_LENGTH()` function.
- Fixed core dump bug in `GROUP BY BINARY column`.
- Added support for `NULL` keys in `HEAP` tables.
- Use index for `ORDER BY` in queries of type: `SELECT * FROM t WHERE key_part1=1 ORDER BY key_part1 DESC,key_part2 DESC`
- Fixed bug in `FLUSH QUERY CACHE`.
- Added `CAST()` and `CONVERT()` functions. The `CAST` and `CONVERT` functions are nearly identical and mainly useful when you want to create a column with a specific type in a `CREATE ... SELECT` statement. For more information, read Section 6.3.5 [Cast Functions], page 513.
- `CREATE ... SELECT` on `DATE` and `TIME` functions now create columns of the expected type.
- Changed order in which keys are created in tables.
- Added new columns `Null` and `Index_type` to `SHOW INDEX` output.
- Added `--no-beep` and `--prompt` options to `mysql` command-line client.

- New feature: management of user resources.

```
GRANT ... WITH MAX_QUERIES_PER_HOUR N1
               MAX_UPDATES_PER_HOUR N2
               MAX_CONNECTIONS_PER_HOUR N3;
```

  See Section 4.4.7 [User resources], page 249.
- Added `mysql_secure_installation` to the '`scripts/`' directory.

D.3.17 Changes in release 4.0.1 (23 Dec 2001)

- Added `system` command to `mysql`.
- Fixed bug when `HANDLER` was used with some unsupported table type.
- `mysqldump` now puts `ALTER TABLE tbl_name DISABLE KEYS` and `ALTER TABLE tbl_name ENABLE KEYS` in the sql dump.
- Added `mysql_fix_extensions` script.
- Fixed stack overrun problem with `LOAD DATA FROM MASTER` on OSF/1.
- Fixed shutdown problem on HP-UX.
- Added `DES_ENCRYPT()` and `DES_DECRYPT()` functions.
- Added `FLUSH DES_KEY_FILE` statement.
- Added `--des-key-file` option to `mysqld`.
- `HEX(string)` now returns the characters in `string` converted to hexadecimal.
- Fixed problem with `GRANT` when using `lower_case_table_names=1`.
- Changed `SELECT ... IN SHARE MODE` to `SELECT ... LOCK IN SHARE MODE` (as in MySQL 3.23).
- A new query cache to cache results from identical `SELECT` queries.
- Fixed core dump bug on 64-bit machines when it got an incorrect communication packet.
- `MATCH ... AGAINST(... IN BOOLEAN MODE)` can now work without `FULLTEXT` index.
- Fixed slave to replicate from 3.23 master.
- Miscellaneous replication fixes/cleanup.
- Got shutdown to work on Mac OS X.
- Added `myisam/ft_dump` utility for low-level inspection of `FULLTEXT` indexes.
- Fixed bug in `DELETE ... WHERE ... MATCH ...`.
- Added support for `MATCH ... AGAINST(... IN BOOLEAN MODE)`. **Note: you must rebuild your tables with `ALTER TABLE tablename TYPE=MyISAM` to be able to use boolean full-text search**.
- `LOCATE()` and `INSTR()` are now case-sensitive if either argument is a binary string.
- Changed `RAND()` initialisation so that `RAND(N)` and `RAND(N+1)` are more distinct.
- Fixed core dump bug in `UPDATE ... ORDER BY`.
- In 3.23, `INSERT INTO ... SELECT` always had `IGNORE` enabled. Now MySQL will stop (and possibly roll back) by default in case of an error unless you specify `IGNORE`.
- Ignore `DATA DIRECTORY` and `INDEX DIRECTORY` directives on Windows.

- Added boolean full-text search code. It should be considered early alpha.
- Extended `MODIFY` and `CHANGE` in `ALTER TABLE` to accept the `FIRST` and `AFTER` keywords.
- Indexes are now used with `ORDER BY` on a whole `InnoDB` table.

D.3.18 Changes in release 4.0.0 (Oct 2001: Alpha)

- Added `--xml` option to `mysql` for producing XML output.
- Added full-text variables `ft_min_word_len`, `ft_max_word_len`, and `ft_max_word_len_for_sort`.
- Added documentation for `libmysqld`, the embedded MySQL server library. Also added example programs (a `mysql` client and `mysqltest` test program) which use `libmysqld`.
- Removed all Gemini hooks from MySQL server.
- Removed `my_thread_init()` and `my_thread_end()` from '`mysql_com.h`', and added `mysql_thread_init()` and `mysql_thread_end()` to '`mysql.h`'.
- Support for communication packets > 16M. In 4.0.1 we will extend `MyISAM` to be able to handle these.
- Secure connections (with SSL).
- Unsigned `BIGINT` constants now work. `MIN()` and `MAX()` now handle signed and unsigned `BIGINT` numbers correctly.
- New character set `latin1_de` which provides correct German sorting.
- `STRCMP()` now uses the current character set when doing comparisons, which means that the default comparison behaviour now is case-insensitive.
- `TRUNCATE TABLE` and `DELETE FROM tbl_name` are now separate functions. One bonus is that `DELETE FROM tbl_name` now returns the number of deleted rows, rather than zero.
- `DROP DATABASE` now executes a `DROP TABLE` on all tables in the database, which fixes a problem with `InnoDB` tables.
- Added support for `UNION`.
- Added support for multi-table `DELETE` operations.
- A new `HANDLER` interface to `MyISAM` tables.
- Added support for `INSERT` on `MERGE` tables. Patch from Benjamin Pflugmann.
- Changed `WEEK(date,0)` to match the calendar in the USA.
- `COUNT(DISTINCT)` is about 30% faster.
- Speed up all internal list handling.
- Speed up `IS NULL`, `ISNULL()` and some other internal primitives.
- Full-text index creation now is much faster.
- Tree-like cache to speed up bulk inserts and `myisam_bulk_insert_tree_size` variable.
- Searching on packed (`CHAR`/`VARCHAR`) keys is now much faster.
- Optimised queries of type: `SELECT DISTINCT * from tbl_name ORDER by key_part1 LIMIT row_count`.
- `SHOW CREATE TABLE` now shows all table attributes.
- `ORDER BY ... DESC` can now use keys.

- `LOAD DATA FROM MASTER` "automatically" sets up a slave.
- Renamed `safe_mysqld` to `mysqld_safe` to make this name more in line with other MySQL scripts/commands.
- Added support for symbolic links to `MyISAM` tables. Symlink handling is now enabled by default for Windows.
- Added `SQL_CALC_FOUND_ROWS` and `FOUND_ROWS()`. This makes it possible to know how many rows a query would have returned without a `LIMIT` clause.
- Changed output format of `SHOW OPEN TABLES`.
- Allow `SELECT expression LIMIT ...`.
- Added `ORDER BY` syntax to `UPDATE` and `DELETE`.
- `SHOW INDEXES` is now a synonym for `SHOW INDEX`.
- Added `ALTER TABLE tbl_name DISABLE KEYS` and `ALTER TABLE tbl_name ENABLE KEYS` commands.
- Allow use of `IN` as a synonym for `FROM` in `SHOW` commands.
- Implemented "repair by sort" for `FULLTEXT` indexes. `REPAIR TABLE`, `ALTER TABLE`, and `OPTIMIZE TABLE` for tables with `FULLTEXT` indexes are now up to 100 times faster.
- Allow SQL-99 syntax `X'hexadecimal-number'`.
- Cleaned up global lock handling for `FLUSH TABLES WITH READ LOCK`.
- Fixed problem with `DATETIME = constant` in `WHERE` optimisation.
- Added `--master-data` and `--no-autocommit` options to `mysqldump`. (Thanks to Brian Aker for this.)
- Added script `mysql_explain_log.sh` to distribution. (Thanks to mobile.de).

D.4 Changes in release 3.23.x (Recent; still supported)

Please note that since release 4.0 is now production level, only critical fixes are done in the 3.23 release series. You are recommended to upgrade when possible, to take advantage of all speed and feature improvements in 4.0. See Section 2.5.2 [Upgrading-from-3.23], page 113.

The 3.23 release has several major features that are not present in previous versions. We have added three new table types:

`MyISAM` A new ISAM library which is tuned for SQL and supports large files.

`InnoDB` A transaction-safe storage engine that supports row level locking, and many Oracle-like features.

`BerkeleyDB` or `BDB`
Uses the Berkeley DB library from Sleepycat Software to implement transaction-safe tables.

Note that only `MyISAM` is available in the standard binary distribution.

The 3.23 release also includes support for database replication between a master and many slaves, full-text indexing, and much more.

All new features are being developed in the 4.x version. Only bug fixes and minor enhancements to existing features will be added to 3.23.

The replication code and BerkeleyDB code is still not as tested and as the rest of the code, so we will probably need to do a couple of future releases of 3.23 with small fixes for this part of the code. As long as you don't use these features, you should be quite safe with MySQL 3.23!

Note that the above doesn't mean that replication or Berkeley DB don't work. We have done a lot of testing of all code, including replication and `BDB` without finding any problems. It only means that not as many users use this code as the rest of the code and because of this we are not yet 100% confident in this code.

D.4.1 Changes in release 3.23.59 (not released yet)

- If a query was ignored on the slave (because of `replicate-ignore-table` and other similar rules), the slave still checked if the query got the same error code (0, no error) as on the master. So if the master had an error on the query (for example, "Duplicate entry" in a multiple-row insert), then the slave stopped and warned that the error codes didn't match. This is a backport of the fix for MySQL 4.0. (Bug #797)
- `mysqlbinlog` now asks for a password at console when the `-p/--password` option is used with no argument. This is how the other clients (`mysqladmin`, `mysqldump`..) already behave. Note that one now has to use `mysqlbinlog -p<my_password>`; `mysqlbinlog -p <my_password>` will not work anymore (in other words, put no space after `-p`). (Bug #1595)
- On some 64-bit machines (some HP-UX and Solaris machines), a slave installed with the 64-bit MySQL binary could not connect to its master (it connected to itself instead). (Bug #1256, #1381)
- Fixed a Windows-specific bug present since MySQL version 3.23.57 and 3.23.58, which caused Windows slaves to crash when they started replication if a '`master.info`' file existed. (Bug #1720)

D.4.2 Changes in release 3.23.58 (11 Sep 2003)

- Fixed buffer overflow in password handling which could potentially be exploited by MySQL users with `ALTER` privilege on the `mysql.user` table to execute random code or to gain shell access with the UID of the mysqld process (thanks to Jedi/Sector One for spotting and reporting this bug).
- `mysqldump` now correctly quotes all identifiers when communicating with the server. This assures that during the dump process, `mysqldump` will never send queries to the server that result in a syntax error. This problem is **not** related to the `mysqldump` program's output, which was not changed. (Bug #1148)
- Fixed table/column grant handling - proper sort order (from most specific to less specific, see Section 4.3.10 [Request access], page 228) was not honored. (Bug #928)
- Fixed overflow bug in `MyISAM` and `ISAM` when a row is updated in a table with a large number of columns and at least one `BLOB/TEXT` column.
- Fixed MySQL so that field length (in C API) for the second column in `SHOW CREATE TABLE` is always larger than the data length. The only known application that was affected by the old behaviour was Borland dbExpress, which truncated the output from the command. (Bug #1064)

- Fixed `ISAM` bug in `MAX()` optimisation.
- Fixed `Unknown error` when doing `ORDER BY` on reference table which was used with `NULL` value on `NOT NULL` column. (Bug #479)

D.4.3 Changes in release 3.23.57 (06 Jun 2003)

- Fixed problem in alarm handling that could cause problems when getting a packet that is too large.
- Fixed problem when installing MySQL as a service on Windows when one gave 2 arguments (option file group name and service name) to `mysqld`.
- Fixed `kill pid-of-mysqld` to work on Mac OS X.
- `SHOW TABLE STATUS` displayed incorrect `Row_format` value for tables that have been compressed with `myisampack`. (Bug #427)
- `SHOW VARIABLES LIKE 'innodb_data_file_path'` displayed only the name of the first datafile. (Bug #468)
- Fixed security problem where `mysqld` didn't allow one to `UPDATE` rows in a table even if one had a global `UPDATE` privilege and a database `SELECT` privilege.
- Fixed a security problem with `SELECT` and wildcarded select list, when user only had partial column `SELECT` privileges on the table.
- Fixed unlikely problem in optimising `WHERE` clause with a constant expression such as in `WHERE 1 AND (a=1 AND b=1)`.
- Fixed problem on IA-64 with timestamps that caused `mysqlbinlog` to fail.
- The default option for `innodb_flush_log_at_trx_commit` was changed from 0 to 1 to make `InnoDB` tables ACID by default. See Section 7.5.3 [`InnoDB` start], page 607.
- Fixed problem with too many allocated alarms on slave when connecting to master many times (normally not a very critical error).
- Fixed a bug in replication of temporary tables. (Bug #183)
- Fixed 64 bit bug that affected at least AMD hammer systems.
- Fixed a bug when doing `LOAD DATA INFILE IGNORE`: When reading the binary log, `mysqlbinlog` and the replication code read `REPLACE` instead of `IGNORE`. This could make the slave's table become different from the master's table. (Bug #218)
- Fixed overflow bug in `MyISAM` when a row is inserted into a table with a large number of columns and at least one `BLOB/TEXT` column. Bug was caused by incorrect calculation of the needed buffer to pack data.
- The binary log was not locked during `TRUNCATE table_name` or `DELETE FROM table_name` statements, which could cause an `INSERT` to `table_name` to be written to the log before the `TRUNCATE` or `DELETE` statements.
- Fixed rare bug in `UPDATE` of `InnoDB` tables where one row could be updated multiple times.
- Produce an error for empty table and column names.
- Changed `PROCEDURE ANALYSE()` to report `DATE` instead of `NEWDATE`.
- Changed `PROCEDURE ANALYSE(#)` to restrict the number of values in an `ENUM` column to `#` also for string values.

- `mysqldump` no longer silently deletes the binary logs when invoked with the `--master-data` or `--first-slave` option; while this behaviour was convenient for some users, others may suffer from it. Now one has to explicitly ask for binary logs to be deleted by using the new `--delete-master-logs` option.
- Fixed a bug in `mysqldump` when it was invoked with the `--master-data` option: The `CHANGE MASTER TO` statements that were appended to the SQL dump had incorrect coordinates. (Bug #159)

D.4.4 Changes in release 3.23.56 (13 Mar 2003)

- Fixed `mysqld` crash on extremely small values of `sort_buffer` variable.
- Fixed a bug in privilege system for `GRANT UPDATE` on column level.
- Fixed a rare bug when using a date in `HAVING` with `GROUP BY`.
- Fixed checking of random part of `WHERE` clause. (Bug #142)
- Fixed MySQL (and `myisamchk`) crash on artificially corrupted '`.MYI`' files.
- Security enhancement: `mysqld` no longer reads options from world-writeable config files.
- Security enhancement: `mysqld` and `safe_mysqld` now only use the first `--user` option specified on the command line. (Normally this comes from '`/etc/my.cnf`')
- Security enhancement: Don't allow `BACKUP TABLE` to overwrite existing files.
- Fixed unlikely deadlock bug when one thread did a `LOCK TABLE` and another thread did a `DROP TABLE`. In this case one could do a `KILL` on one of the threads to resolve the deadlock.
- `LOAD DATA INFILE` was not replicated by slave if `replicate_*_table` was set on the slave.
- Fixed a bug in handling `CHAR(0)` columns that could cause wrong results from the query.
- Fixed a bug in `SHOW VARIABLES` on 64-bit platforms. The bug was caused by wrong declaration of variable `server_id`.
- The Comment column in `SHOW TABLE STATUS` now reports that it can contain `NULL` values (which is the case for a crashed '`.frm`' file).
- Fixed the `rpl_rotate_logs` test to not fail on certain platforms (e.g. Mac OS X) due to a too long file name (changed `slave-master-info.opt` to `.slave-mi`).
- Fixed a problem with `BLOB NOT NULL` columns used with `IS NULL`.
- Fixed bug in `MAX()` optimisation in `MERGE` tables.
- Better `RAND()` initialisation for new connections.
- Fixed bug with connect timeout. This bug was manifested on OS's with `poll()` system call, which resulted in timeout the value specified as it was executed in both `select()` and `poll()`.
- Fixed bug in `SELECT * FROM table WHERE datetime1 IS NULL OR datetime2 IS NULL`.
- Fixed bug in using aggregate functions as argument for `INTERVAL`, `CASE`, `FIELD`, `CONCAT_WS`, `ELT` and `MAKE_SET` functions.

- When running with `--lower-case-table-names` (default on Windows) and you had tables or databases with mixed case on disk, then executing `SHOW TABLE STATUS` followed with `DROP DATABASE` or `DROP TABLE` could fail with `Errcode 13`.
- Fixed bug in logging to binary log (which affects replication) a query that inserts a `NULL` in an `auto_increment` field and also uses `LAST_INSERT_ID()`.
- Fixed bug in `mysqladmin --relative`.
- On some 64 bit systems, `show status` reported a strange number for `Open_files` and `Open_streams`.

D.4.5 Changes in release 3.23.55 (23 Jan 2003)

- Fixed double `free`'d pointer bug in `mysql_change_user()` handling, that enabled a specially hacked version of MySQL client to crash `mysqld`. **Note**, that one needs to login to the server by using a valid user account to be able to exploit this bug.
- Fixed bug with the `--slow-log` when logging an administrator command (like `FLUSH TABLES`).
- Fixed bug in `GROUP BY` when used on BLOB column with `NULL` values.
- Fixed a bug in handling `NULL` values in `CASE ... WHEN ...`.
- Bugfix for `--chroot` (see Section D.4.6 [News-3.23.54], page 932) is reverted. Unfortunately, there is no way to make it to work, without introducing backward-incompatible changes in '`my.cnf`'. Those who need `--chroot` functionality, should upgrade to MySQL 4.0. (The fix in the 4.0 branch did not break backward-compatibility).
- Make `--lower-case-table-names` default on Mac OS X as the default file system (HFS+) is case insensitive.
- Fixed a bug in '`scripts/mysqld_safe.sh`' in `NOHUP_NICENESS` testing.
- Transactions in `AUTOCOMMIT=0` mode didn't rotate binary log.
- Fixed a bug in `scripts/make_binary_distribution` that resulted in a remaining `@HOSTNAME@` variable instead of replacing it with the correct path to the `hostname` binary.
- Fixed a very unlikely bug that could cause `SHOW PROCESSLIST` to core dump in pthread_mutex_unlock() if a new thread was connecting.
- Forbid `SLAVE STOP` if the thread executing the query has locked tables. This removes a possible deadlock situation.

D.4.6 Changes in release 3.23.54 (05 Dec 2002)

- Fixed a bug, that allowed to crash `mysqld` with a specially crafted packet.
- Fixed a rare crash (double `free`'d pointer) when altering a temporary table.
- Fixed buffer overrun in `libmysqlclient` library that allowed malicious MySQL server to crash the client application.
- Fixed security-related bug in `mysql_change_user()` handling. All users are strongly recommended to upgrade to the version 3.23.54.
- Fixed bug that prevented `--chroot` command-line option of `mysqld` from working.

- Fixed bug that made `OPTIMIZE TABLE` to corrupt the table under some rare circumstances.
- Fixed `mysqlcheck` so it can deal with table names containing dashes.
- Fixed shutdown problem on Mac OS X.
- Fixed bug with comparing an indexed `NULL` field with `<=> NULL`.
- Fixed bug that caused `IGNORE INDEX` and `USE INDEX` sometimes to be ignored.
- Fixed rare core dump problem in complicated `GROUP BY` queries that didn't return any result.
- Fixed a bug where `MATCH ... AGAINST () >=0` was treated as if it was `>`.
- Fixed core dump in `SHOW PROCESSLIST` when running with an active slave (unlikely timing bug).
- Make it possible to use multiple MySQL servers on Windows (code backported from 4.0.2).
- One can create `TEMPORARY MERGE` tables now.
- Fixed that `--core-file` works on Linux (at least on kernel 2.4.18).
- Fixed a problem with `BDB` and `ALTER TABLE`.
- Fixed reference to freed memory when doing complicated `GROUP BY ... ORDER BY` queries. Symptom was that `mysqld` died in function `send_fields`.
- Allocate heap rows in smaller blocks to get better memory usage.
- Fixed memory allocation bug when storing `BLOB` values in internal temporary tables used for some (unlikely) `GROUP BY` queries.
- Fixed a bug in key optimising handling where the expression `WHERE column_name = key_column_name` was calculated as true for `NULL` values.
- Fixed core dump bug when doing `LEFT JOIN ... WHERE key_column=NULL`.
- Fixed `MyISAM` crash when using dynamic-row tables with huge numbers of packed fields.
- Updated source tree to be built using `automake 1.5` and `libtool 1.4`.

D.4.7 Changes in release 3.23.53 (09 Oct 2002)

- Fixed crash when `SHOW INNODB STATUS` was used and `skip-innodb` was defined.
- Fixed possible memory corruption bug in binary log file handling when slave rotated the logs (only affected 3.23, not 4.0).
- Fixed problem in `LOCK TABLES` on Windows when one connects to a database that contains upper case letters.
- Fixed that `--skip-show-databases` doesn't reset the `--port` option.
- Small fix in `safe_mysqld` for some shells.
- Fixed that `FLUSH STATUS` doesn't reset `delayed_insert_threads`.
- Fixed core dump bug when using the `BINARY` cast on a `NULL` value.
- Fixed race condition when someone did a `GRANT` at the same time a new user logged in or did a `USE database`.
- Fixed bug in `ALTER TABLE` and `RENAME TABLE` when running with `-O lower_case_table_names=1` (typically on Windows) when giving the table name in uppercase.

- Fixed that `-O lower_case_table_names=1` also converts database names to lower case.
- Fixed unlikely core dump with `SELECT ... ORDER BY ... LIMIT`.
- Changed `AND/OR` to report that they can return NULL. This fixes a bug in `GROUP BY` on `AND/OR` expressions that return `NULL`.
- Fixed a bug that `OPTIMIZE` of locked and modified MyISAM table, reported table corruption.
- Fixed a `BDB`-related `ALTER TABLE` bug with dropping a column and shutting down immediately thereafter.
- Fixed problem with `configure ... --localstatedir=...`.
- Fixed problem with `UNSIGNED BIGINT` on AIX (again).
- Fixed bug in pthread_mutex_trylock() on HPUX 11.0.
- Multi-threaded stress tests for `InnoDB`.

D.4.8 Changes in release 3.23.52 (14 Aug 2002)

- Wrap `BEGIN/COMMIT` around transaction in the binary log. This makes replication honour transactions.
- Fixed security bug when having an empty database name in the `user.db` table.
- Changed initialisation of `RND()` to make it less predicatable.
- Fixed problem with `GROUP BY` on result with expression that created a `BLOB` field.
- Fixed problem with `GROUP BY` on columns that have `NULL` values. To solve this we now create an `MyISAM` temporary table when doing a `GROUP BY` on a possible `NULL` item. From MySQL 4.0.5 we can use in memory `HEAP` tables for this case.
- Fixed problem with privilege tables when downgrading from 4.0.2 to 3.23.
- Fixed thread bug in `SLAVE START`, `SLAVE STOP` and automatic repair of MyISAM tables that could cause table cache to be corrupted.
- Fixed possible thread related key-cache-corruption problem with `OPTIMIZE TABLE` and `REPAIR TABLE`.
- Added name of 'administrator command' logs.
- Fixed bug with creating an auto-increment value on second part of a `UNIQUE()` key where first part could contain `NULL` values.
- Don't write slave-timeout reconnects to the error log.
- Fixed bug with slave net read timeouting
- Fixed a core-dump bug with `MERGE` tables and `MAX()` function.
- Fixed bug in `ALTER TABLE` with `BDB` tables.
- Fixed bug when logging `LOAD DATA INFILE` to binary log with no active database.
- Fixed a bug in range optimiser (causing crashes).
- Fixed possible problem in replication when doing `DROP DATABASE` on a database with `InnoDB` tables.
- Fixed that `mysql_info()` returns 0 for 'Duplicates' when using `INSERT DELAYED IGNORE`.
- Added `-DHAVE_BROKEN_REALPATH` to the Mac OS X (darwin) compile options in '`configure.in`' to fix a failure under high load.

D.4.9 Changes in release 3.23.51 (31 May 2002)

- Fix bug with closing tags missing slash for `mysqldump` XML output.
- Remove end space from `ENUM` values. (This fixed a problem with `SHOW CREATE TABLE`.)
- Fixed bug in `CONCAT_WS()` that cut the result.
- Changed name of server variables `Com_show_master_stat` to `Com_show_master_status` and `Com_show_slave_stat` to `Com_show_slave_status`.
- Changed handling of `gethostbyname()` to make the client library thread-safe even if `gethostbyname_r` doesn't exist.
- Fixed core-dump problem when giving a wrong password string to `GRANT`.
- Fixed bug in `DROP DATABASE` with symlinked directory.
- Fixed optimisation problem with `DATETIME` and value outside `DATETIME` range.
- Removed Sleepycat's `BDB` doc files from the source tree, as they're not needed (MySQL covers `BDB` in its own documentation).
- Fixed MIT-pthreads to compile with `glibc` 2.2 (needed for `make dist`).
- Fixed the `FLOAT(X+1,X)` is not converted to `FLOAT(X+2,X)`. (This also affected `DECIMAL`, `DOUBLE` and `REAL` types)
- Fixed the result from `IF()` is case in-sensitive if the second and third arguments are case sensitive.
- Fixed core dump problem on OSF/1 in `gethostbyname_r`.
- Fixed that underflowed decimal fields are not zero filled.
- If we get an overflow when inserting `'+11111'` for `DECIMAL(5,0) UNSIGNED` columns, we will just drop the sign.
- Fixed optimisation bug with `ISNULL(expression_which_cannot_be_null)` and `ISNULL(constant_expression)`.
- Fixed host lookup bug in the `glibc` library that we used with the 3.23.50 Linux-x86 binaries.

D.4.10 Changes in release 3.23.50 (21 Apr 2002)

- Fixed buffer overflow problem if someone specified a too long datadir parameter to mysqld
- Add missing `<row>` tags for `mysqldump` XML output.
- Fixed problem with `crash-me` and `gcc` 3.0.4.
- Fixed that `@@unknown_variable` doesn't hang server.
- Added `@@VERSION` as a synonym for `VERSION()`.
- `SHOW VARIABLES LIKE 'xxx'` is now case-insensitive.
- Fixed timeout for `GET_LOCK()` on HP-UX with DCE threads.
- Fixed memory allocation bug in the glibc library used to build Linux binaries, which caused mysqld to die in 'free()'.
- Fixed `SIGINT` and `SIGQUIT` problems in `mysql`.

- Fixed bug in character table converts when used with big (> 64K) strings.
- InnoDB now retains foreign key constraints through ALTER TABLE and CREATE/DROP INDEX.
- InnoDB now allows foreign key constraints to be added through the ALTER TABLE syntax.
- InnoDB tables can now be set to automatically grow in size (autoextend).
- Our Linux RPMS and binaries are now compiled with gcc 3.0.4, which should make them a bit faster.
- Fixed some buffer overflow problems when reading startup parameters.
- Because of problems on shutdown we have now disabled named pipes on Windows by default. One can enable named pipes by starting mysqld with --enable-named-pipe.
- Fixed bug when using WHERE key_column = 'J' or key_column='j'.
- Fixed core-dump bug when using --log-bin with LOAD DATA INFILE without an active database.
- Fixed bug in RENAME TABLE when used with lower_case_table_names=1 (default on Windows).
- Fixed unlikely core-dump bug when using DROP TABLE on a table that was in use by a thread that also used queries on only temporary tables.
- Fixed problem with SHOW CREATE TABLE and PRIMARY KEY when using 32 indexes.
- Fixed that one can use SET PASSWORD for the anonymous user.
- Fixed core dump bug when reading client groups from option files using mysql_options().
- Memory leak (16 bytes per every **corrupted** table) closed.
- Fixed binary builds to use --enable-local-infile.
- Update source to work with new version of bison.
- Updated shell scripts to now agree with new POSIX standard.
- Fixed bug where DATE_FORMAT() returned empty string when used with GROUP BY.

D.4.11 Changes in release 3.23.49

- Don't give warning for a statement that is only a comment; this is needed for mysqldump --disable-keys to work.
- Fixed unlikely caching bug when doing a join without keys. In this case the last used field for a table always returned NULL.
- Added options to make LOAD DATA LOCAL INFILE more secure.
- MySQL binary release 3.23.48 for Linux contained a new glibc library, which has serious problems under high load and Red Hat 7.2. The 3.23.49 binary release doesn't have this problem.
- Fixed shutdown problem on NT.

D.4.12 Changes in release 3.23.48 (07 Feb 2002)

- Added --xml option to mysqldump for producing XML output.

- Changed to use `autoconf` 2.52 (from `autoconf` 2.13)
- Fixed bug in complicated join with `const` tables.
- Added internal safety checks for `InnoDB`.
- Some `InnoDB` variables were always shown in `SHOW VARIABLES` as `OFF` on high-byte-first systems (like SPARC).
- Fixed problem with one thread using an `InnoDB` table and another thread doing an `ALTER TABLE` on the same table. Before that, `mysqld` could crash with an assertion failure in '`row0row.c`', line 474.
- Tuned the `InnoDB` SQL optimiser to favor index searches more often over table scans.
- Fixed a performance problem with `InnoDB` tables when several large `SELECT` queries are run concurrently on a multiprocessor Linux computer. Large CPU-bound `SELECT` queries will now also generally run faster on all platforms.
- If MySQL binlogging is used, `InnoDB` now prints after crash recovery the latest MySQL binlog name and the offset `InnoDB` was able to recover to. This is useful, for example, when resynchronising a master and a slave database in replication.
- Added better error messages to help in installation problems of `InnoDB` tables.
- It is now possible to recover MySQL temporary tables that have become orphaned inside the `InnoDB` tablespace.
- `InnoDB` now prevents a `FOREIGN KEY` declaration where the signedness is not the same in the referencing and referenced integer columns.
- Calling `SHOW CREATE TABLE` or `SHOW TABLE STATUS` could cause memory corruption and make `mysqld` crash. Especially at risk was `mysqldump`, because it frequently calls `SHOW CREATE TABLE`.
- If inserts to several tables containing an `AUTO_INCREMENT` column were wrapped inside one `LOCK TABLES`, `InnoDB` asserted in '`lock0lock.c`'.
- In 3.23.47 we allowed several `NULL` values in a `UNIQUE` secondary index for an `InnoDB` table. But `CHECK TABLE` was not relaxed: it reports the table as corrupt. `CHECK TABLE` no longer complains in this situation.
- `SHOW GRANTS` now shows `REFERENCES` instead of `REFERENCE`.

D.4.13 Changes in release 3.23.47 (27 Dec 2001)

- Fixed bug when using the following construct: `SELECT ... WHERE key=@var_name OR key=@var_name2`
- Restrict `InnoDB` keys to 500 bytes.
- `InnoDB` now supports `NULL` in keys.
- Fixed shutdown problem on HP-UX. (Introduced in 3.23.46)
- Fixed core dump bug in replication when using `SELECT RELEASE_LOCK()`.
- Added new command: `DO expression,[expression]`
- Added `slave-skip-errors` option.
- Added statistics variables for all MySQL commands. (`SHOW STATUS` is now much longer.)

- Fixed default values for `InnoDB` tables.
- Fixed that `GROUP BY expr DESC` works.
- Fixed bug when using `t1 LEFT JOIN t2 ON t2.key=constant`.
- `mysql_config` now also works with binary (relocated) distributions.

D.4.14 Changes in release 3.23.46 (29 Nov 2001)

- Fixed problem with aliased temporary table replication.
- `InnoDB` and `BDB` tables will now use index when doing an `ORDER BY` on the whole table.
- Fixed bug where one got an empty set instead of a DEADLOCK error when using `BDB` tables.
- One can now kill `ANALYZE`, `REPAIR`, and `OPTIMIZE TABLE` when the thread is waiting to get a lock on the table.
- Fixed race condition in `ANALYZE TABLE`.
- Fixed bug when joining with caching (unlikely to happen).
- Fixed race condition when using the binary log and `INSERT DELAYED` which could cause the binary log to have rows that were not yet written to `MyISAM` tables.
- Changed caching of binary log to make replication slightly faster.
- Fixed bug in replication on Mac OS X.

D.4.15 Changes in release 3.23.45 (22 Nov 2001)

- `(UPDATE|DELETE) ...WHERE MATCH` bugfix.
- shutdown should now work on Darwin (Mac OS X).
- Fixed core dump when repairing corrupted packed `MyISAM` files.
- `--core-file` now works on Solaris.
- Fix a bug which could cause `InnoDB` to complain if it cannot find free blocks from the buffer cache during recovery.
- Fixed bug in `InnoDB` insert buffer B-tree handling that could cause crashes.
- Fixed bug in `InnoDB` lock timeout handling.
- Fixed core dump bug in `ALTER TABLE` on a `TEMPORARY InnoDB` table.
- Fixed bug in `OPTIMIZE TABLE` that reset index cardinality if it was up to date.
- Fixed problem with `t1 LEFT_JOIN t2 ... WHERE t2.date_column IS NULL` when date_column was declared as `NOT NULL`.
- Fixed bug with `BDB` tables and keys on `BLOB` columns.
- Fixed bug in `MERGE` tables on OS with 32-bit file pointers.
- Fixed bug in `TIME_TO_SEC()` when using negative values.

D.4.16 Changes in release 3.23.44 (31 Oct 2001)

- Fixed `Rows_examined` count in slow query log.
- Fixed bug when using a reference to an `AVG()` column in `HAVING`.

- Fixed that date functions that require correct dates, like `DAYOFYEAR(column)`, will return `NULL` for `0000-00-00` dates.
- Fixed bug in const-propagation when comparing columns of different types. (`SELECT * FROM date_col="2001-01-01" and date_col=time_col`)
- Fixed bug that caused error message `Can't write, because of unique constraint` with some `GROUP BY` queries.
- Fixed problem with `sjis` character strings used within quoted table names.
- Fixed core dump when using `CREATE ... FULLTEXT` keys with other storage engines than `MyISAM`.
- Don't use `signal()` on Windows because this appears to not be 100% reliable.
- Fixed bug when doing `WHERE col_name=NULL` on an indexed column that had `NULL` values.
- Fixed bug when doing `LEFT JOIN ... ON (col_name = constant) WHERE col_name = constant`.
- When using replications, aborted queries that contained `%` could cause a core dump.
- `TCP_NODELAY` was not used on some systems. (Speed problem.)
- Applied portability fixes for OS/2. (Patch by Yuri Dario.)

The following changes are for `InnoDB` tables:

- Add missing `InnoDB` variables to `SHOW VARIABLES`.
- Foreign keys checking is now done for `InnoDB` tables.
- `DROP DATABASE` now works also for `InnoDB` tables.
- `InnoDB` now supports datafiles and raw disk partitions bigger than 4 GB on those operating systems that have big files.
- `InnoDB` calculates better table cardinality estimates for the MySQL optimiser.
- Accent characters in the default character set `latin1` are ordered according to the MySQL ordering.

  Note: if you are using `latin1` and have inserted characters whose code is greater than 127 into an indexed `CHAR` column, you should run `CHECK TABLE` on your table when you upgrade to 3.23.44, and drop and reimport the table if `CHECK TABLE` reports an error!
- A new '`my.cnf`' parameter, `innodb_thread_concurrency`, helps in performance tuning in heavily concurrent environments.
- A new '`my.cnf`' parameter, `innodb_fast_shutdown`, speeds up server shutdown.
- A new '`my.cnf`' parameter, `innodb_force_recovery`, helps to save your data in case the disk image of the database becomes corrupt.
- `innodb_monitor` has been improved and a new `innodb_table_monitor` added.
- Increased maximum key length from 500 to 7000 bytes.
- Fixed a bug in replication of `AUTO_INCREMENT` columns with multiple-line inserts.
- Fixed a bug when the case of letters changes in an update of an indexed secondary column.
- Fixed a hang when there are > 24 datafiles.

- Fixed a crash when `MAX(col)` is selected from an empty table, and `col` is not the first column in a multi-column index.
- Fixed a bug in purge which could cause crashes.

D.4.17 Changes in release 3.23.43 (04 Oct 2001)

- Fixed a bug in `INSERT DELAYED` and `FLUSH TABLES` introduced in 3.23.42.
- Fixed unlikely bug, which returned non-matching rows, in `SELECT` with many tables and multi-column indexes and 'range' type.
- Fixed an unlikely core dump bug when doing `EXPLAIN SELECT` when using many tables and `ORDER BY`.
- Fixed bug in `LOAD DATA FROM MASTER` when using table with `CHECKSUM=1`.
- Added unique error message when one gets a DEADLOCK during a transaction with `BDB` tables.
- Fixed problem with `BDB` tables and `UNIQUE` columns defined as `NULL`.
- Fixed problem with `myisampack` when using pre-space filled `CHAR` columns.
- Applied patch from Yuri Dario for OS/2.
- Fixed bug in `--safe-user-create`.

D.4.18 Changes in release 3.23.42 (08 Sep 2001)

- Fixed problem when using `LOCK TABLES` and `BDB` tables.
- Fixed problem with `REPAIR TABLE` on `MyISAM` tables with row lengths in the range from 65517 to 65520 bytes.
- Fixed rare hang when doing `mysqladmin shutdown` when there was a lot of activity in other threads.
- Fixed problem with `INSERT DELAYED` where delay thread could be hanging on `upgrading locks` with no apparent reason.
- Fixed problem with `myisampack` and `BLOB`.
- Fixed problem when one edited '`.MRG`' tables by hand. (Patch from Benjamin Pflugmann).
- Enforce that all tables in a `MERGE` table come from the same database.
- Fixed bug with `LOAD DATA INFILE` and transactional tables.
- Fix bug when using `INSERT DELAYED` with wrong column definition.
- Fixed core dump during `REPAIR` of some particularly broken tables.
- Fixed bug in `InnoDB` and `AUTO_INCREMENT` columns.
- Fixed bug in `InnoDB` and `RENAME TABLE` columns.
- Fixed critical bug in `InnoDB` and `BLOB` columns. If you have used `BLOB` columns larger than 8000 bytes in an `InnoDB` table, it is necessary to dump the table with `mysqldump`, drop it and restore it from the dump.
- Applied large patch for OS/2 from Yuri Dario.

- Fixed problem with `InnoDB` when one could get the error `Can't execute the given command...` even when no transaction was active.
- Applied some minor fixes that concern Gemini.
- Use real arithmetic operations even in integer context if not all arguments are integers. (Fixes uncommon bug in some integer contexts).
- Don't force everything to lowercase on Windows. (To fix problem with Windows and `ALTER TABLE`). Now `--lower_case_names` also works on Unix.
- Fixed that automatic rollback is done when thread end doesn't lock other threads.

D.4.19 Changes in release 3.23.41 (11 Aug 2001)

- Added `--sql-mode=value[,value[,value]]` option to `mysqld`. See Section 4.1.1 [Command-line options], page 195.
- Fixed possible problem with `shutdown` on Solaris where the '`.pid`' file wasn't deleted.
- `InnoDB` now supports < 4 GB rows. The former limit was 8000 bytes.
- The `doublewrite` file flush method is used in `InnoDB`. It reduces the need for Unix `fsync()` calls to a fraction and improves performance on most Unix flavors.
- You can now use the `InnoDB` Monitor to print a lot of `InnoDB` state information, including locks, to the standard output. This is useful in performance tuning.
- Several bugs which could cause hangs in `InnoDB` have been fixed.
- Split `record_buffer` to `record_buffer` and `record_rnd_buffer`. To make things compatible to previous MySQL versions, if `record_rnd_buffer` is not set, then it takes the value of `record_buffer`.
- Fixed optimising bug in `ORDER BY` where some `ORDER BY` parts where wrongly removed.
- Fixed overflow bug with `ALTER TABLE` and `MERGE` tables.
- Added prototypes for `my_thread_init()` and `my_thread_end()` to '`mysql_com.h`'
- Added `--safe-user-create` option to `mysqld`.
- Fixed bug in `SELECT DISTINCT ... HAVING` that caused error message `Can't find record in #...`

D.4.20 Changes in release 3.23.40

- Fixed problem with `--low-priority-updates` and `INSERT` statements.
- Fixed bug in slave thread when under some rare circumstances it could get 22 bytes ahead on the offset in the master.
- Added `slave_net_timeout` for replication.
- Fixed problem with `UPDATE` and `BDB` tables.
- Fixed hard bug in `BDB` tables when using key parts.
- Fixed problem when using `GRANT FILE ON database.* ...`; previously we added the `DROP` privilege for the database.
- Fixed `DELETE FROM tbl_name ... LIMIT 0` and `UPDATE FROM tbl_name ... LIMIT 0`, which acted as though the `LIMIT` clause was not present (they deleted or updated all selected rows).

- `CHECK TABLE` now checks if an `AUTO_INCREMENT` column contains the value 0.
- Sending a `SIGHUP` to `mysqld` will now only flush the logs, not reset the replication.
- Fixed parser to allow floats of type `1.0e1` (no sign after `e`).
- Option `--force` to `myisamchk` now also updates states.
- Added option `--warnings` to `mysqld`. Now `mysqld` prints the error `Aborted connection` only if this option is used.
- Fixed problem with `SHOW CREATE TABLE` when you didn't have a `PRIMARY KEY`.
- Properly fixed the rename of `innodb_unix_file_flush_method` variable to `innodb_flush_method`.
- Fixed bug when converting `BIGINT UNSIGNED` to `DOUBLE`. This caused a problem when doing comparisons with `BIGINT` values outside of the signed range.
- Fixed bug in `BDB` tables when querying empty tables.
- Fixed a bug when using `COUNT(DISTINCT)` with `LEFT JOIN` and there weren't any matching rows.
- Removed all documentation referring to the `GEMINI` table type. `GEMINI` is not released under an `Open Source` license.

D.4.21 Changes in release 3.23.39 (12 Jun 2001)

- The `AUTO_INCREMENT` sequence wasn't reset when dropping and adding an `AUTO_INCREMENT` column.
- `CREATE ... SELECT` now creates non-unique indexes delayed.
- Fixed problem where `LOCK TABLES tbl_name READ` followed by `FLUSH TABLES` put an exclusive lock on the table.
- `REAL @variable` values were represented with only 2 digits when converted to strings.
- Fixed problem that client "hung" when `LOAD TABLE FROM MASTER` failed.
- `myisamchk --fast --force` will no longer repair tables that only had the open count wrong.
- Added functions to handle symbolic links to make life easier in 4.0.
- We are now using the `-lcma` thread library on HP-UX 10.20 so that MySQL will be more stable on HP-UX.
- Fixed problem with `IF()` and number of decimals in the result.
- Fixed date-part extraction functions to work with dates where day and/or month is 0.
- Extended argument length in option files from 256 to 512 chars.
- Fixed problem with shutdown when `INSERT DELAYED` was waiting for a `LOCK TABLE`.
- Fixed core dump bug in `InnoDB` when tablespace was full.
- Fixed problem with `MERGE` tables and big tables (> 4G) when using `ORDER BY`.

D.4.22 Changes in release 3.23.38 (09 May 2001)

- Fixed a bug when `SELECT` from `MERGE` table sometimes results in incorrectly ordered rows.

- Fixed a bug in `REPLACE()` when using the `ujis` character set.
- Applied Sleepycat `BDB` patches 3.2.9.1 and 3.2.9.2.
- Added `--skip-stack-trace` option to `mysqld`.
- `CREATE TEMPORARY` now works with `InnoDB` tables.
- `InnoDB` now promotes sub keys to whole keys.
- Added option `CONCURRENT` to `LOAD DATA`.
- Better error message when slave `max_allowed_packet` is too low to read a very long log event from the master.
- Fixed bug when too many rows where removed when using `SELECT DISTINCT ... HAVING`.
- `SHOW CREATE TABLE` now returns `TEMPORARY` for temporary tables.
- Added `Rows_examined` to slow query log.
- Fixed problems with function returning empty string when used together with a group function and a `WHERE` that didn't match any rows.
- New program `mysqlcheck`.
- Added database name to output for administrative commands like `CHECK`, `REPAIR`, `OPTIMIZE`.
- Lots of portability fixes for `InnoDB`.
- Changed optimiser so that queries like `SELECT * FROM tbl_name,tbl_name2 ... ORDER BY key_part1 LIMIT row_count` will use index on `key_part1` instead of `filesort`.
- Fixed bug when doing `LOCK TABLE to_table WRITE,...; INSERT INTO to_table... SELECT ...` when `to_table` was empty.
- Fixed bug with `LOCK TABLE` and `BDB` tables.

D.4.23 Changes in release 3.23.37 (17 Apr 2001)

- Fixed a bug when using `MATCH()` in `HAVING` clause.
- Fixed a bug when using `HEAP` tables with `LIKE`.
- Added `--mysql-version` option to `safe_mysqld`
- Changed `INNOBASE` to `InnoDB` (because the `INNOBASE` name was already used). All `configure` options and `mysqld` start options now use `innodb` instead of `innobase`. This means that before upgrading to this version, you have to change any configuration files where you have used `innobase` options!
- Fixed bug when using indexes on `CHAR(255) NULL` columns.
- Slave thread will now be started even if `master-host` is not set, as long as `server-id` is set and valid '`master.info`' is present.
- Partial updates (terminated with kill) are now logged with a special error code to the binary log. Slave will refuse to execute them if the error code indicates the update was terminated abnormally, and will have to be recovered with `SET SQL_SLAVE_SKIP_COUNTER=1; SLAVE START` after a manual sanity check/correction of data integrity.
- Fixed bug that erroneously logged a drop of internal temporary table on thread termination to the binary log — this bug affected replication.

- Fixed a bug in `REGEXP` on 64-bit machines.
- `UPDATE` and `DELETE` with `WHERE unique_key_part IS NULL` didn't update/delete all rows.
- Disabled `INSERT DELAYED` for tables that support transactions.
- Fixed bug when using date functions on `TEXT`/`BLOB` column with wrong date format.
- UDFs now also work on Windows. (Patch by Ralph Mason.)
- Fixed bug in `ALTER TABLE` and `LOAD DATA INFILE` that disabled key-sorting. These commands should now be faster in most cases.
- Fixed performance bug where reopened tables (tables that had been waiting for `FLUSH` or `REPAIR`) would not use indexes for the next query.
- Fixed problem with `ALTER TABLE` to `InnoDB` tables on FreeBSD.
- Added `mysqld` variables `myisam_max_sort_file_size` and `myisam_max_extra_sort_file_size`.
- Initialise signals early to avoid problem with signals in `InnoDB`.
- Applied patch for the `tis620` character set to make comparisons case-independent and to fix a bug in `LIKE` for this character set. **Note**: All tables that uses the `tis620` character set must be fixed with `myisamchk -r` or `REPAIR TABLE` !
- Added `--skip-safemalloc` option to `mysqld`.

D.4.24 Changes in release 3.23.36 (27 Mar 2001)

- Fixed a bug that allowed use of database names containing a '`.`' character. This fixes a serious security issue when `mysqld` is run as root.
- Fixed bug when thread creation failed (could happen when doing a **lot** of connections in a short time).
- Fixed some problems with `FLUSH TABLES` and `TEMPORARY` tables. (Problem with freeing the key cache and error `Can't reopen table...`.)
- Fixed a problem in `InnoDB` with other character sets than `latin1` and another problem when using many columns.
- Fixed bug that caused a core dump when using a very complex query involving `DISTINCT` and summary functions.
- Added `SET TRANSACTION ISOLATION LEVEL ...`
- Added `SELECT ... FOR UPDATE`.
- Fixed bug where the number of affected rows was not returned when MySQL was compiled without transaction support.
- Fixed a bug in `UPDATE` where keys weren't always used to find the rows to be updated.
- Fixed a bug in `CONCAT_WS()` where it returned incorrect results.
- Changed `CREATE ... SELECT` and `INSERT ... SELECT` to not allow concurrent inserts as this could make the binary log hard to repeat. (Concurrent inserts are enabled if you are not using the binary or update log.)
- Changed some macros to be able to use fast mutex with `glibc` 2.2.

D.4.25 Changes in release 3.23.35 (15 Mar 2001)

- Fixed newly introduced bug in `ORDER BY`.
- Fixed wrong define `CLIENT_TRANSACTIONS`.
- Fixed bug in `SHOW VARIABLES` when using `INNOBASE` tables.
- Setting and using user variables in `SELECT DISTINCT` didn't work.
- Tuned `SHOW ANALYZE` for small tables.
- Fixed handling of arguments in the benchmark script `run-all-tests`.

D.4.26 Changes in release 3.23.34a

- Added extra files to the distribution to allow `INNOBASE` support to be compiled.

D.4.27 Changes in release 3.23.34 (10 Mar 2001)

- Added the `INNOBASE` storage engine and the `BDB` storage engine to the MySQL source distribution.
- Updated the documentation about `GEMINI` tables.
- Fixed a bug in `INSERT DELAYED` that caused threads to hang when inserting `NULL` into an `AUTO_INCREMENT` column.
- Fixed a bug in `CHECK TABLE` / `REPAIR TABLE` that could cause a thread to hang.
- `REPLACE` will not replace a row that conflicts with an `AUTO_INCREMENT` generated key.
- `mysqld` now only sets `CLIENT_TRANSACTIONS` in `mysql->server_capabilities` if the server supports a transaction-safe storage engine.
- Fixed `LOAD DATA INFILE` to allow numeric values to be read into `ENUM` and `SET` columns.
- Improved error diagnostic for slave thread exit.
- Fixed bug in `ALTER TABLE ... ORDER BY`.
- Added `max_user_connections` variable to `mysqld`.
- Limit query length for replication by `max_allowed_packet`, not the arbitrary limit of 4 MB.
- Allow space around `=` in argument to `--set-variable`.
- Fixed problem in automatic repair that could leave some threads in state `Waiting for table`.
- `SHOW CREATE TABLE` now displays the `UNION=()` for `MERGE` tables.
- `ALTER TABLE` now remembers the old `UNION=()` definition.
- Fixed bug when replicating timestamps.
- Fixed bug in bidirectional replication.
- Fixed bug in the `BDB` storage engine that occurred when using an index on multi-part key where a key part may be `NULL`.
- Fixed `MAX()` optimisation on sub-key for `BDB` tables.
- Fixed problem where garbage results were returned when using `BDB` tables and `BLOB` or `TEXT` fields when joining many tables.

- Fixed a problem with `BDB` tables and `TEXT` columns.
- Fixed bug when using a `BLOB` key where a const row wasn't found.
- Fixed that `mysqlbinlog` writes the timestamp value for each query. This ensures that one gets same values for date functions like `NOW()` when using `mysqlbinlog` to pipe the queries to another server.
- Allow `--skip-gemini`, `--skip-bdb`, and `--skip-innodb` options to be specified when invoking `mysqld`, even if these storage engines are not compiled in to `mysqld`.
- One can now do `GROUP BY ... DESC`.
- Fixed a deadlock in the `SET` code, when one ran `SET @foo=bar`, where `bar` is a column reference, an error was not properly generated.

D.4.28 Changes in release 3.23.33 (09 Feb 2001)

- Fixed DNS lookups not to use the same mutex as the hostname cache. This will enable known hosts to be quickly resolved even if a DNS lookup takes a long time.
- Added `--character-sets-dir` option to `myisampack`.
- Removed warnings when running `REPAIR TABLE ... EXTENDED`.
- Fixed a bug that caused a core dump when using `GROUP BY` on an alias, where the alias was the same as an existing column name.
- Added `SEQUENCE()` as an example UDF function.
- Changed `mysql_install_db` to use `BINARY` for `CHAR` columns in the privilege tables.
- Changed `TRUNCATE tbl_name` to `TRUNCATE TABLE tbl_name` to use the same syntax as Oracle. Until 4.0 we will also allow `TRUNCATE tbl_name` to not crash old code.
- Fixed "no found rows" bug in `MyISAM` tables when a `BLOB` was first part of a multi-part key.
- Fixed bug where `CASE` didn't work with `GROUP BY`.
- Added `--sort-recover` option to `myisamchk`.
- `myisamchk -S` and `OPTIMIZE TABLE` now work on Windows.
- Fixed bug when using `DISTINCT` on results from functions that referred to a group function, like:

```
SELECT a, DISTINCT SEC_TO_TIME(SUM(a))
FROM tbl_name GROUP BY a, b;
```

- Fixed buffer overrun in `libmysqlclient` library. Fixed bug in handling `STOP` event after `ROTATE` event in replication.
- Fixed another buffer overrun in `DROP DATABASE`.
- Added `Table_locks_immediate` and `Table_locks_waited` status variables.
- Fixed bug in replication that broke slave server start with existing '`master.info`'. This fixes a bug introduced in 3.23.32.
- Added `SET SQL_SLAVE_SKIP_COUNTER=n` command to recover from replication glitches without a full database copy.
- Added `max_binlog_size` variable; the binary log will be rotated automatically when the size crosses the limit.

- Added `Last_error`, `Last_errno`, and `Slave_skip_counter` variables to `SHOW SLAVE STATUS`.
- Fixed bug in `MASTER_POS_WAIT()` function.
- Execute core dump handler on `SIGILL`, and `SIGBUS` in addition to `SIGSEGV`.
- On x86 Linux, print the current query and thread (connection) id, if available, in the core dump handler.
- Fixed several timing bugs in the test suite.
- Extended `mysqltest` to take care of the timing issues in the test suite.
- `ALTER TABLE` can now be used to change the definition for a `MERGE` table.
- Fixed creation of `MERGE` tables on Windows.
- Portability fixes for OpenBSD and OS/2.
- Added `--temp-pool` option to `mysqld`. Using this option will cause most temporary files created to use a small set of names, rather than a unique name for each new file. This is to work around a problem in the Linux kernel dealing with creating a bunch of new files with different names. With the old behaviour, Linux seems to "leak" memory, as it's being allocated to the directory entry cache instead of the disk cache.

D.4.29 Changes in release 3.23.32 (22 Jan 2001: Production)

- Changed code to get around compiler bug in Compaq C++ on OSF/1, that broke `BACKUP`, `RESTORE`, `CHECK`, `REPAIR`, and `ANALYZE TABLE`.
- Added option `FULL` to `SHOW COLUMNS`. Now we show the privilege list for the columns only if this option is given.
- Fixed bug in `SHOW LOGS` when there weren't any `BDB` logs.
- Fixed a timing problem in replication that could delay sending an update to the client until a new update was done.
- Don't convert field names when using `mysql_list_fields()`. This is to keep this code compatible with `SHOW FIELDS`.
- `MERGE` tables didn't work on Windows.
- Fixed problem with `SET PASSWORD=...` on Windows.
- Added missing '`my_config.h`' to RPM distribution.
- `TRIM("foo" from "foo")` didn't return an empty string.
- Added `--with-version-suffix` option to `configure`.
- Fixed core dump when client aborted connection without `mysql_close()`.
- Fixed a bug in `RESTORE TABLE` when trying to restore from a non-existent directory.
- Fixed a bug which caused a core dump on the slave when replicating `SET PASSWORD`.
- Added `MASTER_POS_WAIT()`.

D.4.30 Changes in release 3.23.31 (17 Jan 2001)

- The test suite now tests all reachable `BDB` interface code. During testing we found and fixed many errors in the interface code.

- Using `HAVING` on an empty table could produce one result row when it shouldn't.
- Fixed the MySQL RPM so it no longer depends on Perl5.
- Fixed some problems with `HEAP` tables on Windows.
- `SHOW TABLE STATUS` didn't show correct average row length for tables larger than 4G.
- `CHECK TABLE ... EXTENDED` didn't check row links for fixed size tables.
- Added option `MEDIUM` to `CHECK TABLE`.
- Fixed problem when using `DECIMAL()` keys on negative numbers.
- `HOUR()` (and some other `TIME` functions) on a `CHAR` column always returned `NULL`.
- Fixed security bug in something (please upgrade if you are using an earlier MySQL 3.23 version).
- Fixed buffer overflow bug when writing a certain error message.
- Added usage of `setrlimit()` on Linux to get `-O --open-files-limit=#` to work on Linux.
- Added `bdb_version` variable to `mysqld`.
- Fixed bug when using expression of type:

  ```
  SELECT ... FROM t1 LEFT JOIN t2 ON (t1.a=t2.a) WHERE t1.a=t2.a
  ```

  In this case the test in the `WHERE` clause was wrongly optimised away.
- Fixed bug in `MyISAM` when deleting keys with possible `NULL` values, but the first key-column was not a prefix-compressed text column.
- Fixed `mysql.server` to read the `[mysql.server]` option file group rather than the `[mysql_server]` group.
- Fixed `safe_mysqld` and `mysql.server` to also read the `server` option section.
- Added `Threads_created` status variable to `mysqld`.

D.4.31 Changes in release 3.23.30 (04 Jan 2001)

- Added `SHOW OPEN TABLES` command.
- Fixed that `myisamdump` works against old `mysqld` servers.
- Fixed `myisamchk -k#` so that it works again.
- Fixed a problem with replication when the binary log file went over 2G on 32-bit systems.
- `LOCK TABLES` will now automatically start a new transaction.
- Changed `BDB` tables to not use internal subtransactions and reuse open files to get more speed.
- Added `--mysqld=#` option to `safe_mysqld`.
- Allow hex constants in the `--fields-*-by` and `--lines-terminated-by` options to `mysqldump` and `mysqlimport`. By Paul DuBois.
- Added `--safe-show-database` option to `mysqld`.
- Added `have_bdb`, `have_gemini`, `have_innobase`, `have_raid` and `have_openssl` to `SHOW VARIABLES` to make it easy to test for supported extensions.
- Added `--open-files-limit` option to `mysqld`.

- Changed `--open-files` option to `--open-files-limit` in `safe_mysqld`.
- Fixed a bug where some rows were not found with `HEAP` tables that had many keys.
- Fixed that `--bdb-no-sync` works.
- Changed `--bdb-recover` to `--bdb-no-recover` as recover should be on by default.
- Changed the default number of `BDB` locks to 10000.
- Fixed a bug from 3.23.29 when allocating the shared structure needed for `BDB` tables.
- Changed `mysqld_multi.sh` to use configure variables. Patch by Christopher McCrory.
- Added fixing of include files for Solaris 2.8.
- Fixed bug with `--skip-networking` on Debian Linux.
- Fixed problem that some temporary files where reported as having the name `UNOPENED` in error messages.
- Fixed bug when running two simultaneous `SHOW LOGS` queries.

D.4.32 Changes in release 3.23.29 (16 Dec 2000)

- Configure updates for Tru64, large file support, and better TCP wrapper support. By Albert Chin-A-Young.
- Fixed bug in `<=>` operator.
- Fixed bug in `REPLACE` with `BDB` tables.
- `LPAD()` and `RPAD()` will shorten the result string if it's longer than the length argument.
- Added `SHOW LOGS` command.
- Remove unused `BDB` logs on shutdown.
- When creating a table, put `PRIMARY` keys first, followed by `UNIQUE` keys.
- Fixed a bug in `UPDATE` involving multi-part keys where one specified all key parts both in the update and the `WHERE` part. In this case MySQL could try to update a record that didn't match the whole `WHERE` part.
- Changed drop table to first drop the tables and then the '`.frm`' file.
- Fixed a bug in the hostname cache which caused `mysqld` to report the hostname as `''` in some error messages.
- Fixed a bug with `HEAP` type tables; the variable `max_heap_table_size` wasn't used. Now either `MAX_ROWS` or `max_heap_table_size` can be used to limit the size of a `HEAP` type table.
- Changed the default server-id to 1 for masters and 2 for slaves to make it easier to use the binary log.
- Renamed `bdb_lock_max` variable to `bdb_max_lock`.
- Added support for `AUTO_INCREMENT` on sub-fields for `BDB` tables.
- Added `ANALYZE` of `BDB` tables.
- In `BDB` tables, we now store the number of rows; this helps to optimise queries when we need an approximation of the number of rows.
- If we get an error in a multi-row statement, we now only roll back the last statement, not the entire transaction.

- If you do a `ROLLBACK` when you have updated a non-transactional table you will get an error as a warning.
- Added `--bdb-shared-data` option to `mysqld`.
- Added `Slave_open_temp_tables` status variable to `mysqld`
- Added `binlog_cache_size` and `max_binlog_cache_size` variables to `mysqld`.
- `DROP TABLE`, `RENAME TABLE`, `CREATE INDEX` and `DROP INDEX` are now transaction endpoints.
- If you do a `DROP DATABASE` on a symbolically linked database, both the link and the original database is deleted.
- Fixed `DROP DATABASE` to work on OS/2.
- Fixed bug when doing a `SELECT DISTINCT ... table1 LEFT JOIN table2 ...` when `table2` was empty.
- Added `--abort-slave-event-count` and `--disconnect-slave-event-count` options to `mysqld` for debugging and testing of replication.
- Fixed replication of temporary tables. Handles everything except slave server restart.
- `SHOW KEYS` now shows whether key is `FULLTEXT`.
- New script `mysqld_multi`. See Section 4.8.3 [mysqld_multi], page 313.
- Added new script, `mysql-multi.server.sh`. Thanks to Tim Bunce `Tim.Bunce@ig.co.uk` for modifying `mysql.server` to easily handle hosts running many `mysqld` processes.
- `safe_mysqld`, `mysql.server`, and `mysql_install_db` have been modified to use `mysql_print_defaults` instead of various hacks to read the '`my.cnf`' files. In addition, the handling of various paths has been made more consistent with how `mysqld` handles them by default.
- Automatically remove Berkeley DB transaction logs that no longer are in use.
- Fixed bug with several `FULLTEXT` indexes in one table.
- Added a warning if number of rows changes on `REPAIR`/`OPTIMIZE`.
- Applied patches for OS/2 by `Yuri Dario`.
- `FLUSH TABLES tbl_name` didn't always flush the index tree to disk properly.
- `--bootstrap` is now run in a separate thread. This fixes a problem that caused `mysql_install_db` to core dump on some Linux machines.
- Changed `mi_create()` to use less stack space.
- Fixed bug with optimiser trying to over-optimise `MATCH()` when used with `UNIQUE` key.
- Changed `crash-me` and the MySQL benchmarks to also work with FrontBase.
- Allow `RESTRICT` and `CASCADE` after `DROP TABLE` to make porting easier.
- Reset status variable which could cause problem if one used `--slow-log`.
- Added `connect_timeout` variable to `mysql` and `mysqladmin`.
- Added `connect-timeout` as an alias for `timeout` for option files read by `mysql_options()`.

D.4.33 Changes in release 3.23.28 (22 Nov 2000: Gamma)

- Added new options `--pager[=...]`, `--no-pager`, `--tee=...` and `--no-tee` to the `mysql` client. The new corresponding interactive commands are `pager`, `nopager`, `tee` and `notee`. See Section 4.9.2 [mysql], page 327, `mysql --help` and the interactive help for more information.
- Fixed crash when automatic repair of `MyISAM` table failed.
- Fixed a major performance bug in the table locking code when one constantly had a lot of `SELECT`, `UPDATE` and `INSERT` statements running. The symptom was that the `UPDATE` and `INSERT` queries were locked for a long time while new `SELECT` statements were executed before the updates.
- When reading `options_files` with `mysql_options()` the `return-found-rows` option was ignored.
- One can now specify `interactive-timeout` in the option file that is read by `mysql_options()`. This makes it possible to force programs that run for a long time (like `mysqlhotcopy`) to use the `interactive_timeout` time instead of the `wait_timeout` time.
- Added to the slow query log the time and the user name for each logged query. If you are using `--log-long-format` then also queries that do not use an index are logged, even if the query takes less than `long_query_time` seconds.
- Fixed a problem in `LEFT JOIN` which caused all columns in a reference table to be `NULL`.
- Fixed a problem when using `NATURAL JOIN` without keys.
- Fixed a bug when using a multi-part keys where the first part was of type `TEXT` or `BLOB`.
- `DROP` of temporary tables wasn't stored in the update/binary log.
- Fixed a bug where `SELECT DISTINCT * ... LIMIT row_count` only returned one row.
- Fixed a bug in the assembler code in `strstr()` for SPARC and cleaned up the '`global.h`' header file to avoid a problem with bad aliasing with the compiler submitted with Red Hat 7.0. (Reported by Trond Eivind Glomsrød)
- The `--skip-networking` option now works properly on NT.
- Fixed a long outstanding bug in the `ISAM` tables when a row with a length of more than 65K was shortened by a single byte.
- Fixed a bug in `MyISAM` when running multiple updating processes on the same table.
- Allow one to use `FLUSH TABLE tbl_name`.
- Added `--replicate-ignore-table`, `--replicate-do-table`, `--replicate-wild-ignore-table`, and `--replicate-wild-do-table` options to `mysqld`.
- Changed all log files to use our own `IO_CACHE` mechanism instead of `FILE` to avoid OS problems when there are many files open.
- Added `--open-files` and `--timezone` options to `safe_mysqld`.
- Fixed a fatal bug in `CREATE TEMPORARY TABLE ... SELECT ...`.
- Fixed a problem with `CREATE TABLE ... SELECT NULL`.
- Added variables `large_file_support`,`net_read_timeout`, `net_write_timeout` and `query_buffer_size` to `SHOW VARIABLES`.

- Added status variables `created_tmp_files` and `sort_merge_passes` to `SHOW STATUS`.
- Fixed a bug where we didn't allow an index name after the `FOREIGN KEY` definition.
- Added `TRUNCATE table_name` as a synonym for `DELETE FROM table_name`.
- Fixed a bug in a `BDB` key compare function when comparing part keys.
- Added `bdb_lock_max` variable to `mysqld`.
- Added more tests to the benchmark suite.
- Fixed an overflow bug in the client code when using overly long database names.
- `mysql_connect()` now aborts on Linux if the server doesn't answer in `timeout` seconds.
- `SLAVE START` did not work if you started with `--skip-slave-start` and had not explicitly run `CHANGE MASTER TO`.
- Fixed the output of `SHOW MASTER STATUS` to be consistent with `SHOW SLAVE STATUS`. (It now has no directory in the log name.)
- Added `PURGE MASTER LOGS TO`.
- Added `SHOW MASTER LOGS`.
- Added `--safemalloc-mem-limit` option to `mysqld` to simulate memory shortage when compiled with the `--with-debug=full` option.
- Fixed several core dumps in out-of-memory conditions.
- `SHOW SLAVE STATUS` was using an uninitialised mutex if the slave had not been started yet.
- Fixed bug in `ELT()` and `MAKE_SET()` when the query used a temporary table.
- `CHANGE MASTER TO` without specifying `MASTER_LOG_POS` would set it to 0 instead of 4 and hit the magic number in the master binlog.
- `ALTER TABLE ... ORDER BY ...` syntax added. This will create the new table with the rows in a specific order.

D.4.34 Changes in release 3.23.27 (24 Oct 2000)

- Fixed a bug where the automatic repair of `MyISAM` tables sometimes failed when the datafile was corrupt.
- Fixed a bug in `SHOW CREATE` when using `AUTO_INCREMENT` columns.
- Changed `BDB` tables to use new compare function in Berkeley DB 3.2.3.
- You can now use Unix sockets with MIT-pthreads.
- Added the `latin5` (turkish) character set.
- Small portability fixes.

D.4.35 Changes in release 3.23.26 (18 Oct 2000)

- Renamed `FLUSH MASTER` and `FLUSH SLAVE` to `RESET MASTER` and `RESET SLAVE`.
- Fixed `<>` to work properly with `NULL`.
- Fixed a problem with `SUBSTRING_INDEX()` and `REPLACE()`. (Patch by Alexander Igonitchev)

- Fix `CREATE TEMPORARY TABLE IF NOT EXISTS` not to produce an error if the table exists.
- If you don't create a `PRIMARY KEY` in a `BDB` table, a hidden `PRIMARY KEY` will be created.
- Added read-only-key optimisation to `BDB` tables.
- `LEFT JOIN` in some cases preferred a full table scan when there was no `WHERE` clause.
- When using `--log-slow-queries`, don't count the time waiting for a lock.
- Fixed bug in lock code on Windows which could cause the key cache to report that the key file was crashed even if it was okay.
- Automatic repair of `MyISAM` tables if you start `mysqld` with `--myisam-recover`.
- Removed the `TYPE=` keyword from `CHECK` and `REPAIR`. Allow `CHECK` options to be combined. (You can still use `TYPE=`, but this usage is deprecated.)
- Fixed mutex bug in the binary replication log — long update queries could be read only in part by the slave if it did it at the wrong time, which was not fatal, but resulted in a performance-degrading reconnect and a scary message in the error log.
- Changed the format of the binary log — added magic number, server version, binlog version. Added the server ID and query error code for each query event.
- Replication thread from the slave now will kill all the stale threads from the same server.
- Long replication user names were not being handled properly.
- Added `--replicate-rewrite-db` option to `mysqld`.
- Added `--skip-slave-start` option to `mysqld`.
- Updates that generated an error code (such as `INSERT INTO foo(some_key) values (1),(1)`) erroneously terminated the slave thread.
- Added optimisation of queries where `DISTINCT` is only used on columns from some of the tables.
- Allow floating-point numbers where there is no sign after the exponent (like `1e1`).
- `SHOW GRANTS` didn't always show all column grants.
- Added `--default-extra-file=#` option to all MySQL clients.
- Columns referenced in `INSERT` statements now are initialised properly.
- `UPDATE` didn't always work when used with a range on a timestamp that was part of the key that was used to find rows.
- Fixed a bug in `FULLTEXT` index when inserting a `NULL` column.
- Changed to use `mkstemp()` instead of `tempnam()`. Based on a patch from John Jones.

D.4.36 Changes in release 3.23.25 (29 Sep 2000)

- Fixed that `databasename` works as second argument to `mysqlhotcopy`.
- The values for the `UMASK` and `UMASK_DIR` environment variables now can be specified in octal by beginning the value with a zero.
- Added `RIGHT JOIN`. This makes `RIGHT` a reserved word.
- Added `@@IDENTITY` as a synonym for `LAST_INSERT_ID()`. (This is for MSSQL compatibility.)

- Fixed a bug in `myisamchk` and `REPAIR` when using `FULLTEXT` index.
- `LOAD DATA INFILE` now works with FIFOs. (Patch by Toni L. Harbaugh-Blackford.)
- `FLUSH LOGS` broke replication if you specified a log name with an explicit extension as the value of the `log-bin` option.
- Fixed a bug in `MyISAM` with packed multi-part keys.
- Fixed crash when using `CHECK TABLE` on Windows.
- Fixed a bug where `FULLTEXT` index always used the `koi8_ukr` character set.
- Fixed privilege checking for `CHECK TABLE`.
- The `MyISAM` repair/reindex code didn't use the `--tmpdir` option for its temporary files.
- Added `BACKUP TABLE` and `RESTORE TABLE`.
- Fixed core dump on `CHANGE MASTER TO` when the slave did not have the master to start with.
- Fixed incorrect `Time` in the processlist for `Connect` of the slave thread.
- The slave now logs when it connects to the master.
- Fixed a core dump bug when doing `FLUSH MASTER` if you didn't specify a filename argument to `--log-bin`.
- Added missing '`ha_berkeley.x`' files to the MySQL Windows distribution.
- Fixed some mutex bugs in the log code that could cause thread blocks if new log files couldn't be created.
- Added lock time and number of selected processed rows to slow query log.
- Added `--memlock` option to `mysqld` to lock `mysqld` in memory on systems with the `mlockall()` call (as in Solaris).
- `HEAP` tables didn't use keys properly. (Bug from 3.23.23.)
- Added better support for `MERGE` tables (keys, mapping, creation, documentation...). See Section 7.2 [MERGE], page 601.
- Fixed bug in `mysqldump` from 3.23 which caused some `CHAR` columns not to be quoted.
- Merged `analyze`, `check`, `optimize` and repair code.
- `OPTIMIZE TABLE` is now mapped to `REPAIR` with statistics and sorting of the index tree. This means that for the moment it only works on `MyISAM` tables.
- Added a pre-alloced block to root_malloc to get fewer mallocs.
- Added a lot of new statistics variables.
- Fixed `ORDER BY` bug with `BDB` tables.
- Removed warning that `mysqld` couldn't remove the '`.pid`' file under Windows.
- Changed `--log-isam` to log `MyISAM` tables instead of isam tables.
- Fixed `CHECK TABLE` to work on Windows.
- Added file mutexes to make `pwrite()` safe on Windows.

D.4.37 Changes in release 3.23.24 (08 Sep 2000)

- Added `created_tmp_disk_tables` variable to `mysqld`.

- To make it possible to reliably dump and restore tables with `TIMESTAMP(X)` columns, MySQL now reports columns with `X` other than 14 or 8 to be strings.
- Changed sort order for `latin1` as it was before MySQL Version 3.23.23. Any table that was created or modified with 3.23.22 must be repaired if it has `CHAR` columns that may contain characters with ASCII values greater than 128!
- Fixed small memory leak introduced from 3.23.22 when creating a temporary table.
- Fixed problem with `BDB` tables and reading on a unique (not primary) key.
- Restored the `win1251` character set (it's now only marked deprecated).

D.4.38 Changes in release 3.23.23 (01 Sep 2000)

- Changed sort order for 'German'; all tables created with 'German' sortorder must be repaired with `REPAIR TABLE` or `myisamchk` before use!
- Added `--core-file` option to `mysqld` to get a core file on Linux if `mysqld` dies on the `SIGSEGV` signal.
- MySQL client `mysql` now starts with option `--no-named-commands` (`-g`) by default. This option can be disabled with `--enable-named-commands` (`-G`). This may cause incompatibility problems in some cases, for example, in SQL scripts that use named commands without a semicolon, etc.! Long format commands still work from the first line.
- Fixed a problem when using many pending `DROP TABLE` statements at the same time.
- Optimiser didn't use keys properly when using `LEFT JOIN` on an empty table.
- Added shorter help text when invoking `mysqld` with incorrect options.
- Fixed non-fatal `free()` bug in `mysqlimport`.
- Fixed bug in `MyISAM` index handling of `DECIMAL/NUMERIC` keys.
- Fixed a bug in concurrent insert in `MyISAM` tables. In some contexts, usage of `MIN(key_part)` or `MAX(key_part)` returned an empty set.
- Updated `mysqlhotcopy` to use the new `FLUSH TABLES table_list` syntax. Only tables which are being backed up are flushed now.
- Changed behaviour of `--enable-thread-safe-client` so that both non-threaded (`-lmysqlclient`) and threaded (`-lmysqlclient_r`) libraries are built. Users who linked against a threaded `-lmysqlclient` will need to link against `-lmysqlclient_r` now.
- Added atomic `RENAME TABLE` command.
- Don't count `NULL` values in `COUNT(DISTINCT ...)`.
- Changed `ALTER TABLE`, `LOAD DATA INFILE` on empty tables and `INSERT ... SELECT ...` on empty tables to create non-unique indexes in a separate batch with sorting. This will make the above calls much faster when you have many indexes.
- `ALTER TABLE` now logs the first used insert_id correctly.
- Fixed crash when adding a default value to a `BLOB` column.
- Fixed a bug with `DATE_ADD/DATE_SUB` where it returned a datetime instead of a date.
- Fixed a problem with the thread cache which made some threads show up as `***DEAD***` in `SHOW PROCESSLIST`.

- Fixed a lock in our thr_rwlock code, which could make selects that run at the same time as concurrent inserts crash. This only affects systems that don't have the `pthread_rwlock_rdlock` code.
- When deleting rows with a non-unique key in a `HEAP` table, all rows weren't always deleted.
- Fixed bug in range optimiser for `HEAP` tables for searches on a part index.
- Fixed `SELECT` on part keys to work with `BDB` tables.
- Fixed `INSERT INTO bdb_table ... SELECT` to work with `BDB` tables.
- `CHECK TABLE` now updates key statistics for the table.
- `ANALYZE TABLE` will now only update tables that have been changed since the last `ANALYZE`. Note that this is a new feature and tables will not be marked to be analysed until they are updated in any way with 3.23.23 or newer. For older tables, you have to do `CHECK TABLE` to update the key distribution.
- Fixed some minor privilege problems with `CHECK`, `ANALYZE`, `REPAIR` and `SHOW CREATE` commands.
- Added `CHANGE MASTER TO` statement.
- Added `FAST`, `QUICK EXTENDED` check types to `CHECK TABLES`.
- Changed `myisamchk` so that `--fast` and `--check-only-changed` are also honored with `--sort-index` and `--analyze`.
- Fixed fatal bug in `LOAD TABLE FROM MASTER` that did not lock the table during index re-build.
- `LOAD DATA INFILE` broke replication if the database was excluded from replication.
- More variables in `SHOW SLAVE STATUS` and `SHOW MASTER STATUS`.
- `SLAVE STOP` now will not return until the slave thread actually exits.
- Full-text search via the `MATCH()` function and `FULLTEXT` index type (for `MyISAM` files). This makes `FULLTEXT` a reserved word.

D.4.39 Changes in release 3.23.22 (31 Jul 2000)

- Fixed that `lex_hash.h` is created properly for each MySQL distribution.
- Fixed that `MASTER` and `COLLECTION` are not reserved words.
- The log generated by `--slow-query-log` didn't contain the whole queries.
- Fixed that open transactions in `BDB` tables are rolled back if the connection is closed unexpectedly.
- Added workaround for a bug in `gcc` 2.96 (intel) and `gcc` 2.9 (IA-64) in `gen_lex_hash.c`.
- Fixed memory leak in the client library when using `host=` in the '`my.cnf`' file.
- Optimised functions that manipulate the hours/minutes/seconds.
- Fixed bug when comparing the result of `DATE_ADD()`/`DATE_SUB()` against a number.
- Changed the meaning of `-F, --fast` for `myisamchk`. Added `-C, --check-only-changed` option to `myisamchk`.
- Added `ANALYZE tbl_name` to update key statistics for tables.

- Changed binary items `0x...` to be regarded as integers by default.
- Fix for SCO and `SHOW PROCESSLIST`.
- Added `auto-rehash` on reconnect for the `mysql` client.
- Fixed a newly introduced bug in `MyISAM`, where the index file couldn't get bigger than 64M.
- Added `SHOW MASTER STATUS` and `SHOW SLAVE STATUS`.

D.4.40 Changes in release 3.23.21

- Added `mysql_character_set_name()` function to the MySQL C API.
- Made the update log ASCII 0 safe.
- Added the `mysql_config` script.
- Fixed problem when using `<` or `>` with a char column that was only partly indexed.
- One would get a core dump if the log file was not readable by the MySQL user.
- Changed `mysqladmin` to use `CREATE DATABASE` and `DROP DATABASE` statements instead of the old deprecated API calls.
- Fixed `chown` warning in `safe_mysqld`.
- Fixed a bug in `ORDER BY` that was introduced in 3.23.19.
- Only optimise the `DELETE FROM tbl_name` to do a drop+create of the table if we are in `AUTOCOMMIT` mode (needed for `BDB` tables).
- Added extra checks to avoid index corruption when the `ISAM`/`MyISAM` index files get full during an `INSERT`/`UPDATE`.
- `myisamchk` didn't correctly update row checksum when used with `-ro` (this only gave a warning in subsequent runs).
- Fixed bug in `REPAIR TABLE` so that it works with tables without indexes.
- Fixed buffer overrun in `DROP DATABASE`.
- `LOAD TABLE FROM MASTER` is sufficiently bug-free to announce it as a feature.
- `MATCH` and `AGAINST` are now reserved words.

D.4.41 Changes in release 3.23.20

- Fixed bug in 3.23.19; `DELETE FROM tbl_name` removed the '`.frm`' file.
- Added `SHOW CREATE TABLE`.

D.4.42 Changes in release 3.23.19

- Changed copyright for all files to `GPL` for the server code and utilities and to LGPL for the client libraries.
- Fixed bug where all rows matching weren't updated on a `MyISAM` table when doing update based on key on a table with many keys and some key changed values.
- The Linux MySQL RPMs and binaries are now statically linked with a linuxthread version that has faster mutex handling when used with MySQL.

- `ORDER BY` can now use `REF` keys to find subsets of the rows that need to be sorted.
- Changed name of `print_defaults` program to `my_print_defaults` to avoid name confusion.
- Fixed `NULLIF()` to work as required by SQL-99.
- Added `net_read_timeout` and `net_write_timeout` as startup parameters to `mysqld`.
- Fixed bug that destroyed index when doing `myisamchk --sort-records` on a table with prefix compressed index.
- Added `pack_isam` and `myisampack` to the standard MySQL distribution.
- Added the syntax `BEGIN WORK` (the same as `BEGIN`).
- Fixed core dump bug when using `ORDER BY` on a `CONV()` expression.
- Added `LOAD TABLE FROM MASTER`.
- Added `FLUSH MASTER` and `FLUSH SLAVE`.
- Fixed big/little endian problem in the replication.

D.4.43 Changes in release 3.23.18

- Fixed a problem from 3.23.17 when choosing character set on the client side.
- Added `FLUSH TABLES WITH READ LOCK` to make a global lock suitable for making a copy of MySQL datafiles.
- `CREATE TABLE ... SELECT ... PROCEDURE` now works.
- Internal temporary tables will now use compressed index when using `GROUP BY` on `VARCHAR/CHAR` columns.
- Fixed a problem when locking the same table with both a `READ` and a `WRITE` lock.
- Fixed problem with `myisamchk` and `RAID` tables.

D.4.44 Changes in release 3.23.17

- Fixed a bug in `FIND_IN_SET()` when the first argument was `NULL`.
- Added table locks to Berkeley DB.
- Fixed a bug with `LEFT JOIN` and `ORDER BY` where the first table had only one matching row.
- Added 4 sample '`my.cnf`' example files in the '`support-files`' directory.
- Fixed `duplicated key` problem when doing big `GROUP BY` operations. (This bug was probably introduced in 3.23.15.)
- Changed syntax for `INNER JOIN` to match SQL-99.
- Added `NATURAL JOIN` syntax.
- A lot of fixes in the `BDB` interface.
- Added handling of `--no-defaults` and `--defaults-file` to `safe_mysqld.sh` and `mysql_install_db.sh`.
- Fixed bug in reading compressed tables with many threads.
- Fixed that `USE INDEX` works with `PRIMARY` keys.

- Added `BEGIN` statement to start a transaction in `AUTOCOMMIT` mode.
- Added support for symbolic links for Windows.
- Changed protocol to let client know if the server is in `AUTOCOMMIT` mode and if there is a pending transaction. If there is a pending transaction, the client library will give an error before reconnecting to the server to let the client know that the server did a rollback. The protocol is still backward-compatible with old clients.
- `KILL` now works on a thread that is locked on a 'write' to a dead client.
- Fixed memory leak in the replication slave thread.
- Added new `log-slave-updates` option to `mysqld`, to allow daisy-chaining the slaves.
- Fixed compile error on FreeBSD and other systems where `pthread_t` is not the same as `int`.
- Fixed master shutdown aborting the slave thread.
- Fixed a race condition in `INSERT DELAYED` code when doing `ALTER TABLE`.
- Added deadlock detection sanity checks to `INSERT DELAYED`.

D.4.45 Changes in release 3.23.16

- Added `SLAVE START` and `SLAVE STOP` statements.
- Added `TYPE=QUICK` option to `CHECK` and to `REPAIR`.
- Fixed bug in `REPAIR TABLE` when the table was in use by other threads.
- Added a thread cache to make it possible to debug MySQL with `gdb` when one does a lot of reconnects. This will also improve systems where you can't use persistent connections.
- Lots of fixes in the Berkeley DB interface.
- `UPDATE IGNORE` will not abort if an update results in a `DUPLICATE_KEY` error.
- Put `CREATE TEMPORARY TABLE` commands in the update log.
- Fixed bug in handling of masked IP numbers in the privilege tables.
- Fixed bug with `delay_key_write` tables and `CHECK TABLE`.
- Added `replicate-do-db` and `replicate-ignore-db` options to `mysqld`, to restrict which databases get replicated.
- Added `SQL_LOG_BIN` option.

D.4.46 Changes in release 3.23.15 (May 2000: Beta)

- To start `mysqld` as `root`, you must now use the `--user=root` option.
- Added interface to Berkeley DB. (This is not yet functional; play with it at your own risk!)
- Replication between master and slaves.
- Fixed bug that other threads could steal a lock when a thread had a lock on a table and did a `FLUSH TABLES` command.
- Added the `slow_launch_time` variable and the `Slow_launch_threads` status variable to `mysqld`. These can be examined with `mysqladmin variables` and `mysqladmin extended-status`.

- Added functions `INET_NTOA()` and `INET_ATON()`.
- The default type of `IF()` now depends on the second and third arguments and not only on the second argument.
- Fixed case when `myisamchk` could go into a loop when trying to repair a crashed table.
- Don't write `INSERT DELAYED` to update log if `SQL_LOG_UPDATE=0`.
- Fixed problem with `REPLACE` on `HEAP` tables.
- Added possible character sets and time zone to `SHOW VARIABLES` output.
- Fixed bug in locking code that could result in locking problems with concurrent inserts under high load.
- Fixed a problem with `DELETE` of many rows on a table with compressed keys where MySQL scanned the index to find the rows.
- Fixed problem with `CHECK` on table with deleted keyblocks.
- Fixed a bug in reconnect (at the client side) where it didn't free memory properly in some contexts.
- Fixed problems in update log when using `LAST_INSERT_ID()` to update a table with an `AUTO_INCREMENT` key.
- Added `NULLIF()` function.
- Fixed bug when using `LOAD DATA INFILE` on a table with `BLOB/TEXT` columns.
- Optimised `MyISAM` to be faster when inserting keys in sorted order.
- `EXPLAIN SELECT ...` now also prints out whether MySQL needs to create a temporary table or use file sorting when resolving the `SELECT`.
- Added optimisation to skip `ORDER BY` parts where the part is a constant expression in the `WHERE` part. Indexes can now be used even if the `ORDER BY` doesn't match the index exactly, as long as all the unused index parts and all the extra `ORDER BY` columns are constants in the `WHERE` clause. See Section 5.4.3 [MySQL indexes], page 421.
- `UPDATE` and `DELETE` on a whole unique key in the `WHERE` part are now faster than before.
- Changed `RAID_CHUNKSIZE` to be in 1024-byte increments.
- Fixed core dump in `LOAD_FILE(NULL)`.

D.4.47 Changes in release 3.23.14

- Added `mysql_real_escape_string()` function to the MySQL C API.
- Fixed a bug in `CONCAT()` where one of the arguments was a function that returned a modified argument.
- Fixed a critical bug in `myisamchk`, where it updated the header in the index file when one only checked the table. This confused the `mysqld` daemon if it updated the same table at the same time. Now the status in the index file is only updated if one uses `--update-state`. With older `myisamchk` versions you should use `--read-only` when only checking tables, if there is the slightest chance that the `mysqld` server is working on the table at the same time!
- Fixed that `DROP TABLE` is logged in the update log.
- Fixed problem when searching on `DECIMAL()` key field where the column data contained leading zeros.

- Fix bug in `myisamchk` when the `AUTO_INCREMENT` column isn't the first key.
- Allow `DATETIME` in ISO8601 format: 2000-03-12T12:00:00
- Dynamic character sets. A `mysqld` binary can now handle many different character sets (you can choose which when starting `mysqld`).
- Added command `REPAIR TABLE`.
- Added `mysql_thread_safe()` function to the MySQL C API.
- Added the `UMASK_DIR` environment variable.
- Added `CONNECTION_ID()` function to return the client connection thread ID.
- When using `=` on `BLOB` or `VARCHAR BINARY` keys, where only a part of the column was indexed, the whole column of the result row wasn't compared.
- Fix for `sjis` character set and `ORDER BY`.
- When running in ANSI mode, don't allow columns to be used that aren't in the `GROUP BY` part.

D.4.48 Changes in release 3.23.13

- Fixed problem when doing locks on the same table more than 2 times in the same `LOCK TABLE` command; this fixed the problem one got when running the test-ATIS test with `--fast` or `--check-only-changed`.
- Added `SQL_BUFFER_RESULT` option to `SELECT`.
- Removed end space from double/float numbers in results from temporary tables.
- Added `CHECK TABLE` command.
- Added changes for `MyISAM` in 3.23.12 that didn't get into the source distribution because of CVS problems.
- Fixed bug so that `mysqladmin shutdown` will wait for the local server to close down.
- Fixed a possible endless loop when calculating timestamp.
- Added `print_defaults` program to the '`.rpm`' files. Removed `mysqlbug` from the client '`.rpm`' file.

D.4.49 Changes in release 3.23.12 (07 Mar 2000)

- Fixed bug in `MyISAM` involving `REPLACE ... SELECT ...` which could give a corrupted table.
- Fixed bug in `myisamchk` where it incorrectly reset the `AUTO_INCREMENT` value.
- LOTS of patches for Linux Alpha. MySQL now appears to be relatively stable on Alpha.
- Changed `DISTINCT` on `HEAP` temporary tables to use hashed keys to quickly find duplicated rows. This mostly concerns queries of type `SELECT DISTINCT ... GROUP BY ...`. This fixes a problem where not all duplicates were removed in queries of the above type. In addition, the new code is MUCH faster.
- Added patches to make MySQL compile on Mac OS X.
- Added `IF NOT EXISTS` clause to `CREATE DATABASE`.

- Added `--all-databases` and `--databases` options to `mysqldump` to allow dumping of many databases at the same time.
- Fixed bug in compressed `DECIMAL()` index in `MyISAM` tables.
- Fixed bug when storing 0 into a timestamp.
- When doing `mysqladmin shutdown` on a local connection, `mysqladmin` now waits until the PID file is gone before terminating.
- Fixed core dump with some `COUNT(DISTINCT ...)` queries.
- Fixed that `myisamchk` works properly with RAID tables.
- Fixed problem with `LEFT JOIN` and `key_field IS NULL`.
- Fixed bug in `net_clear()` which could give the error `Aborted connection` in the MySQL clients.
- Added options `USE INDEX (key_list)` and `IGNORE INDEX (key_list)` as parameters in `SELECT`.
- `DELETE` and `RENAME` should now work on `RAID` tables.

D.4.50 Changes in release 3.23.11

- Allow the `ALTER TABLE tbl_name ADD (field_list)` syntax.
- Fixed problem with optimiser that could sometimes use incorrect keys.
- Fixed that `GRANT/REVOKE ALL PRIVILEGES` doesn't affect `GRANT OPTION`.
- Removed extra '`)`' from the output of `SHOW GRANTS`.
- Fixed problem when storing numbers in timestamps.
- Fix problem with timezones that have half hour offsets.
- Allow the syntax `UNIQUE INDEX` in `CREATE` statements.
- `mysqlhotcopy` - fast online hot-backup utility for local MySQL databases. By Tim Bunce.
- New more secure `mysqlaccess`. Thanks to Steve Harvey for this.
- Added `--i-am-a-dummy` and `--safe-updates` options to `mysql`.
- Added `select_limit` and `max_join_size` variables to `mysql`.
- Added `SQL_MAX_JOIN_SIZE` and `SQL_SAFE_UPDATES` options.
- Added `READ LOCAL` lock that doesn't lock the table for concurrent inserts. (This is used by `mysqldump`.)
- Changed that `LOCK TABLES ... READ` doesn't anymore allow concurrent inserts.
- Added `--skip-delay-key-write` option to `mysqld`.
- Fixed security problem in the protocol regarding password checking.
- `_rowid` can now be used as an alias for an integer type unique indexed column.
- Added back blocking of `SIGPIPE` when compiling with `--thread-safe-clients` to make things safe for old clients.

D.4.51 Changes in release 3.23.10

- Fixed bug in 3.23.9 where memory wasn't properly freed when using `LOCK TABLES`.

D.4.52 Changes in release 3.23.9

- Fixed problem that affected queries that did arithmetic on group functions.
- Fixed problem with timestamps and `INSERT DELAYED`.
- Fixed that `date_col BETWEEN const_date AND const_date` works.
- Fixed problem when only changing a 0 to `NULL` in a table with `BLOB/TEXT` columns.
- Fixed bug in range optimiser when using many key parts and or on the middle key parts: `WHERE K1=1 and K3=2 and (K2=2 and K4=4 or K2=3 and K4=5)`
- Added `source` command to `mysql` to allow reading of batch files inside the `mysql` client. Original patch by Matthew Vanecek.
- Fixed critical problem with the `WITH GRANT OPTION` option.
- Don't give an unnecessary `GRANT` error when using tables from many databases in the same query.
- Added VIO wrapper (needed for SSL support; by Andrei Errapart and Tõnu Samuel).
- Fixed optimiser problem on `SELECT` when using many overlapping indexes. MySQL should now be able to choose keys even better when there are many keys to choose from.
- Changed optimiser to prefer a range key instead of a ref key when the range key can uses more columns than the ref key (which only can use columns with `=`). For example, the following type of queries should now be faster: `SELECT * from key_part_1=const and key_part_2 > const2`
- Fixed bug that a change of all `VARCHAR` columns to `CHAR` columns didn't change row type from dynamic to fixed.
- Disabled floating-point exceptions for FreeBSD to fix core dump when doing `SELECT FLOOR(POW(2,63))`.
- Renamed `mysqld` startup option from `--delay-key-write` to `--delay-key-write-for-all-tables`.
- Added `read-next-on-key` to `HEAP` tables. This should fix all problems with `HEAP` tables when using non-`UNIQUE` keys.
- Added option to print default arguments to all clients.
- Added `--log-slow-queries` option to `mysqld` to log all queries that take a long time to a separate log file with a time indicating how long the query took.
- Fixed core dump when doing `WHERE key_col=RAND(...)`.
- Fixed optimisation bug in `SELECT ... LEFT JOIN ... key_col IS NULL`, when `key_col` could contain `NULL` values.
- Fixed problem with 8-bit characters as separators in `LOAD DATA INFILE`.

D.4.53 Changes in release 3.23.8 (02 Jan 2000)

- Fixed problem when handling indexfiles larger than 8G.
- Added latest patches to MIT-pthreads for NetBSD.
- Fixed problem with timezones that are < GMT - 11.

- Fixed a bug when deleting packed keys in `NISAM`.
- Fixed problem with `ISAM` when doing some `ORDER BY ... DESC` queries.
- Fixed bug when doing a join on a text key which didn't cover the whole key.
- Option `--delay-key-write` didn't enable delayed key writing.
- Fixed update of `TEXT` column which involved only case changes.
- Fixed that `INSERT DELAYED` doesn't update timestamps that are given.
- Added function `YEARWEEK()` and options `x`, `X`, `v` and `V` to `DATE_FORMAT()`.
- Fixed problem with `MAX(indexed_column)` and `HEAP` tables.
- Fixed problem with `BLOB NULL` keys and `LIKE "prefix%"`.
- Fixed problem with `MyISAM` and fixed-length rows < 5 bytes.
- Fixed problem that could cause MySQL to touch freed memory when doing very complicated `GROUP BY` queries.
- Fixed core dump if you got a crashed table where an `ENUM` field value was too big.

D.4.54 Changes in release 3.23.7 (10 Dec 1999)

- Fixed workaround under Linux to avoid problems with `pthread_mutex_timedwait`, which is used with `INSERT DELAYED`. See Section 2.6.2 [Linux], page 126.
- Fixed that one will get a 'disk full' error message if one gets disk full when doing sorting (instead of waiting until we got more disk space).
- Fixed a bug in `MyISAM` with keys > 250 characters.
- In `MyISAM` one can now do an `INSERT` at the same time as other threads are reading from the table.
- Added `max_write_lock_count` variable to `mysqld` to force a `READ` lock after a certain number of `WRITE` locks.
- Inverted flag `delay_key_write` on `show variables`.
- Renamed `concurrency` variable to `thread_concurrency`.
- The following functions are now multi-byte-safe: `LOCATE(substr,str)`, `POSITION(substr IN str)`, `LOCATE(substr,str,pos)`, `INSTR(str,substr)`, `LEFT(str,len)`, `RIGHT(str,len)`, `SUBSTRING(str,pos,len)`, `SUBSTRING(str FROM pos FOR len)`, `MID(str,pos,len)`, `SUBSTRING(str,pos)`, `SUBSTRING(str FROM pos)`, `SUBSTRING_INDEX(str,delim,count)`, `RTRIM(str)`, `TRIM([[BOTH | TRAILING] [remstr] FROM] str)`, `REPLACE(str,from_str,to_str)`, `REVERSE(str)`, `INSERT(str,pos,len,newstr)`, `LCASE(str)`, `LOWER(str)`, `UCASE(str)` and `UPPER(str)`; patch by Wei He.
- Fix core dump when releasing a lock from a non-existent table.
- Remove locks on tables before starting to remove duplicates.
- Added option `FULL` to `SHOW PROCESSLIST`.
- Added option `--verbose` to `mysqladmin`.
- Fixed problem when automatically converting `HEAP` to `MyISAM`.
- Fixed bug in `HEAP` tables when doing insert + delete + insert + scan the table.

- Fixed bugs on Alpha with `REPLACE()` and `LOAD DATA INFILE`.
- Added `interactive_timeout` variable to `mysqld`.
- Changed the argument to `mysql_data_seek()` from `ulong` to `ulonglong`.

D.4.55 Changes in release 3.23.6

- Added `-O lower_case_table_names={0|1}` option to `mysqld` to allow users to force table names to lowercase.
- Added `SELECT ... INTO DUMPFILE`.
- Added `--ansi` option to `mysqld` to make some functions SQL-99 compatible.
- Temporary table names now start with `#sql`.
- Added quoting of identifiers with ‘ (`"` in `--ansi` mode).
- Changed to use `snprintf()` when printing floats to avoid some buffer overflows on FreeBSD.
- Made `FLOOR()` overflow safe on FreeBSD.
- Added `--quote-names` option to `mysqldump`.
- Fixed bug that one could make a part of a `PRIMARY KEY NOT NULL`.
- Fixed `encrypt()` to be thread-safe and not reuse buffer.
- Added `mysql_odbc_escape_string()` function to support big5 characters in MyODBC.
- Rewrote the storage engine to use classes. This introduces a lot of new code, but will make table handling faster and better.
- Added patch by Sasha for user-defined variables.
- Changed that `FLOAT` and `DOUBLE` (without any length modifiers) no longer are fixed decimal point numbers.
- Changed the meaning of `FLOAT(X)`: Now this is the same as `FLOAT` if `X` <= 24 and a `DOUBLE` if 24 < `X` <= 53.
- `DECIMAL(X)` is now an alias for `DECIMAL(X,0)` and `DECIMAL` is now an alias for `DECIMAL(10,0)`. The same goes for `NUMERIC`.
- Added option `ROW_FORMAT={DEFAULT | DYNAMIC | FIXED | COMPRESSED}` to `CREATE_TABLE`.
- `DELETE FROM table_name` didn’t work on temporary tables.
- Changed function `CHAR_LENGTH()` to be multi-byte character safe.
- Added function `ORD(string)`.

D.4.56 Changes in release 3.23.5 (20 Oct 1999)

- Fixed some Y2K problems in the new date handling in 3.23.
- Fixed problem with `SELECT DISTINCT ... ORDER BY RAND()`.
- Added patches by Sergei A. Golubchik for text searching on the `MyISAM` level.
- Fixed cache overflow problem when using full joins without keys.

- Fixed some configure issues.
- Some small changes to make parsing faster.
- Adding a column after the last field with `ALTER TABLE` didn't work.
- Fixed problem when using an `AUTO_INCREMENT` column in two keys
- With `MyISAM`, you now can have an `AUTO_INCREMENT` column as a key sub part: `CREATE TABLE foo (a INT NOT NULL AUTO_INCREMENT, b CHAR(5), PRIMARY KEY (b,a))`
- Fixed bug in `MyISAM` with packed char keys that could be `NULL`.
- `AS` on field name with `CREATE TABLE table_name SELECT ...` didn't work.
- Allow use of `NATIONAL` and `NCHAR` when defining character columns. This is the same as not using `BINARY`.
- Don't allow `NULL` columns in a `PRIMARY KEY` (only in `UNIQUE` keys).
- Clear `LAST_INSERT_ID()` if one uses this in ODBC: `WHERE auto_increment_column IS NULL`. This seems to fix some problems with Access.
- `SET SQL_AUTO_IS_NULL=0|1` now turns on/off the handling of searching after the last inserted row with `WHERE auto_increment_column IS NULL`.
- Added new variable `concurrency` to `mysqld` for Solaris.
- Added `--relative` option to `mysqladmin` to make `extended-status` more useful to monitor changes.
- Fixed bug when using `COUNT(DISTINCT ...)` on an empty table.
- Added support for the Chinese character set GBK.
- Fixed problem with `LOAD DATA INFILE` and `BLOB` columns.
- Added bit operator `~` (negation).
- Fixed problem with `UDF` functions.

D.4.57 Changes in release 3.23.4 (28 Sep 1999)

- Inserting a `DATETIME` into a `TIME` column no longer will try to store 'days' in it.
- Fixed problem with storage of float/double on little endian machines. (This affected `SUM()`.)
- Added connect timeout on TCP/IP connections.
- Fixed problem with `LIKE "%"` on an index that may have `NULL` values.
- `REVOKE ALL PRIVILEGES` didn't revoke all privileges.
- Allow creation of temporary tables with same name as the original table.
- When granting a user a `GRANT` option for a database, he couldn't grant privileges to other users.
- New command: `SHOW GRANTS FOR user` (by Sinisa).
- New `date_add` syntax: `date/datetime + INTERVAL # interval_type`. By Joshua Chamas.
- Fixed privilege check for `LOAD DATA REPLACE`.
- Automatic fixing of broken include files on Solaris 2.7
- Some configure issues to fix problems with big filesystem detection.
- `REGEXP` is now case-insensitive if you use non-binary strings.

D.4.58 Changes in release 3.23.3

- Added patches for MIT-pthreads on NetBSD.
- Fixed range bug in `MyISAM`.
- `ASC` is now the default again for `ORDER BY`.
- Added `LIMIT` to `UPDATE`.
- Added `mysql_change_user()` function to the MySQL C API.
- Added character set to `SHOW VARIABLES`.
- Added support of `--[whitespace]` comments.
- Allow `INSERT into tbl_name VALUES ()`, that is, you may now specify an empty value list to insert a row in which each column is set to its default value.
- Changed `SUBSTRING(text FROM pos)` to conform to SQL-99. (Before this construct returned the rightmost `pos` characters.)
- `SUM()` with `GROUP BY` returned 0 on some systems.
- Changed output for `SHOW TABLE STATUS`.
- Added `DELAY_KEY_WRITE` option to `CREATE TABLE`.
- Allow `AUTO_INCREMENT` on any key part.
- Fixed problem with `YEAR(NOW())` and `YEAR(CURDATE())`.
- Added `CASE` construct.
- New function `COALESCE()`.

D.4.59 Changes in release 3.23.2 (09 Aug 1999)

- Fixed range optimiser bug: `SELECT * FROM table_name WHERE key_part1 >= const AND (key_part2 = const OR key_part2 = const)`. The bug was that some rows could be duplicated in the result.
- Running `myisamchk` without `-a` updated the index distribution incorrectly.
- `SET SQL_LOW_PRIORITY_UPDATES=1` was causing a parse error.
- You can now update index columns that are used in the `WHERE` clause. `UPDATE tbl_name SET KEY=KEY+1 WHERE KEY > 100`
- Date handling should now be a bit faster.
- Added handling of fuzzy dates (dates where day or month is 0), such as `'1999-01-00'`.
- Fixed optimisation of `SELECT ... WHERE key_part1=const1 AND key_part_2=const2 AND key_part1=const4 AND key_part2=const4`; indextype should be `range` instead of `ref`.
- Fixed `egcs` 1.1.2 optimiser bug (when using `BLOB` values) on Linux Alpha.
- Fixed problem with `LOCK TABLES` combined with `DELETE FROM table`.
- `MyISAM` tables now allow keys on `NULL` and `BLOB/TEXT` columns.
- The following join is now much faster: `SELECT ... FROM t1 LEFT JOIN t2 ON ... WHERE t2.not_null_column IS NULL`.
- `ORDER BY` and `GROUP BY` can be done on functions.

- Changed handling of 'const_item' to allow handling of `ORDER BY RAND()`.
- Indexes are now used for `WHERE key_column = function`.
- Indexes are now used for `WHERE key_column = col_name` even if the columns are not identically packed.
- Indexes are now used for `WHERE col_name IS NULL`.
- Changed heap tables to be stored in low_byte_first order (to make it easy to convert to `MyISAM` tables)
- Automatic change of `HEAP` temporary tables to `MyISAM` tables in case of "table is full" errors.
- Added `--init-file=file_name` option to `mysqld`.
- Added `COUNT(DISTINCT value, [value, ...])`.
- `CREATE TEMPORARY TABLE` now creates a temporary table, in its own namespace, that is automatically deleted if connection is dropped.
- New reserved words (required for `CASE`): `CASE, THEN, WHEN, ELSE and END`.
- New functions `EXPORT_SET()` and `MD5()`.
- Support for the GB2312 Chinese character set.

D.4.60 Changes in release 3.23.1

- Fixed some compilation problems.

D.4.61 Changes in release 3.23.0 (05 Aug 1999: Alpha)

- A new storage engine library (`MyISAM`) with a lot of new features. See Section 7.1 [MyISAM], page 595.
- You can create in-memory `HEAP` tables which are extremely fast for lookups.
- Support for big files (63-bit) on OSs that support big files.
- New function `LOAD_FILE(filename)` to get the contents of a file as a string value.
- New operator `<=>` which will act as `=` but will return TRUE if both arguments are `NULL`. This is useful for comparing changes between tables.
- Added the ODBC 3.0 `EXTRACT(interval FROM datetime)` function.
- Columns defined as `FLOAT(X)` are not rounded on storage and may be in scientific notation (1.0 E+10) when retrieved.
- `REPLACE` is now faster than before.
- Changed `LIKE` character comparison to behave as `=`; This means that `'e' LIKE 'é'` is now true. (If the line doesn't display correctly, the latter 'e' is a French 'e' with a dot above.)
- `SHOW TABLE STATUS` returns a lot of information about the tables.
- Added `LIKE` to the `SHOW STATUS` command.
- Added `Privileges` column to `SHOW COLUMNS`.
- Added `Packed` and `Comment` columns to `SHOW INDEX`.
- Added comments to tables (with `CREATE TABLE ... COMMENT "xxx"`).

- Added `UNIQUE`, as in `CREATE TABLE table_name (col INT not null UNIQUE)`
- New create syntax: `CREATE TABLE table_name SELECT ...`
- New create syntax: `CREATE TABLE IF NOT EXISTS ...`
- Allow creation of `CHAR(0)` columns.
- `DATE_FORMAT()` now requires '`%`' before any format character.
- `DELAYED` is now a reserved word (sorry about that :( ).
- An example procedure is added: `analyse`, file: '`sql_analyse.c`'. This will describe the data in your query. Try the following:

```
SELECT ... FROM ...
WHERE ... PROCEDURE ANALYSE([max elements,[max memory]])
```

  This procedure is extremely useful when you want to check the data in your table!
- `BINARY` cast to force a string to be compared in case-sensitive fashion.
- Added `--skip-show-database` option to `mysqld`.
- Check whether a row has changed in an `UPDATE` now also works with `BLOB`/`TEXT` columns.
- Added the `INNER` join syntax. **NOTE**: This made `INNER` a reserved word!
- Added support for netmasks to the hostname in the MySQL grant tables. You can specify a netmask using the `IP/NETMASK` syntax.
- If you compare a `NOT NULL DATE/DATETIME` column with `IS NULL`, this is changed to a compare against `0` to satisfy some ODBC applications. (By `shreeve@uci.edu`.)
- `NULL IN (...)` now returns `NULL` instead of `0`. This will ensure that `null_column NOT IN (...)` doesn't match `NULL` values.
- Fix storage of floating-point values in `TIME` columns.
- Changed parsing of `TIME` strings to be more strict. Now the fractional second part is detected (and currently skipped). The following formats are supported:
  - [[DAYS] [H]H:]MM:]SS[.fraction]
  - [[[[[H]H]H]H]MM]SS[.fraction]
- Detect (and ignore) fractional second part from `DATETIME`.
- Added the `LOW_PRIORITY` attribute to `LOAD DATA INFILE`.
- The default index name now uses the same case as the column name on which the index name is based.
- Changed default number of connections to 100.
- Use bigger buffers when using `LOAD DATA INFILE`.
- `DECIMAL(x,y)` now works according to SQL-99.
- Added aggregate UDF functions. Thanks to Andreas F. Bobak (`bobak@relog.ch`) for this!
- `LAST_INSERT_ID()` is now updated for `INSERT INTO ... SELECT`.
- Some small changes to the join table optimiser to make some joins faster.
- `SELECT DISTINCT` is much faster; it uses the new `UNIQUE` functionality in `MyISAM`. One difference compared to MySQL Version 3.22 is that the output of `DISTINCT` is no longer sorted.

- All C client API macros are now functions to make shared libraries more reliable. Because of this, you can no longer call `mysql_num_fields()` on a `MYSQL` object, you must use `mysql_field_count()` instead.
- Added use of `LIBWRAP`; patch by Henning P. Schmiedehausen.
- Don't allow `AUTO_INCREMENT` for other than numerical columns.
- Using `AUTO_INCREMENT` will now automatically make the column `NOT NULL`.
- Show `NULL` as the default value for `AUTO_INCREMENT` columns.
- Added `SQL_BIG_RESULT`; `SQL_SMALL_RESULT` is now default.
- Added a shared library RPM. This enhancement was contributed by David Fox (`dsfox@cogsci.ucsd.edu`).
- Added `--enable-large-files` and `--disable-large-files` switches to `configure`. See '`configure.in`' for some systems where this is automatically turned off because of broken implementations.
- Upgraded `readline` to 4.0.
- New `CREATE TABLE` options: `PACK_KEYS` and `CHECKSUM`.
- Added `--default-table-type` option to `mysqld`.

D.5 Changes in release 3.22.x (Old; discontinued)

The 3.22 version has faster and safer connect code than version 3.21, as well as a lot of new nice enhancements. As there aren't really any major changes, upgrading from 3.21 to 3.22 should be very easy and painless. See Section 2.5.4 [Upgrading-from-3.21], page 118.

D.5.1 Changes in release 3.22.35

- Fixed problem with `STD()`.
- Merged changes from the newest `ISAM` library from 3.23.
- Fixed problem with `INSERT DELAYED`.
- Fixed a bug core dump when using a `LEFT JOIN/STRAIGHT_JOIN` on a table with only one row.

D.5.2 Changes in release 3.22.34

- Fixed problem with `GROUP BY` on `TINYBLOB` columns; this caused bugzilla to not show rows in some queries.
- Had to do total recompile of the Windows binary version as VC++ didn't compile all relevant files for 3.22.33 :(

D.5.3 Changes in release 3.22.33

- Fixed problems in Windows when locking tables with `LOCK TABLE`.
- Quicker kill of `SELECT DISTINCT` queries.

D.5.4 Changes in release 3.22.32 (14 Feb 2000)

- Fixed problem when storing numbers in timestamps.
- Fix problem with timezones that have half hour offsets.
- Added `mysqlhotcopy`, a fast online hot-backup utility for local MySQL databases. By Tim Bunce.
- New more secure `mysqlaccess`. Thanks to Steve Harvey for this.
- Fixed security problem in the protocol regarding password checking.
- Fixed problem that affected queries that did arithmetic on `GROUP` functions.
- Fixed a bug in the `ISAM` code when deleting rows on tables with packed indexes.

D.5.5 Changes in release 3.22.31

- A few small fixes for the Windows version.

D.5.6 Changes in release 3.22.30

- Fixed optimiser problem on `SELECT` when using many overlapping indexes.
- Disabled floating-point exceptions for FreeBSD to fix core dump when doing `SELECT FLOOR(POW(2,63))`.
- Added print of default arguments options to all clients.
- Fixed critical problem with the `WITH GRANT OPTION` option.
- Fixed non-critical Y2K problem when writing short date to log files.

D.5.7 Changes in release 3.22.29 (02 Jan 2000)

- Upgraded the configure and include files to match the latest 3.23 version. This should increase portability and make it easier to build shared libraries.
- Added latest patches to MIT-pthreads for NetBSD.
- Fixed problem with timezones that are < GMT -11.
- Fixed a bug when deleting packed keys in NISAM.
- Fixed problem that could cause MySQL to touch freed memory when doing very complicated `GROUP BY` queries.
- Fixed core dump if you got a crashed table where an `ENUM` field value was too big.
- Added `mysqlshutdown.exe` and `mysqlwatch.exe` to the Windows distribution.
- Fixed problem when doing `ORDER BY` on a reference key.
- Fixed that `INSERT DELAYED` doesn't update timestamps that are given.

D.5.8 Changes in release 3.22.28 (20 Oct 1999)

- Fixed problem with `LEFT JOIN` and `COUNT()` on a column which was declared `NULL +` and it had a `DEFAULT` value.
- Fixed core dump problem when using `CONCAT()` in a `WHERE` clause.
- Fixed problem with `AVG()` and `STD()` with `NULL` values.

D.5.9 Changes in release 3.22.27

- Fixed prototype in '`my_ctype.h`' when using other character sets.
- Some configure issues to fix problems with big filesystem detection.
- Fixed problem when sorting on big `BLOB` columns.
- `ROUND()` will now work on Windows.

D.5.10 Changes in release 3.22.26 (16 Sep 1999)

- Fixed core dump with empty `BLOB/TEXT` column argument to `REVERSE()`.
- Extended `/*! */` with version numbers.
- Changed `SUBSTRING(text FROM pos)` to conform to SQL-99. (Before this construct returned the rightmost 'pos' characters.)
- Fixed problem with `LOCK TABLES` combined with `DELETE FROM table`
- Fixed problem that `INSERT ... SELECT` didn't use `BIG_TABLES`.
- `SET SQL_LOW_PRIORITY_UPDATES=#` didn't work.
- Password wasn't updated correctly if privileges didn't change on: `GRANT ... IDENTIFIED BY`
- Fixed range optimiser bug in `SELECT * FROM table_name WHERE key_part1 >= const AND (key_part2 = const OR key_part2 = const)`.
- Fixed bug in compression key handling in `ISAM`.

D.5.11 Changes in release 3.22.25

- Fixed some small problems with the installation.

D.5.12 Changes in release 3.22.24 (05 Jul 1999)

- `DATA` is no longer a reserved word.
- Fixed optimiser bug with tables with only one row.
- Fixed bug when using `LOCK TABLES table_name READ; FLUSH TABLES;`
- Applied some patches for HP-UX.
- `isamchk` should now work on Windows.
- Changed '`configure`' to not use big file handling on Linux as this crashes some Red Hat 6.0 systems

D.5.13 Changes in release 3.22.23 (08 Jun 1999)

- Upgraded to use Autoconf 2.13, Automake 1.4 and `libtool` 1.3.2.
- Better support for SCO in `configure`.
- Added option `--defaults-file=file_name` to option file handling to force use of only one specific option file.
- Extended `CREATE` syntax to ignore MySQL Version 3.23 keywords.

- Fixed deadlock problem when using `INSERT DELAYED` on a table locked with `LOCK TABLES`.
- Fixed deadlock problem when using `DROP TABLE` on a table that was locked by another thread.
- Add logging of `GRANT/REVOKE` commands in the update log.
- Fixed `isamchk` to detect a new error condition.
- Fixed bug in `NATURAL LEFT JOIN`.

D.5.14 Changes in release 3.22.22 (30 Apr 1999)

- Fixed problem in the C API when you called `mysql_close()` directly after `mysql_init()`.
- Better client error message when you can't open socket.
- Fixed `delayed_insert_thread` counting when you couldn't create a new delayed_insert thread.
- Fixed bug in `CONCAT()` with many arguments.
- Added patches for DEC 3.2 and SCO.
- Fixed path-bug when installing MySQL as a service on NT.
- MySQL on Windows is now compiled with VC++ 6.0 instead of with VC++ 5.0.
- New installation setup for MySQL on Windows.

D.5.15 Changes in release 3.22.21

- Fixed problem with `DELETE FROM TABLE` when table was locked by another thread.
- Fixed bug in `LEFT JOIN` involving empty tables.
- Changed the `mysql.db` column from `CHAR(32)` to `CHAR(60)`.
- `MODIFY` and `DELAYED` are no longer reserved words.
- Fixed a bug when storing days in a `TIME` column.
- Fixed a problem with `Host '...' is not allowed to connect to this MySQL server` after one had inserted a new MySQL user with a `GRANT` command.
- Changed to use `TCP_NODELAY` also on Linux (should give faster TCP/IP connections).

D.5.16 Changes in release 3.22.20 (18 Mar 1999)

- Fixed `STD()` for big tables when result should be 0.
- The update log didn't have newlines on some operating systems.
- `INSERT DELAYED` had some garbage at end in the update log.

D.5.17 Changes in release 3.22.19 (Mar 1999: Production)

- Fixed bug in `mysql_install_db` (from 3.22.17).
- Changed default key cache size to 8M.
- Fixed problem with queries that needed temporary tables with `BLOB` columns.

D.5.18 Changes in release 3.22.18

- Fixes a fatal problem in 3.22.17 on Linux; after `shutdown` not all threads died properly.
- Added option `-O flush_time=#` to `mysqld`. This is mostly useful on Windows and tells how often MySQL should close all unused tables and flush all updated tables to disk.
- Fixed problem that a `VARCHAR` column compared with `CHAR` column didn't use keys efficiently.

D.5.19 Changes in release 3.22.17

- Fixed a core dump problem when using `--log-update` and connecting without a default database.
- Fixed some `configure` and portability problems.
- Using `LEFT JOIN` on tables that had circular dependencies caused `mysqld` to hang forever.

D.5.20 Changes in release 3.22.16 (Feb 1999: Gamma)

- `mysqladmin processlist` could kill the server if a new user logged in.
- `DELETE FROM tbl_name WHERE key_column=col_name` didn't find any matching rows. Fixed.
- `DATE_ADD(column, ...)` didn't work.
- `INSERT DELAYED` could deadlock with status 'upgrading lock'
- Extended `ENCRYPT()` to take longer salt strings than 2 characters.
- `longlong2str` is now much faster than before. For `Intel x86` platforms, this function is written in optimised assembler.
- Added the `MODIFY` keyword to `ALTER TABLE`.

D.5.21 Changes in release 3.22.15

- `GRANT` used with `IDENTIFIED BY` didn't take effect until privileges were flushed.
- Name change of some variables in `SHOW STATUS`.
- Fixed problem with `ORDER BY` with 'only index' optimisation when there were multiple key definitions for a used column.
- `DATE` and `DATETIME` columns are now up to 5 times faster than before.
- `INSERT DELAYED` can be used to let the client do other things while the server inserts rows into a table.
- `LEFT JOIN USING (col1,col2)` didn't work if one used it with tables from 2 different databases.
- `LOAD DATA LOCAL INFILE` didn't work in the Unix version because of a missing file.
- Fixed problems with `VARCHAR`/`BLOB` on very short rows (< 4 bytes); error 127 could occur when deleting rows.
- Updating `BLOB/TEXT` through formulas didn't work for short (< 256 char) strings.

- When you did a `GRANT` on a new host, `mysqld` could die on the first connect from this host.
- Fixed bug when one used `ORDER BY` on column name that was the same name as an alias.
- Added `BENCHMARK(loop_count,expression)` function to time expressions.

D.5.22 Changes in release 3.22.14

- Allow empty arguments to `mysqld` to make it easier to start from shell scripts.
- Setting a `TIMESTAMP` column to `NULL` didn't record the timestamp value in the update log.
- Fixed lock handler bug when one did `INSERT INTO TABLE ... SELECT ... GROUP BY`.
- Added a patch for `localtime_r()` on Windows so that it will no lonher crash if your date is > 2039, but instead will return a time of all zero.
- Names for user-defined functions are no longer case-sensitive.
- Added escape of `^Z` (ASCII 26) to `\Z` as `^Z` doesn't work with pipes on Windows.
- `mysql_fix_privileges` adds a new column to the `mysql.func` to support aggregate UDF functions in future MySQL releases.

D.5.23 Changes in release 3.22.13

- Saving `NOW()`, `CURDATE()` or `CURTIME()` directly in a column didn't work.
- `SELECT COUNT(*) ... LEFT JOIN ...` didn't work with no `WHERE` part.
- Updated '`config.guess`' to allow MySQL to configure on UnixWare 7.1.x.
- Changed the implementation of `pthread_cond()` on the Windows version. `get_lock()` now correctly times out on Windows!

D.5.24 Changes in release 3.22.12

- Fixed problem when using `DATE_ADD()` and `DATE_SUB()` in a `WHERE` clause.
- You can now set the password for a user with the `GRANT ... TO user IDENTIFIED BY 'password'` syntax.
- Fixed bug in `GRANT` checking with `SELECT` on many tables.
- Added missing file `mysql_fix_privilege_tables` to the RPM distribution. This is not run by default because it relies on the client package.
- Added option `SQL_SMALL_RESULT` to `SELECT` to force use of fast temporary tables when you know that the result set will be small.
- Allow use of negative real numbers without a decimal point.
- Day number is now adjusted to maximum days in month if the resulting month after `DATE_ADD/DATE_SUB()` doesn't have enough days.
- Fix that `GRANT` compares columns in case-insensitive fashion.
- Fixed a bug in '`sql_list.h`' that made `ALTER TABLE` dump core in some contexts.

- The hostname in `user@hostname` can now include '`.`' and '`-`' without quotes in the context of the `GRANT`, `REVOKE` and `SET PASSWORD FOR ...` statements.
- Fix for `isamchk` for tables which need big temporary files.

D.5.25 Changes in release 3.22.11

- **Important**: You must run the `mysql_fix_privilege_tables` script when you upgrade to this version! This is needed because of the new `GRANT` system. If you don't do this, you will get `Access denied` when you try to use `ALTER TABLE`, `CREATE INDEX`, or `DROP INDEX`.
- `GRANT` to allow/deny users table and column access.
- Changed `USER()` to return a value in `user@host` format. Formerly it returned only `user`.
- Changed the syntax for how to set `PASSWORD` for another user.
- New command `FLUSH STATUS` that resets most status variables to zero.
- New status variables: `aborted_threads`, `aborted_connects`.
- New option variable: `connection_timeout`.
- Added support for Thai sorting (by Pruet Boonma `pruet@ds90.intanon.nectec.or.th`).
- Slovak and Japanese error messages.
- Configuration and portability fixes.
- Added option `SET SQL_WARNINGS=1` to get a warning count also for simple inserts.
- MySQL now uses `SIGTERM` instead of `SIGQUIT` with shutdown to work better on FreeBSD.
- Added option `\G` (print vertically) to `mysql`.
- `SELECT HIGH_PRIORITY ...` killed `mysqld`.
- `IS NULL` on a `AUTO_INCREMENT` column in a `LEFT JOIN` didn't work as expected.
- New function `MAKE_SET()`.

D.5.26 Changes in release 3.22.10

- `mysql_install_db` no longer starts the MySQL server! You should start `mysqld` with `safe_mysqld` after installing it! The MySQL RPM will, however, start the server as before.
- Added `--bootstrap` option to `mysqld` and recoded `mysql_install_db` to use it. This will make it easier to install MySQL with RPMs.
- Changed `+`, `-` (sign and minus), `*`, `/`, `%`, `ABS()` and `MOD()` to be `BIGINT` aware (64-bit safe).
- Fixed a bug in `ALTER TABLE` that caused `mysqld` to crash.
- MySQL now always reports the conflicting key values when a duplicate key entry occurs. (Before this was only reported for `INSERT`.)
- New syntax: `INSERT INTO tbl_name SET col_name=value, col_name=value, ...`
- Most errors in the '`.err`' log are now prefixed with a time stamp.

- Added option `MYSQL_INIT_COMMAND` to `mysql_options()` to make a query on connect or reconnect.
- Added option `MYSQL_READ_DEFAULT_FILE` and `MYSQL_READ_DEFAULT_GROUP` to `mysql_options()` to read the following parameters from the MySQL option files: `port`, `socket`, `compress`, `password`, `pipe`, `timeout`, `user`, `init-command`, `host` and `database`.
- Added `maybe_null` to the UDF structure.
- Added option `IGNORE` to `INSERT` statements with many rows.
- Fixed some problems with sorting of the `koi8` character sets; users of `koi8` **must** run `isamchk -rq` on each table that has an index on a `CHAR` or `VARCHAR` column.
- New script `mysql_setpermission`, by Luuk de Boer. It allows easy creation of new users with permissions for specific databases.
- Allow use of hexadecimal strings (0x...) when specifying a constant string (like in the column separators with `LOAD DATA INFILE`).
- Ported to OS/2 (thanks to Antony T. Curtis `antony.curtis@olcs.net`).
- Added more variables to `SHOW STATUS` and changed format of output to be like `SHOW VARIABLES`.
- Added `extended-status` command to `mysqladmin` which will show the new status variables.

D.5.27 Changes in release 3.22.9

- `SET SQL_LOG_UPDATE=0` caused a lockup of the server.
- New SQL command: `FLUSH [ TABLES | HOSTS | LOGS | PRIVILEGES ] [, ...]`
- New SQL command: `KILL thread_id`.
- Added casts and changed include files to make MySQL easier to compile on AIX and DEC OSF/1 4.x
- Fixed conversion problem when using `ALTER TABLE` from a `INT` to a short `CHAR()` column.
- Added `SELECT HIGH_PRIORITY`; this will get a lock for the `SELECT` even if there is a thread waiting for another `SELECT` to get a `WRITE LOCK`.
- Moved `wild_compare()` to string class to be able to use `LIKE` on `BLOB/TEXT` columns with `\0`.
- Added `ESCAPE` option to `LIKE`.
- Added a lot more output to `mysqladmin debug`.
- You can now start `mysqld` on Windows with the `--flush` option. This will flush all tables to disk after each update. This makes things much safer on the Windows platforms but also **much** slower.

D.5.28 Changes in release 3.22.8

- Czech character sets should now work much better.
- `DATE_ADD()` and `DATE_SUB()` didn't work with group functions.

- `mysql` will now also try to reconnect on `USE database` commands.
- Fix problem with `ORDER BY` and `LEFT JOIN` and `const` tables.
- Fixed problem with `ORDER BY` if the first `ORDER BY` column was a key and the rest of the `ORDER BY` columns wasn't part of the key.
- Fixed a big problem with `OPTIMIZE TABLE`.
- MySQL clients on NT will now by default first try to connect with named pipes and after this with TCP/IP.
- Fixed a problem with `DROP TABLE` and `mysqladmin shutdown` on Windows (a fatal bug from 3.22.6).
- Fixed problems with `TIME columns` and negative strings.
- Added an extra thread signal loop on shutdown to avoid some error messages from the client.
- MySQL now uses the next available number as extension for the update log file.
- Added patches for UNIXWARE 7.

D.5.29 Changes in release 3.22.7 (Sep 1998: Beta)

- Added `LIMIT` clause for the `DELETE` statement.
- You can now use the `/*! ... */` syntax to hide MySQL-specific keywords when you write portable code. MySQL will parse the code inside the comments as if the surrounding `/*!` and `*/` comment characters didn't exist.
- `OPTIMIZE TABLE tbl_name` can now be used to reclaim disk space after many deletes. Currently, this uses `ALTER TABLE` to regenerate the table, but in the future it will use an integrated `isamchk` for more speed.
- Upgraded `libtool` to get the configure more portable.
- Fixed slow `UPDATE` and `DELETE` operations when using `DATETIME` or `DATE` keys.
- Changed optimiser to make it better at deciding when to do a full join and when using keys.
- You can now use `mysqladmin proc` to display information about your own threads. Only users with the `PROCESS` privilege can get information about all threads. (In 4.0.2 one needs the `SUPER` privilege for this.)
- Added handling of formats `YYMMDD`, `YYYYMMDD`, `YYMMDDHHMMSS` for numbers when using `DATETIME` and `TIMESTAMP` types. (Formerly these formats only worked with strings.)
- Added connect option `CLIENT_IGNORE_SPACE` to allow use of spaces after function names and before '`(`' (Powerbuilder requires this). This will make all function names reserved words.
- Added the `--log-long-format` option to `mysqld` to enable timestamps and INSERT_IDs in the update log.
- Added `--where` option to `mysqldump` (patch by Jim Faucette).
- The lexical analyser now uses "perfect hashing" for faster parsing of SQL statements.

D.5.30 Changes in release 3.22.6

- Faster `mysqldump`.
- For the `LOAD DATA INFILE` statement, you can now use the new `LOCAL` keyword to read the file from the client. `mysqlimport` will automatically use `LOCAL` when importing with the TCP/IP protocol.
- Fixed small optimise problem when updating keys.
- Changed makefiles to support shared libraries.
- MySQL-NT can now use named pipes, which means that you can now use MySQL-NT without having to install TCP/IP.

D.5.31 Changes in release 3.22.5

- All table lock handing is changed to avoid some very subtle deadlocks when using `DROP TABLE`, `ALTER TABLE`, `DELETE FROM TABLE` and `mysqladmin flush-tables` under heavy usage. Changed locking code to get better handling of locks of different types.
- Updated `DBI` to 1.00 and `DBD` to 1.2.0.
- Added a check that the error message file contains error messages suitable for the current version of `mysqld`. (To avoid errors if you accidentally try to use an old error message file.)
- All count structures in the client (`affected_rows()`, `insert_id()`, ...) are now of type `BIGINT` to allow 64-bit values to be used. This required a minor change in the MySQL protocol which should affect only old clients when using tables with `AUTO_INCREMENT` values > 16M.
- The return type of `mysql_fetch_lengths()` has changed from `uint *` to `ulong *`. This may give a warning for old clients but should work on most machines.
- Change `mysys` and `dbug` libraries to allocate all thread variables in one struct. This makes it easier to make a threaded '`libmysql.dll`' library.
- Use the result from `gethostname()` (instead of `uname()`) when constructing '`.pid`' file names.
- New better compressed server/client protocol.
- `COUNT()`, `STD()` and `AVG()` are extended to handle more than 4G rows.
- You can now store values in the range `-838:59:59 <= x <= 838:59:59` in a `TIME` column.
- **Warning: incompatible change!!** If you set a `TIME` column to too short a value, MySQL now assumes the value is given as: `[[[D ]HH:]MM:]SS` instead of `HH[:MM[:SS]]`.
- `TIME_TO_SEC()` and `SEC_TO_TIME()` can now handle negative times and hours up to 32767.
- Added new option `SET SQL_LOG_UPDATE={0|1}` to allow users with the `PROCESS` privilege to bypass the update log. (Modified patch from Sergey A Mukhin `violet@rosnet.net`.)
- Fixed fatal bug in `LPAD()`.
- Initialise line buffer in '`mysql.cc`' to make `BLOB` reading from pipes safer.

- Added `-O max_connect_errors=#` option to `mysqld`. Connect errors are now reset for each correct connection.
- Increased the default value of `max_allowed_packet` to `1M` in `mysqld`.
- Added `--low-priority-updates` option to `mysqld`, to give table-modifying operations (`INSERT`, `REPLACE`, `UPDATE`, `DELETE`) lower priority than retrievals. You can now use `{INSERT | REPLACE | UPDATE | DELETE} LOW_PRIORITY ...` You can also use `SET SQL_LOW_PRIORITY_UPDATES={0|1}` to change the priority for one thread. One side effect is that `LOW_PRIORITY` is now a reserved word. :(
- Add support for `INSERT INTO table ... VALUES(...),(...),(...)`, to allow inserting multiple rows with a single statement.
- `INSERT INTO tbl_name` is now also cached when used with `LOCK TABLES`. (Previously only `INSERT ... SELECT` and `LOAD DATA INFILE` were cached.)
- Allow `GROUP BY` functions with `HAVING`:

```
mysql> SELECT col FROM table GROUP BY col HAVING COUNT(*)>0;
```

- `mysqld` will now ignore trailing '`;`' characters in queries. This is to make it easier to migrate from some other SQL servers that require the trailing '`;`'.
- Fix for corrupted fixed-format output generated by `SELECT INTO OUTFILE`.
- **Warning: incompatible change!** Added Oracle `GREATEST()` and `LEAST()` functions. You must now use these instead of the `MAX()` and `MIN()` functions to get the largest/smallest value from a list of values. These can now handle `REAL`, `BIGINT` and string (`CHAR` or `VARCHAR`) values.
- **Warning: incompatible change!** `DAYOFWEEK()` had offset 0 for Sunday. Changed the offset to 1.
- Give an error for queries that mix `GROUP BY` columns and fields when there is no `GROUP BY` specification.
- Added `--vertical` option to `mysql`, for printing results in vertical mode.
- Index-only optimisation; some queries are now resolved using only indexes. Until MySQL 4.0, this works only for numeric columns. See Section 5.4.3 [MySQL indexes], page 421.
- Lots of new benchmarks.
- A new C API chapter and lots of other improvements in the manual.

D.5.32 Changes in release 3.22.4

- Added `--tmpdir` option to `mysqld`, for specifying the location of the temporary file directory.
- MySQL now automatically changes a query from an ODBC client:

```
SELECT ... FROM table WHERE auto_increment_column IS NULL
```

  to:

```
SELECT ... FROM table WHERE auto_increment_column == LAST_INSERT_ID()
```

  This allows some ODBC programs (Delphi, Access) to retrieve the newly inserted row to fetch the `AUTO_INCREMENT` id.

- `DROP TABLE` now waits for all users to free a table before deleting it.
- Fixed small memory leak in the new connect protocol.
- New functions `BIN()`, `OCT()`, `HEX()` and `CONV()` for converting between different number bases.
- Added function `SUBSTRING()` with 2 arguments.
- If you created a table with a record length smaller than 5, you couldn't delete rows from the table.
- Added optimisation to remove const reference tables from `ORDER BY` and `GROUP BY`.
- `mysqld` now automatically disables system locking on Linux and Windows, and for systems that use MIT-pthreads. You can force the use of locking with the `--enable-external-locking` option.
- Added `--console` option to `mysqld`, to force a console window (for error messages) when using Windows.
- Fixed table locks for Windows.
- Allow '`$`' in identifiers.
- Changed name of user-specific configuration file from '`my.cnf`' to '`.my.cnf`' (Unix only).
- Added `DATE_ADD()` and `DATE_SUB()` functions.

D.5.33 Changes in release 3.22.3

- Fixed a lock problem (bug in MySQL Version 3.22.1) when closing temporary tables.
- Added missing `mysql_ping()` to the client library.
- Added `--compress` option to all MySQL clients.
- Changed `byte` to `char` in '`mysql.h`' and '`mysql_com.h`'.

D.5.34 Changes in release 3.22.2

- Searching on multiple constant keys that matched more than 30% of the rows didn't always use the best possible key.
- New functions `<<`, `>>`, `RPAD()` and `LPAD()`.
- You can now save default options (like passwords) in a configuration file ('`my.cnf`').
- Lots of small changes to get `ORDER BY` to work when no records are found when using fields that are not in `GROUP BY` (MySQL extension).
- Added `--chroot` option to `mysqld`, to start `mysqld` in a chroot environment (by Nikki Chumakov `nikkic@cityline.ru`).
- Trailing spaces are now ignored when comparing case-sensitive strings; this should fix some problems with ODBC and flag 512!
- Fixed a core dump bug in the range optimiser.
- Added `--one-thread` option to `mysqld`, for debugging with LinuxThreads (or `glibc`). (This replaces the `-T32` flag)
- Added `DROP TABLE IF EXISTS` to prevent an error from occurring if the table doesn't exist.

- `IF` and `EXISTS` are now reserved words (they would have to be sooner or later).
- Added lots of new options to `mysqldump`.
- Server error messages are now in '`mysqld_error.h`'.
- The server/client protocol now supports compression.
- All bug fixes from MySQL Version 3.21.32.

D.5.35 Changes in release 3.22.1 (Jun 1998: Alpha)

- Added new C API function `mysql_ping()`.
- Added new API functions `mysql_init()` and `mysql_options()`. You now MUST call `mysql_init()` before you call `mysql_real_connect()`. You don't have to call `mysql_init()` if you only use `mysql_connect()`.
- Added `mysql_options(...,MYSQL_OPT_CONNECT_TIMEOUT,...)` so you can set a timeout for connecting to a server.
- Added `--timeout` option to `mysqladmin`, as a test of `mysql_options()`.
- Added `AFTER column` and `FIRST` options to `ALTER TABLE ... ADD columns`. This makes it possible to add a new column at some specific location within a row in an existing table.
- `WEEK()` now takes an optional argument to allow handling of weeks when the week starts on Monday (some European countries). By default, `WEEK()` assumes the week starts on Sunday.
- `TIME` columns weren't stored properly (bug in MySQL Version 3.22.0).
- `UPDATE` now returns information about how many rows were matched and updated, and how many "warnings" occurred when doing the update.
- Fixed incorrect result from `FORMAT(-100,2)`.
- `ENUM` and `SET` columns were compared in binary (case-sensitive) fashion; changed to be case-insensitive.

D.5.36 Changes in release 3.22.0

- New (backward-compatible) connect protocol that allows you to specify the database to use when connecting, to get much faster connections to a specific database.

  The `mysql_real_connect()` call is changed to:

  ```
  mysql_real_connect(MYSQL *mysql, const char *host, const char *user,
                     const char *passwd, const char *db, uint port,
                     const char *unix_socket, uint client_flag)
  ```

- Each connection is handled by its own thread, rather than by the master `accept()` thread. This fixes permanently the telnet bug that was a topic on the mail list some time ago.
- All TCP/IP connections are now checked with backward-resolution of the hostname to get better security. `mysqld` now has a local hostname resolver cache so connections should actually be faster than before, even with this feature.

- A site automatically will be blocked from future connections if someone repeatedly connects with an "improper header" (like when one uses telnet).
- You can now refer to tables in different databases with references of the form `tbl_name@db_name` or `db_name.tbl_name`. This makes it possible to give a user read access to some tables and write access to others simply by keeping them in different databases!
- Added `--user` option to `mysqld`, to allow it to run as another Unix user (if it is started as the Unix `root` user).
- Added caching of users and access rights (for faster access rights checking)
- Normal users (not anonymous ones) can change their password with `mysqladmin password 'new_password'`. This uses encrypted passwords that are not logged in the normal MySQL log!
- All important string functions are now coded in assembler for x86 Linux machines. This gives a speedup of 10% in many cases.
- For tables that have many columns, the column names are now hashed for much faster column name lookup (this will speed up some benchmark tests a lot!)
- Some benchmarks are changed to get better individual timing. (Some loops were so short that a specific test took < 2 seconds. The loops have been changed to take about 20 seconds to make it easier to compare different databases. A test that took 1-2 seconds before now takes 11-24 seconds, which is much better)
- Re-arranged `SELECT` code to handle some very specific queries involving group functions (like `COUNT(*)`) without a `GROUP BY` but with `HAVING`. The following now works:

```
mysql> SELECT COUNT(*) as C FROM table HAVING C > 1;
```

- Changed the protocol for field functions to be faster and avoid some calls to `malloc()`.
- Added `-T32` option to `mysqld`, for running all queries under the main thread. This makes it possible to debug `mysqld` under Linux with `gdb`!
- Added optimisation of `not_null_column IS NULL` (needed for some Access queries).
- Allow `STRAIGHT_JOIN` to be used between two tables to force the optimiser to join them in a specific order.
- String functions now return `VARCHAR` rather than `CHAR` and the column type is now `VARCHAR` for fields saved as `VARCHAR`. This should make the `MyODBC` driver better, but may break some old MySQL clients that don't handle `FIELD_TYPE_VARCHAR` the same way as `FIELD_TYPE_CHAR`.
- `CREATE INDEX` and `DROP INDEX` are now implemented through `ALTER TABLE`. `CREATE TABLE` is still the recommended (fast) way to create indexes.
- Added `--set-variable` option `wait_timeout` to `mysqld`.
- Added time column to `mysqladmin processlist` to show how long a query has taken or how long a thread has slept.
- Added lots of new variables to `show variables` and some new to `show status`.
- Added new type `YEAR`. `YEAR` is stored in 1 byte with allowable values of 0, and 1901 to 2155.
- Added new `DATE` type that is stored in 3 bytes rather than 4 bytes. All new tables are created with the new date type if you don't use the `--old-protocol` option to `mysqld`.

- Fixed bug in record caches; for some queries, you could get `Error from table handler: #` on some operating systems.
- Added `--enable-assembler` option to `configure`, for x86 machines (tested on Linux + `gcc`). This will enable assembler functions for the most important string functions for more speed!

D.6 Changes in release 3.21.x

Version 3.21 is quite old now, and should be avoided if possible. This information is kept here for historical purposes only.

D.6.1 Changes in release 3.21.33

- Fixed problem when sending `SIGHUP` to `mysqld`; `mysqld` core dumped when starting from boot on some systems.
- Fixed problem with losing a little memory for some connections.
- `DELETE FROM tbl_name` without a `WHERE` condition is now done the long way when you use `LOCK TABLES` or if the table is in use, to avoid race conditions.
- `INSERT INTO TABLE (timestamp_column) VALUES (NULL);` didn't set timestamp.

D.6.2 Changes in release 3.21.32

- Fixed some possible race conditions when doing many reopen/close on the same tables under heavy load! This can happen if you execute `mysqladmin refresh` often. This could in some very rare cases corrupt the header of the index file and cause error 126 or 138.
- Fixed fatal bug in `refresh()` when running with the `--skip-external-locking` option. There was a "very small" time gap after a `mysqladmin refresh` when a table could be corrupted if one thread updated a table while another thread did `mysqladmin refresh` and another thread started a new update ont the same table before the first thread had finished. A refresh (or `--flush-tables`) will now not return until all used tables are closed!
- `SELECT DISTINCT` with a `WHERE` clause that didn't match any rows returned a row in some contexts (bug only in 3.21.31).
- `GROUP BY + ORDER BY` returned one empty row when no rows where found.
- Fixed a bug in the range optimiser that wrote `Use_count: Wrong count for ...` in the error log file.

D.6.3 Changes in release 3.21.31

- Fixed a sign extension problem for the `TINYINT` type on Irix.
- Fixed problem with `LEFT("constant_string",function)`.
- Fixed problem with `FIND_IN_SET()`.

- `LEFT JOIN` core dumped if the second table is used with a constant `WHERE/ON` expression that uniquely identifies one record.
- Fixed problems with `DATE_FORMAT()` and incorrect dates. `DATE_FORMAT()` now ignores `'%'` to make it possible to extend it more easily in the future.

D.6.4 Changes in release 3.21.30

- `mysql` now returns an exit code > 0 if the query returned an error.
- Saving of command-line history to file in `mysql` client. By Tommy Larsen `tommy@mix.hive.no`.
- Fixed problem with empty lines that were ignored in '`mysql.cc`'.
- Save the pid of the signal handler thread in the pid file instead of the pid of the main thread.
- Added patch by `tommy@valley.ne.jp` to support Japanese characters SJIS and UJIS.
- Changed `safe_mysqld` to redirect startup messages to `'hostname'.err` instead of `'hostname'.log` to reclaim file space on `mysqladmin refresh`.
- `ENUM` always had the first entry as default value.
- `ALTER TABLE` wrote two entries to the update log.
- `sql_acc()` now closes the `mysql` grant tables after a reload to save table space and memory.
- Changed `LOAD DATA` to use less memory with tables and `BLOB` columns.
- Sorting on a function which made a division / 0 produced a wrong set in some cases.
- Fixed `SELECT` problem with `LEFT()` when using the `czech` character set.
- Fixed problem in `isamchk`; it couldn't repair a packed table in a very unusual case.
- `SELECT` statements with `&` or `|` (bit functions) failed on columns with `NULL` values.
- When comparing a field = field, where one of the fields was a part key, only the length of the part key was compared.

D.6.5 Changes in release 3.21.29

- `LOCK TABLES + DELETE from tbl_name` never removed locks properly.
- Fixed problem when grouping on an `OR` function.
- Fixed permission problem with `umask()` and creating new databases.
- Fixed permission problem on result file with `SELECT ... INTO OUTFILE ...`
- Fixed problem in range optimiser (core dump) for a very complex query.
- Fixed problem when using `MIN(integer)` or `MAX(integer)` in `GROUP BY`.
- Fixed bug on Alpha when using integer keys. (Other keys worked on Alpha.)
- Fixed bug in `WEEK("XXXX-xx-01")`.

D.6.6 Changes in release 3.21.28

- Fixed socket permission (clients couldn't connect to Unix socket on Linux).
- Fixed bug in record caches; for some queries, you could get `Error from table handler: #` on some operating systems.

D.6.7 Changes in release 3.21.27

- Added user level lock functions `GET_LOCK(string,timeout)`, `RELEASE_LOCK(string)`.
- Added `Opened_tables` to `show status`.
- Changed connect timeout to 3 seconds to make it somewhat harder for crackers to kill `mysqld` through telnet + TCP/IP.
- Fixed bug in range optimiser when using `WHERE key_part_1 >= something AND key_part_2 <= something_else`.
- Changed `configure` for detection of FreeBSD 3.0 9803xx and above
- `WHERE` with `string_col_key = constant_string` didn't always find all rows if the column had many values differing only with characters of the same sort value (like e and e with an accent).
- Strings keys looked up with 'ref' were not compared in case-sensitive fashion.
- Added `umask()` to make log files non-readable for normal users.
- Ignore users with old (8-byte) password on startup if not using `--old-protocol` option to `mysqld`.
- `SELECT` which matched all key fields returned the values in the case of the matched values, not of the found values. (Minor problem.)

D.6.8 Changes in release 3.21.26

- `FROM_DAYS(0)` now returns `"0000-00-00"`.
- In `DATE_FORMAT()`, PM and AM were swapped for hours 00 and 12.
- Extended the default maximum key size to 256.
- Fixed bug when using `BLOB/TEXT` in `GROUP BY` with many tables.
- An `ENUM` field that is not declared `NOT NULL` has `NULL` as the default value. (Previously, the default value was the first enumeration value.)
- Fixed bug in the join optimiser code when using many part keys on the same key: `INDEX (Organisation,Surname(35),Initials(35))`.
- Added some tests to the table order optimiser to get some cases with `SELECT ... FROM many_tables` much faster.
- Added a retry loop around `accept()` to possibly fix some problems on some Linux machines.

D.6.9 Changes in release 3.21.25

- Changed `typedef 'string'` to `typedef 'my_string'` for better portability.

- You can now kill threads that are waiting on a disk-full condition.
- Fixed some problems with UDF functions.
- Added long options to `isamchk`. Try `isamchk --help`.
- Fixed a bug when using 8 bytes long (alpha); `filesort()` didn't work. Affects `DISTINCT`, `ORDER BY` and `GROUP BY` on 64-bit processors.

D.6.10 Changes in release 3.21.24

- Dynamic loadable functions. Based on source from Alexis Mikhailov.
- You couldn't delete from a table if no one had done a `SELECT` on the table.
- Fixed problem with range optimiser with many `OR` operators on key parts inside each other.
- Recoded `MIN()` and `MAX()` to work properly with strings and `HAVING`.
- Changed default umask value for new files from `0664` to `0660`.
- Fixed problem with `LEFT JOIN` and constant expressions in the `ON` part.
- Added Italian error messages from `brenno@dewinter.com`.
- `configure` now works better on OSF/1 (tested on 4.0D).
- Added hooks to allow `LIKE` optimisation with international character support.
- Upgraded `DBI` to 0.93.

D.6.11 Changes in release 3.21.23

- The following symbols are now reserved words: `TIME`, `DATE`, `TIMESTAMP`, `TEXT`, `BIT`, `ENUM`, `NO`, `ACTION`, `CHECK`, `YEAR`, `MONTH`, `DAY`, `HOUR`, `MINUTE`, `SECOND`, `STATUS`, `VARIABLES`.
- Setting a `TIMESTAMP` to `NULL` in `LOAD DATA INFILE ...` didn't set the current time for the `TIMESTAMP`.
- Fix `BETWEEN` to recognise binary strings. Now `BETWEEN` is case-sensitive.
- Added `--skip-thread-priority` option to `mysqld`, for systems where `mysqld`'s thread scheduling doesn't work properly (BSDI 3.1).
- Added ODBC functions `DAYNAME()` and `MONTHNAME()`.
- Added function `TIME_FORMAT()`. This works like `DATE_FORMAT()`, but takes a time string (`'HH:MM:SS'`) as argument.
- Fixed unlikely(?) key optimiser bug when using `OR` operators of key parts inside `AND` expressions.
- Added `variables` command to `mysqladmin`.
- A lot of small changes to the binary releases.
- Fixed a bug in the new protocol from MySQL Version 3.21.20.
- Changed `ALTER TABLE` to work with Windows (Windows can't rename open files). Also fixed a couple of small bugs in the Windows version.
- All standard MySQL clients are now ported to MySQL for Windows.
- MySQL can now be started as a service on NT.

D.6.12 Changes in release 3.21.22

- Starting with this version, all MySQL distributions will be configured, compiled and tested with `crash-me` and the benchmarks on the following platforms: SunOS 5.6 sun4u, SunOS 5.5.1 sun4u, SunOS 4.14 sun4c, SunOS 5.6 i86pc, Irix 6.3 mips5k, HP-UX 10.20 hppa, AIX 4.2.1 ppc, OSF/1 V4.0 alpha, FreeBSD 2.2.2 i86pc and BSDI 3.1 i386.
- Fix `COUNT(*)` problems when the `WHERE` clause didn't match any records. (Bug from 3.21.17.)
- Removed that `NULL = NULL` is true. Now you must use `IS NULL` or `IS NOT NULL` to test whether a value is `NULL`. (This is according to SQL-99 but may break old applications that are ported from `mSQL`.) You can get the old behaviour by compiling with `-DmSQL_COMPLIANT`.
- Fixed bug that core dumped when using many `LEFT OUTER JOIN` clauses.
- Fixed bug in `ORDER BY` on string formula with possible `NULL` values.
- Fixed problem in range optimiser when using `<=` on sub index.
- Added functions `DAYOFYEAR()`, `DAYOFMONTH()`, `MONTH()`, `YEAR()`, `WEEK()`, `QUARTER()`, `HOUR()`, `MINUTE()`, `SECOND()` and `FIND_IN_SET()`.
- Added `SHOW VARIABLES` command.
- Added support of "long constant strings" from SQL-99:

```
mysql> SELECT 'first ' 'second';       -> 'first second'
```

- Upgraded Msql-Mysql-modules to 1.1825.
- Upgraded `mysqlaccess` to 2.02.
- Fixed problem with Russian character set and `LIKE`.
- Ported to OpenBSD 2.1.
- New Dutch error messages.

D.6.13 Changes in release 3.21.21a

- Configure changes for some operating systems.

D.6.14 Changes in release 3.21.21

- Fixed optimiser bug when using `WHERE data_field = date_field2 AND date_field2 = constant`.
- Added `SHOW STATUS` command.
- Removed '`manual.ps`' from the source distribution to make it smaller.

D.6.15 Changes in release 3.21.20

- Changed the maximum table name and column name lengths from 32 to 64.
- Aliases can now be of "any" length.
- Fixed `mysqladmin stat` to return the right number of queries.

- Changed protocol (downward compatible) to mark if a column has the `AUTO_INCREMENT` attribute or is a `TIMESTAMP`. This is needed for the new Java driver.
- Added Hebrew sorting order by Zeev Suraski.
- Solaris 2.6: Fixed `configure` bugs and increased maximum table size from 2G to 4G.

D.6.16 Changes in release 3.21.19

- Upgraded `DBD` to 1.1823. This version implements `mysql_use_result` in `DBD-Mysql`.
- Benchmarks updated for empress (by Luuk).
- Fixed a case of slow range searching.
- Configure fixes ('`Docs`' directory).
- Added function `REVERSE()` (by Zeev Suraski).

D.6.17 Changes in release 3.21.18

- Issue error message if client C functions are called in wrong order.
- Added automatic reconnect to the '`libmysql.c`' library. If a write command fails, an automatic reconnect is done.
- Small sort sets no longer use temporary files.
- Upgraded `DBI` to 0.91.
- Fixed a couple of problems with `LEFT OUTER JOIN`.
- Added `CROSS JOIN` syntax. `CROSS` is now a reserved word.
- Recoded `yacc/bison` stack allocation to be even safer and to allow MySQL to handle even bigger expressions.
- Fixed a couple of problems with the update log.
- `ORDER BY` was slow when used with key ranges.

D.6.18 Changes in release 3.21.17

- Changed documentation string of `--with-unix-socket-path` to avoid confusion.
- Added ODBC and SQL-99 style `LEFT OUTER JOIN`.
- The following are new reserved words: `LEFT`, `NATURAL`, `USING`.
- The client library now uses the value of the environment variable `MYSQL_HOST` as the default host if it's defined.
- `SELECT col_name, SUM(expr)` now returns `NULL` for `col_name` when there are matching rows.
- Fixed problem with comparing binary strings and `BLOB` values with ASCII characters over 127.
- Fixed lock problem: when freeing a read lock on a table with multiple read locks, a thread waiting for a write lock would have been given the lock. This shouldn't affect data integrity, but could possibly make `mysqld` restart if one thread was reading data that another thread modified.

- `LIMIT offset,count` didn't work in `INSERT ... SELECT`.
- Optimised key block caching. This will be quicker than the old algorithm when using bigger key caches.

D.6.19 Changes in release 3.21.16

- Added ODBC 2.0 & 3.0 functions `POWER()`, `SPACE()`, `COT()`, `DEGREES()`, `RADIANS()`, `ROUND(2 arg)` and `TRUNCATE()`.
- **Warning: Incompatible change!** `LOCATE()` parameters were swapped according to ODBC standard. Fixed.
- Added function `TIME_TO_SEC()`.
- In some cases, default values were not used for `NOT NULL` fields.
- Timestamp wasn't always updated properly in `UPDATE SET ...` statements.
- Allow empty strings as default values for `BLOB` and `TEXT`, to be compatible with `mysqldump`.

D.6.20 Changes in release 3.21.15

- **Warning: Incompatible change!** `mysqlperl` is now from Msql-Mysql-modules. This means that `connect()` now takes `host`, `database`, `user`, `password` arguments! The old version took `host`, `database`, `password`, `user`.
- Allow `DATE '1997-01-01'`, `TIME '12:10:10'` and `TIMESTAMP '1997-01-01 12:10:10'` formats required by SQL-99. **Warning: Incompatible change!** This has the unfortunate side-effect that you no longer can have columns named `DATE`, `TIME` or `TIMESTAMP`. :(Old columns can still be accessed through `tablename.columnname`!)
- Changed Makefiles to hopefully work better with BSD systems. Also, '`manual.dvi`' is now included in the distribution to avoid having stupid `make` programs trying to rebuild it.
- `readline` library upgraded to version 2.1.
- A new sortorder german-1. That is a normal ISO-Latin1 with a german sort order.
- Perl `DBI/DBD` is now included in the distribution. `DBI` is now the recommended way to connect to MySQL from Perl.
- New portable benchmark suite with `DBD`, with test results from `mSQL` 2.0.3, MySQL, PostgreSQL 6.2.1 and Solid server 2.2.
- `crash-me` is now included with the benchmarks; this is a Perl program designed to find as many limits as possible in an SQL server. Tested with `mSQL`, PostgreSQL, Solid and MySQL.
- Fixed bug in range-optimiser that crashed MySQL on some queries.
- Table and column name completion for `mysql` command-line tool, by Zeev Suraski and Andi Gutmans.
- Added new command `REPLACE` that works like `INSERT` but replaces conflicting records with the new record. `REPLACE INTO TABLE ... SELECT ...` works also.
- Added new commands `CREATE DATABASE db_name` and `DROP DATABASE db_name`.

- Added `RENAME` option to `ALTER TABLE`: `ALTER TABLE name RENAME TO new_name`.
- `make_binary_distribution` now includes '`libgcc.a`' in '`libmysqlclient.a`'. This should make linking work for people who don't have `gcc`.
- Changed `net_write()` to `my_net_write()` because of a name conflict with Sybase.
- New function `DAYOFWEEK()` compatible with ODBC.
- Stack checking and `bison` memory overrun checking to make MySQL safer with weird queries.

D.6.21 Changes in release 3.21.14b

- Fixed a couple of small `configure` problems on some platforms.

D.6.22 Changes in release 3.21.14a

- Ported to SCO Openserver 5.0.4 with FSU Pthreads.
- HP-UX 10.20 should work.
- Added new function `DATE_FORMAT()`.
- Added `NOT IN`.
- Added automatic removal of 'ODBC function conversions': `{fn now() }`
- Handle ODBC 2.50.3 option flags.
- Fixed comparison of `DATE` and `TIME` values with `NULL`.
- Changed language name from germany to german to be consistent with the other language names.
- Fixed sorting problem on functions returning a `FLOAT`. Previously, the values were converted to `INT` values before sorting.
- Fixed slow sorting when sorting on key field when using `key_column=constant`.
- Sorting on calculated `DOUBLE` values sorted on integer results instead.
- `mysql` no longer requires a database argument.
- Changed the place where `HAVING` should be. According to the SQL standards, it should be after `GROUP BY` but before `ORDER BY`. MySQL Version 3.20 incorrectly had it last.
- Added Sybase command `USE database` to start using another database.
- Added automatic adjusting of number of connections and table cache size if the maximum number of files that can be opened is less than needed. This should fix that `mysqld` doesn't crash even if you haven't done a `ulimit -n 256` before starting `mysqld`.
- Added lots of limit checks to make it safer when running with too little memory or when doing weird queries.

D.6.23 Changes in release 3.21.13

- Added retry of interrupted reads and clearing of `errno`. This makes Linux systems much safer!
- Fixed locking bug when using many aliases on the same table in the same `SELECT`.

- Fixed bug with `LIKE` on number key.
- New error message so you can check whether the connection was lost while the command was running or whether the connection was down from the start.
- Added `--table` option to `mysql` to print in table format. Moved time and row information after query result. Added automatic reconnect of lost connections.
- Added `!=` as a synonym for `<>`.
- Added function `VERSION()` to make easier logs.
- New multi-user test '`tests/fork_test.pl`' to put some strain on the thread library.

D.6.24 Changes in release 3.21.12

- Fixed `ftruncate()` call in MIT-pthreads. This made `isamchk` destroy the '`.ISM`' files on (Free)BSD 2.x systems.
- Fixed broken `__P_` patch in MIT-pthreads.
- Many memory overrun checks. All string functions now return `NULL` if the returned string should be longer than `max_allowed_packet` bytes.
- Changed the name of the `INTERVAL` type to `ENUM`, because `INTERVAL` is used in SQL-99.
- In some cases, doing a `JOIN + GROUP + INTO OUTFILE`, the result wasn't grouped.
- `LIKE` with `'_'` as last character didn't work. Fixed.
- Added extended SQL-99 `TRIM()` function.
- Added `CURTIME()`.
- Added `ENCRYPT()` function by Zeev Suraski.
- Fixed better `FOREIGN KEY` syntax skipping. New reserved words: `MATCH`, `FULL`, `PARTIAL`.
- `mysqld` now allows IP number and hostname for the `--bind-address` option.
- Added `SET CHARACTER SET cp1251_koi8` to enable conversions of data to and from the `cp1251_koi8` character set.
- Lots of changes for Windows 95 port. In theory, this version should now be easily portable to Windows 95.
- Changed the `CREATE COLUMN` syntax of `NOT NULL` columns to be after the `DEFAULT` value, as specified in the SQL-99 standard. This will make `mysqldump` with `NOT NULL` and default values incompatible with MySQL Version 3.20.
- Added many function name aliases so the functions can be used with ODBC or SQL-92 syntax.
- Fixed syntax of `ALTER TABLE tbl_name ALTER COLUMN col_name SET DEFAULT NULL`.
- Added `CHAR` and `BIT` as synonyms for `CHAR(1)`.
- Fixed core dump when updating as a user who has only `SELECT` privilege.
- `INSERT ... SELECT ... GROUP BY` didn't work in some cases. An `Invalid use of group function` error occurred.
- When using `LIMIT`, `SELECT` now always uses keys instead of record scan. This will give better performance on `SELECT` and a `WHERE` that matches many rows.
- Added Russian error messages.

D.6.25 Changes in release 3.21.11

- Configure changes.
- MySQL now works with the new thread library on BSD/OS 3.0.
- Added new group functions `BIT_OR()` and `BIT_AND()`.
- Added compatibility functions `CHECK` and `REFERENCES`. `CHECK` is now a reserved word.
- Added `ALL` option to `GRANT` for better compatibility. (`GRANT` is still a dummy function.)
- Added partly-translated Dutch error messages.
- Fixed bug in `ORDER BY` and `GROUP BY` with `NULL` columns.
- Added function `LAST_INSERT_ID()` SQL function to retrieve last `AUTO_INCREMENT` value. This is intended for clients to ODBC that can't use the `mysql_insert_id()` API function, but can be used by any client.
- Added `--flush-logs` option to `mysqladmin`.
- Added command `STATUS` to `mysql`.
- Fixed problem with `ORDER BY/GROUP BY` because of bug in `gcc`.
- Fixed problem with `INSERT ... SELECT ... GROUP BY`.

D.6.26 Changes in release 3.21.10

- New program `mysqlaccess`.
- `CREATE` now supports all ODBC types and the `mSQL` `TEXT` type. All ODBC 2.5 functions are also supported (added `REPEAT`). This provides better portability.
- Added text types `TINYTEXT`, `TEXT`, `MEDIUMTEXT` and `LONGTEXT`. These are actually `BLOB`types, but all searching is done in case-insensitive fashion.
- All old `BLOB` fields are now `TEXT` fields. This only changes that all searching on strings is done in case-sensitive fashion. You must do an `ALTER TABLE` and change the datatype to `BLOB` if you want to have tests done in case-sensitive fashion.
- Fixed some `configure` issues.
- Made the locking code a bit safer. Fixed very unlikely deadlock situation.
- Fixed a couple of bugs in the range optimiser. Now the new range benchmark `test-select` works.

D.6.27 Changes in release 3.21.9

- Added `--enable-unix-socket=pathname` option to `configure`.
- Fixed a couple of portability problems with include files.
- Fixed bug in range calculation that could return empty set when searching on multiple key with only one entry (very rare).
- Most things ported to FSU Pthreads, which should allow MySQL to run on SCO. See Section 2.6.6.9 [SCO], page 149.

D.6.28 Changes in release 3.21.8

- Works now in Solaris 2.6.
- Added handling of calculation of `SUM()` functions. For example, you can now use `SUM(column)/COUNT(column)`.
- Added handling of trigometric functions: `PI()`, `ACOS()`, `ASIN()`, `ATAN()`, `COS()`, `SIN()` and `TAN()`.
- New languages: Norwegian, Norwegian-ny and Portuguese.
- Fixed parameter bug in `net_print()` in '`procedure.cc`'.
- Fixed a couple of memory leaks.
- Now allow also the old `SELECT ... INTO OUTFILE` syntax.
- Fixed bug with `GROUP BY` and `SELECT` on key with many values.
- `mysql_fetch_lengths()` sometimes returned incorrect lengths when you used `mysql_use_result()`. This affected at least some cases of `mysqldump --quick`.
- Fixed bug in optimisation of `WHERE const op field`.
- Fixed problem when sorting on `NULL` fields.
- Fixed a couple of 64-bit (Alpha) problems.
- Added `--pid-file=#` option to `mysqld`.
- Added date formatting to `FROM_UNIXTIME()`, originally by Zeev Suraski.
- Fixed bug in `BETWEEN` in range optimiser (did only test = of the first argument).
- Added machine-dependent files for MIT-pthreads i386-SCO. There is probably more to do to get this to work on SCO 3.5.

D.6.29 Changes in release 3.21.7

- Changed '`Makefile.am`' to take advantage of Automake 1.2.
- Added the beginnings of a benchmark suite.
- Added more secure password handling.
- Added new client function `mysql_errno()`, to get the error number of the error message. This makes error checking in the client much easier. This makes the new server incompatible with the 3.20.x server when running without `--old-protocol`. The client code is backward-compatible. More information can be found in the '`README`' file!
- Fixed some problems when using very long, illegal names.

D.6.30 Changes in release 3.21.6

- Fixed more portability issues (incorrect `sigwait` and `sigset` defines).
- `configure` should now be able to detect the last argument to `accept()`.

D.6.31 Changes in release 3.21.5

- Should now work with FreeBSD 3.0 if used with '`FreeBSD-3.0-libc_r-1.0.diff`', which can be found at `http://www.mysql.com/downloads/os-freebsd.html`.

- Added new `-O tmp_table_size=#` option to `mysqld`.
- New function `FROM_UNIXTIME(timestamp)` which returns a date string in `'YYYY-MM-DD HH:MM:SS'` format.
- New function `SEC_TO_TIME(seconds)` which returns a string in `'HH:MM:SS'` format.
- New function `SUBSTRING_INDEX()`, originally by Zeev Suraski.

D.6.32 Changes in release 3.21.4

- Should now configure and compile on OSF/1 4.0 with the DEC compiler.
- Configuration and compilation on BSD/OS 3.0 works, but due to some bugs in BSD/OS 3.0, `mysqld` doesn't work on it yet.
- Configuration and compilation on FreeBSD 3.0 works, but I couldn't get `pthread_create` to work.

D.6.33 Changes in release 3.21.3

- Added reverse check lookup of hostnames to get better security.
- Fixed some possible buffer overflows if filenames that are too long are used.
- `mysqld` doesn't accept hostnames that start with digits followed by a `'.'`, because the hostname may look like an IP number.
- Added `--skip-networking` option to `mysqld`, to allow only socket connections. (This will not work with MIT-pthreads!)
- Added check of too long table names for alias.
- Added check if database name is okay.
- Added check if too long table names.
- Removed incorrect `free()` that killed the server on `CREATE DATABASE` or `DROP DATABASE`.
- Changed some `mysqld -O` options to better names.
- Added `-O join_cache_size=#` option to `mysqld`.
- Added `-O max_join_size=#` option to `mysqld`, to be able to set a limit how big queries (in this case big = slow) one should be able to handle without specifying `SET SQL_BIG_SELECTS=1`. A # = is about 10 examined records. The default is "unlimited".
- When comparing a `TIME`, `DATE`, `DATETIME` or `TIMESTAMP` column to a constant, the constant is converted to a time value before performing the comparison. This will make it easier to get ODBC (particularly Access97) to work with the above types. It should also make dates easier to use and the comparisons should be quicker than before.
- Applied patch from Jochen Wiedmann that allows `query()` in `mysqlperl` to take a query with `\0` in it.
- Storing a timestamp with a 2-digit year (`YYMMDD`) didn't work.
- Fix that timestamp wasn't automatically updated if set in an `UPDATE` clause.
- Now the automatic timestamp field is the FIRST timestamp field.
- `SELECT * INTO OUTFILE`, which didn't correctly if the outfile already existed.

- `mysql` now shows the thread ID when starting or doing a reconnect.
- Changed the default sort buffer size from 2M to 1M.

D.6.34 Changes in release 3.21.2

- The range optimiser is coded, but only 85% tested. It can be enabled with `--new`, but it crashes core a lot yet...
- More portable. Should compile on AIX and alpha-digital. At least the `isam` library should be relatively 64-bit clean.
- New `isamchk` which can detect and fix more problems.
- New options for `isamlog`.
- Using new version of Automake.
- Many small portability changes (from the AIX and alpha-digital port) Better checking of pthread(s) library.
- czech error messages by `snajdr@pvt.net`.
- Decreased size of some buffers to get fewer problems on systems with little memory. Also added more checks to handle "out of memory" problems.
- `mysqladmin`: you can now do `mysqladmin kill 5,6,7,8` to kill multiple threads.
- When the maximum connection limit is reached, one extra connection by a user with the **process_acl** privilege is granted.
- Added `-O backlog=#` option to `mysqld`.
- Increased maximum packet size from 512K to 1024K for client.
- Almost all of the function code is now tested in the internal test suite.
- `ALTER TABLE` now returns warnings from field conversions.
- Port changed to 3306 (got it reserved from ISI).
- Added a fix for Visual FoxBase so that any schema name from a table specification is automatically removed.
- New function `ASCII()`.
- Removed function `BETWEEN(a,b,c)`. Use the standard SQL syntax instead: `expr BETWEEN expr AND expr`.
- MySQL no longer has to use an extra temporary table when sorting on functions or `SUM()` functions.
- Fixed bug that you couldn't use `tbl_name.field_name` in `UPDATE`.
- Fixed `SELECT DISTINCT` when using 'hidden group'. For example:

```
mysql> SELECT DISTINCT MOD(some_field,10) FROM test
    ->        GROUP BY some_field;
```

  Note: `some_field` is normally in the `SELECT` part. Standard SQL should require it.

D.6.35 Changes in release 3.21.0

- New reserved words used: `INTERVAL`, `EXPLAIN`, `READ`, `WRITE`, `BINARY`.
- Added ODBC function `CHAR(num,...)`.

- New operator `IN`. This uses a binary search to find a match.
- New command `LOCK TABLES tbl_name [AS alias] {READ|WRITE} ...`
- Added `--log-update` option to `mysqld`, to get a log suitable for incremental updates.
- New command `EXPLAIN SELECT ...` to get information about how the optimiser will do the join.
- For easier client code, the client should no longer use `FIELD_TYPE_TINY_BLOB`, `FIELD_TYPE_MEDIUM_BLOB`, `FIELD_TYPE_LONG_BLOB` or `FIELD_TYPE_VAR_STRING` (as previously returned by `mysql_list_fields`). You should instead only use `FIELD_TYPE_BLOB` or `FIELD_TYPE_STRING`. If you want exact types, you should use the command `SHOW FIELDS`.
- Added varbinary syntax: `0x######` which can be used as a string (default) or a number.
- `FIELD_TYPE_CHAR` is renamed to `FIELD_TYPE_TINY`.
- Changed all fields to C++ classes.
- Removed FORM struct.
- Fields with `DEFAULT` values no longer need to be `NOT NULL`.
- New field types:

  `ENUM` A string which can take only a couple of defined values. The value is stored as a 1-3 byte number that is mapped automatically to a string. This is sorted according to string positions!

  `SET` A string which may have one or many string values separated with ','. The string is stored as a 1-, 2-, 3-, 4- or 8-byte number where each bit stands for a specific set member. This is sorted according to the unsigned value of the stored packed number.
- Now all function calculation is done with `double` or `long long`. This will provide the full 64-bit range with bit functions and fix some conversions that previously could result in precision losses. One should avoid using `unsigned long long` columns with full 64-bit range (numbers bigger than 9223372036854775807) because calculations are done with `signed long long`.
- `ORDER BY` will now put `NULL` field values first. `GROUP BY` will also work with `NULL` values.
- Full `WHERE` with expressions.
- New range optimiser that can resolve ranges when some keypart prefix is constant. Example:

```
mysql> SELECT * FROM tbl_name
    ->          WHERE key_part_1="customer"
    ->          AND key_part_2>=10 AND key_part_2<=10;
```

D.7 Changes in release 3.20.x

Version 3.20 is quite old now, and should be avoided if possible. This information is kept here for historical purposes only.

Changes from 3.20.18 to 3.20.32b are not documented here because the 3.21 release branched here. And the relevant changes are also documented as changes to the 3.21 version.

D.7.1 Changes in release 3.20.18

- Added `-p#` (remove `#` directories from path) to `isamlog`. All files are written with a relative path from the database directory Now `mysqld` shouldn't crash on shutdown when using the `--log-isam` option.
- New `mysqlperl` version. It is now compatible with `msqlperl-0.63`.
- New `DBD` module available.
- Added group function `STD()` (standard deviation).
- The `mysqld` server is now compiled by default without debugging information. This will make the daemon smaller and faster.
- Now one usually only has to specify the `--basedir` option to `mysqld`. All other paths are relative in a normal installation.
- `BLOB` columns sometimes contained garbage when used with a `SELECT` on more than one table and `ORDER BY`.
- Fixed that calculations that are not in `GROUP BY` work as expected (SQL-99 extension). Example:

```
mysql> SELECT id,id+1 FROM table GROUP BY id;
```

- The test of using `MYSQL_PWD` was reversed. Now `MYSQL_PWD` is enabled as default in the default release.
- Fixed conversion bug which caused `mysqld` to core dump with Arithmetic error on SPARC-386.
- Added `--unbuffered` option to `mysql`, for new `mysqlaccess`.
- When using overlapping (unnecessary) keys and join over many tables, the optimiser could get confused and return 0 records.

D.7.2 Changes in release 3.20.17

- You can now use `BLOB` columns and the functions `IS NULL` and `IS NOT NULL` in the `WHERE` clause.
- All communication packets and row buffers are now allocated dynamically on demand. The default value of `max_allowed_packet` is now 64K for the server and 512K for the client. This is mainly used to catch incorrect packets that could trash all memory. The server limit may be changed when it is started.
- Changed stack usage to use less memory.
- Changed `safe_mysqld` to check for running daemon.
- The `ELT()` function is renamed to `FIELD()`. The new `ELT()` function returns a value based on an index: `FIELD()` is the inverse of `ELT()` Example: `ELT(2,"A","B","C")` returns `"B"`. `FIELD("B","A","B","C")` returns 2.
- `COUNT(field)`, where `field` could have a `NULL` value, now works.
- A couple of bugs fixed in `SELECT ... GROUP BY`.
- Fixed memory overrun bug in `WHERE` with many unoptimisable brace levels.
- Fixed some small bugs in the grant code.

- If hostname isn't found by `get_hostname`, only the IP is checked. Previously, you got `Access denied`.
- Inserts of timestamps with values didn't always work.
- `INSERT INTO ... SELECT ... WHERE` could give the error `Duplicated field`.
- Added some tests to `safe_mysqld` to make it "safer".
- `LIKE` was case-sensitive in some places and case-insensitive in others. Now `LIKE` is always case-insensitive.
- '`mysql.cc`': Allow `'#'` anywhere on the line.
- New command `SET SQL_SELECT_LIMIT=#`. See the FAQ for more details.
- New version of the `mysqlaccess` script.
- Change `FROM_DAYS()` and `WEEKDAY()` to also take a full `TIMESTAMP` or `DATETIME` as argument. Before they only took a number of type `YYYYMMDD` or `YYMMDD`.
- Added new function `UNIX_TIMESTAMP(timestamp_column)`.

D.7.3 Changes in release 3.20.16

- More changes in MIT-pthreads to get them safer. Fixed also some link bugs at least in SunOS.
- Changed `mysqld` to work around a bug in MIT-pthreads. This makes multiple small `SELECT` operations 20 times faster. Now `lock_test.pl` should work.
- Added `mysql_FetchHash(handle)` to `mysqlperl`.
- The `mysqlbug` script is now distributed built to allow for reporting bugs that appear during the build with it.
- Changed '`libmysql.c`' to prefer `getpwuid()` instead of `cuserid()`.
- Fixed bug in `SELECT` optimiser when using many tables with the same column used as key to different tables.
- Added new `latin2` and Russian `KOI8` character tables.
- Added support for a dummy `GRANT` command to satisfy Powerbuilder.

D.7.4 Changes in release 3.20.15

- Fixed fatal bug `packets out of order` when using MIT-pthreads.
- Removed possible loop when a thread waits for command from client and `fcntl()` fails. Thanks to Mike Bretz for finding this bug.
- Changed alarm loop in '`mysqld.cc`' because shutdown didn't always succeed in Linux.
- Removed use of `termbits` from '`mysql.cc`'. This conflicted with `glibc` 2.0.
- Fixed some syntax errors for at least BSD and Linux.
- Fixed bug when doing a `SELECT` as superuser without a database.
- Fixed bug when doing `SELECT` with group calculation to outfile.

D.7.5 Changes in release 3.20.14

- If one gives `-p` or `--password` option to `mysql` without an argument, the user is solicited for the password from the tty.
- Added default password from `MYSQL_PWD` (by Elmar Haneke).
- Added command `kill` to `mysqladmin` to kill a specific MySQL thread.
- Sometimes when doing a reconnect on a down connection this succeeded first on second try.
- Fixed adding an `AUTO_INCREMENT` key with `ALTER_TABLE`.
- `AVG()` gave too small value on some `SELECT` statements with `GROUP BY` and `ORDER BY`.
- Added new `DATETIME` type (by Giovanni Maruzzelli `maruzz@matrice.it`).
- Fixed that defining `DONT_USE_DEFAULT_FIELDS` works.
- Changed to use a thread to handle alarms instead of signals on Solaris to avoid race conditions.
- Fixed default length of signed numbers. (George Harvey `georgeh@pinacl.co.uk`.)
- Allow anything for `CREATE INDEX`.
- Add prezeros when packing numbers to `DATE`, `TIME` and `TIMESTAMP`.
- Fixed a bug in `OR` of multiple tables (gave empty set).
- Added many patches to MIT-pthreads. This fixes at least one lookup bug.

D.7.6 Changes in release 3.20.13

- Added standard SQL-92 `DATE` and `TIME` types.
- Fixed bug in `SELECT` with `AND-OR` levels.
- Added support for Slovenian characters. The '`Contrib`' directory contains source and instructions for adding other character sets.
- Fixed bug with `LIMIT` and `ORDER BY`.
- Allow `ORDER BY` and `GROUP BY` on items that aren't in the `SELECT` list. (Thanks to Wim Bonis `bonis@kiss.de`, for pointing this out.)
- Allow setting of timestamp values in `INSERT`.
- Fixed bug with `SELECT ... WHERE ... = NULL`.
- Added changes for `glibc` 2.0. To get `glibc` to work, you should add the '`gibc-2.0-sigwait-patch`' before compiling `glibc`.
- Fixed bug in `ALTER TABLE` when changing a `NOT NULL` field to allow `NULL` values.
- Added some SQL-92 synonyms as field types to `CREATE TABLE`. `CREATE TABLE` now allows `FLOAT(4)` and `FLOAT(8)` to mean `FLOAT` and `DOUBLE`.
- New utility program `mysqlaccess` by `Yves.Carlier@rug.ac.be`. This program shows the access rights for a specific user and the grant rows that determine this grant.
- Added `WHERE const op field` (by `bonis@kiss.de`).

D.7.7 Changes in release 3.20.11

- When using `SELECT ... INTO OUTFILE`, all temporary tables are ISAM instead of HEAP to allow big dumps.
- Changed date functions to be string functions. This fixed some "funny" side effects when sorting on dates.
- Extended `ALTER TABLE` for SQL-92 compliance.
- Some minor compatibility changes.
- Added `--port` and `--socket` options to all utility programs and `mysqld`.
- Fixed MIT-pthreads `readdir_r()`. Now `mysqladmin create database` and `mysqladmin drop database` should work.
- Changed MIT-pthreads to use our `tempnam()`. This should fix the "sort aborted" bug.
- Added sync of records count in `sql_update`. This fixed slow updates on first connection. (Thanks to Vaclav Bittner for the test.)

D.7.8 Changes in release 3.20.10

- New insert type: `INSERT INTO ... SELECT ...`
- `MEDIUMBLOB` fixed.
- Fixed bug in `ALTER TABLE` and `BLOB` values.
- `SELECT ... INTO OUTFILE` now creates the file in the current database directory.
- `DROP TABLE` now can take a list of tables.
- Oracle synonym `DESCRIBE` (`DESC`).
- Changes to `make_binary_distribution`.
- Added some comments to installation instructions about `configure`'s C++ link test.
- Added `--without-perl` option to `configure`.
- Lots of small portability changes.

D.7.9 Changes in release 3.20.9

- `ALTER TABLE` didn't copy null bit. As a result, fields that were allowed to have `NULL` values were always `NULL`.
- `CREATE` didn't take numbers as `DEFAULT`.
- Some compatibility changes for SunOS.
- Removed '`config.cache`' from old distribution.

D.7.10 Changes in release 3.20.8

- Fixed bug with `ALTER TABLE` and multi-part keys.

D.7.11 Changes in release 3.20.7

- New commands: `ALTER TABLE`, `SELECT ... INTO OUTFILE` and `LOAD DATA INFILE`.
- New function: `NOW()`.
- Added new field `File_priv` to `mysql/user` table.
- New script `add_file_priv` which adds the new field `File_priv` to the `user` table. This script must be executed if you want to use the new `SELECT ... INTO` and `LOAD DATA INFILE ...` commands with a version of MySQL earlier than 3.20.7.
- Fixed bug in locking code, which made `lock_test.pl` test fail.
- New files '`NEW`' and '`BUGS`'.
- Changed '`select_test.c`' and '`insert_test.c`' to include '`config.h`'.
- Added `status` command to `mysqladmin` for short logging.
- Increased maximum number of keys to 16 and maximum number of key parts to 15.
- Use of sub keys. A key may now be a prefix of a string field.
- Added `-k` option to `mysqlshow`, to get key information for a table.
- Added long options to `mysqldump`.

D.7.12 Changes in release 3.20.6

- Portable to more systems because of MIT-pthreads, which will be used automatically if `configure` cannot find a `-lpthreads` library.
- Added GNU-style long options to almost all programs. Test with *`program`* `--help`.
- Some shared library support for Linux.
- The FAQ is now in '`.texi`' format and is available in '`.html`', '`.txt`' and '`.ps`' formats.
- Added new SQL function `RAND([init])`.
- Changed `sql_lex` to handle `\0` unquoted, but the client can't send the query through the C API, because it takes a str pointer. You must use `mysql_real_query()` to send the query.
- Added API function `mysql_get_client_info()`.
- `mysqld` now uses the `N_MAX_KEY_LENGTH` from '`nisam.h`' as the maximum allowable key length.
- The following now works:

  ```
  mysql> SELECT filter_nr,filter_nr FROM filter ORDER BY filter_nr;
  ```

  Previously, this resulted in the error: `Column: 'filter_nr' in order clause is ambiguous`.
- `mysql` now outputs `'\0'`, `'\t'`, `'\n'` and `'\\'` when encountering ASCII 0, tab, newline or `'\'` while writing tab-separated output. This is to allow printing of binary data in a portable format. To get the old behaviour, use `-r` (or `--raw`).
- Added german error messages (60 of 80 error messages translated).
- Added new API function `mysql_fetch_lengths(MYSQL_RES *)`, which returns an array of column lengths (of type `uint`).

- Fixed bug with `IS NULL` in `WHERE` clause.
- Changed the optimiser a little to get better results when searching on a key part.
- Added `SELECT` option `STRAIGHT_JOIN` to tell the optimiser that it should join tables in the given order.
- Added support for comments starting with `'--'` in '`mysql.cc`' (Postgres syntax).
- You can have `SELECT` expressions and table columns in a `SELECT` which are not used in the group part. This makes it efficient to implement lookups. The column that is used should be a constant for each group because the value is calculated only once for the first row that is found for a group.

```
mysql> SELECT id,lookup.text,SUM(*) FROM test,lookup
    ->        WHERE test.id=lookup.id GROUP BY id;
```

- Fixed bug in `SUM(function)` (could cause a core dump).
- Changed `AUTO_INCREMENT` placement in the SQL query:

```
INSERT INTO table (auto_field) VALUES (0);
```

  inserted 0, but it should insert an `AUTO_INCREMENT` value.
- '`mysqlshow.c`': Added number of records in table. Had to change the client code a little to fix this.
- `mysql` now allows doubled `''` or `""` within strings for embedded `'` or `"`.
- New math functions: `EXP()`, `LOG()`, `SQRT()`, `ROUND()`, `CEILING()`.

D.7.13 Changes in release 3.20.3

- The `configure` source now compiles a thread-free client library `-lmysqlclient`. This is the only library that needs to be linked with client applications. When using the binary releases, you must link with `-lmysql -lmysys -ldbug -lmystrings` as before.
- New `readline` library from `bash-2.0`.
- LOTS of small changes to `configure` and makefiles (and related source).
- It should now be possible to compile in another directory using `VPATH`. Tested with GNU Make 3.75.
- `safe_mysqld` and `mysql.server` changed to be more compatible between the source and the binary releases.
- `LIMIT` now takes one or two numeric arguments. If one argument is given, it indicates the maximum number of rows in a result. If two arguments are given, the first argument indicates the offset of the first row to return, the second is the maximum number of rows. With this it's easy to do a poor man's next page/previous page WWW application.
- Changed name of SQL function `FIELDS()` to `ELT()`. Changed SQL function `INTERVALL()` to `INTERVAL()`.
- Made `SHOW COLUMNS` a synonym for `SHOW FIELDS`. Added compatibility syntax `FRIEND KEY` to `CREATE TABLE`. In MySQL, this creates a non-unique key on the given columns.
- Added `CREATE INDEX` and `DROP INDEX` as compatibility functions. In MySQL, `CREATE INDEX` only checks if the index exists and issues an error if it doesn't exist. `DROP INDEX` always succeeds.

- '`mysqladmin.c`': added client version to version information.
- Fixed core dump bug in `sql_acl` (core on new connection).
- Removed `host`, `user` and `db` tables from database `test` in the distribution.
- `FIELD_TYPE_CHAR` can now be signed (-128 to 127) or unsigned (0 to 255) Previously, it was always unsigned.
- Bug fixes in `CONCAT()` and `WEEKDAY()`.
- Changed a lot of source to get `mysqld` to be compiled with SunPro compiler.
- SQL functions must now have a `'('` immediately after the function name (no intervening space). For example, `'USER('` is regarded as beginning a function call, and `'USER ('` is regarded as an identifier `USER` followed by a `'('`, not as a function call.

D.7.14 Changes in release 3.20.0

- The source distribution is done with `configure` and Automake. It will make porting much easier. The `readline` library is included in the distribution.
- Separate client compilation: the client code should be very easy to compile on systems which don't have threads.
- The old Perl interface code is automatically compiled and installed. Automatic compiling of `DBD` will follow when the new `DBD` code is ported.
- Dynamic language support: `mysqld` can now be started with Swedish or English (default) error messages.
- New functions: `INSERT()`, `RTRIM()`, `LTRIM()` and `FORMAT()`.
- `mysqldump` now works correctly for all field types (even `AUTO_INCREMENT`). The format for `SHOW FIELDS FROM tbl_name` is changed so the `Type` column contains information suitable for `CREATE TABLE`. In previous releases, some `CREATE TABLE` information had to be patched when re-creating tables.
- Some parser bugs from 3.19.5 (`BLOB` and `TIMESTAMP`) are corrected. `TIMESTAMP` now returns different date information depending on its create length.
- Changed parser to allow a database, table or field name to start with a number or `'_'`.
- All old C code from Unireg changed to C++ and cleaned up. This makes the daemon a little smaller and easier to understand.
- A lot of small bug fixes done.
- New '`INSTALL`' files (not final version) and some information regarding porting.

D.8 Changes in release 3.19.x

Version 3.19 is quite old now, and should be avoided if possible. This information is kept here for historical purposes only.

D.8.1 Changes in release 3.19.5

- Some new functions, some more optimisation on joins.
- Should now compile clean on Linux (2.0.x).

- Added functions `DATABASE()`, `USER()`, `POW()`, `LOG10()` (needed for ODBC).
- In a `WHERE` with an `ORDER BY` on fields from only one table, the table is now preferred as first table in a multi-join.
- `HAVING` and `IS NULL` or `IS NOT NULL` now works.
- A group on one column and a sort on a group function (`SUM()`, `AVG()`...) didn't work together. Fixed.
- `mysqldump`: Didn't send password to server.

D.8.2 Changes in release 3.19.4

- Fixed horrible locking bug when inserting in one thread and reading in another thread.
- Fixed one-off decimal bug. 1.00 was output as 1.0.
- Added attribute `'Locked'` to process list as information if a query is locked by another query.
- Fixed full magic timestamp. Timestamp length may now be 14, 12, 10, 8, 6, 4 or 2 bytes.
- Sort on some numeric functions could sort incorrectly on last number.
- `IF(arg,syntax_error,syntax_error)` crashed.
- Added functions `CEILING()`, `ROUND()`, `EXP()`, `LOG()` and `SQRT()`.
- Enhanced `BETWEEN` to handle strings.

D.8.3 Changes in release 3.19.3

- Fixed `SELECT` with grouping on `BLOB` columns not to return incorrect `BLOB` info. Grouping, sorting and distinct on `BLOB` columns will not yet work as expected (probably it will group/sort by the first 7 characters in the `BLOB`). Grouping on formulas with a fixed string size (use `MID()` on a `BLOB`) should work.
- When doing a full join (no direct keys) on multiple tables with `BLOB` fields, the `BLOB` was garbage on output.
- Fixed `DISTINCT` with calculated columns.

Appendix E Porting to Other Systems

This appendix will help you port MySQL to other operating systems. Do check the list of currently supported operating systems first. See Section 2.2.3 [Which OS], page 73. If you have created a new port of MySQL, please let us know so that we can list it here and on our web site (`http://www.mysql.com/`), recommending it to other users.

Note: If you create a new port of MySQL, you are free to copy and distribute it under the `GPL` license, but it does not make you a copyright holder of MySQL.

A working Posix thread library is needed for the server. On Solaris 2.5 we use Sun PThreads (the native thread support in 2.4 and earlier versions is not good enough), on Linux we use LinuxThreads by Xavier Leroy, `Xavier.Leroy@inria.fr`.

The hard part of porting to a new Unix variant without good native thread support is probably to port MIT-pthreads. See '`mit-pthreads/README`' and Programming POSIX Threads (`http://www.humanfactor.com/pthreads/`).

Up to MySQL 4.0.2, the MySQL distribution included a patched version of Chris Provenzano's Pthreads from MIT (see the MIT Pthreads web page at `http://www.mit.edu/afs/sipb/project/pthreads/` and a programming introduction at `http://www.mit.edu:8001/people/proven/IAP_2000/`). These can be used for some operating systems that do not have POSIX threads. See Section 2.3.6 [MIT-pthreads], page 99.

It is also possible to use another user level thread package named FSU Pthreads (see `http://moss.csc.ncsu.edu/~mueller/pthreads/`). This implementation is being used for the SCO port.

See the '`thr_lock.c`' and '`thr_alarm.c`' programs in the '`mysys`' directory for some tests/examples of these problems.

Both the server and the client need a working C++ compiler. We use `gcc` on many platforms. Other compilers that are known to work are SPARCworks, Sun Forte, Irix `cc`, HP-UX `aCC`, IBM AIX `xlC_r`), Intel `ecc` and Compaq `cxx`).

To compile only the client use `./configure --without-server`.

There is currently no support for only compiling the server, nor is it likly to be added unless someone has a good reason for it.

If you want/need to change any '`Makefile`' or the configure script you will also need GNU Automake and Autoconf. See Section 2.3.4 [Installing source tree], page 94.

All steps needed to remake everything from the most basic files.

```
/bin/rm */.deps/*.P
/bin/rm -f config.cache
aclocal
autoheader
aclocal
automake
autoconf
./configure --with-debug=full --prefix='your installation directory'

# The makefiles generated above need GNU make 3.75 or newer.
```

```
# (called gmake below)
gmake clean all install init-db
```

If you run into problems with a new port, you may have to do some debugging of MySQL! See Section E.1 [Debugging server], page 1007.

Note: before you start debugging `mysqld`, first get the test programs `mysys/thr_alarm` and `mysys/thr_lock` to work. This will ensure that your thread installation has even a remote chance to work!

E.1 Debugging a MySQL server

If you are using some functionality that is very new in MySQL, you can try to run `mysqld` with the `--skip-new` (which will disable all new, potentially unsafe functionality) or with `--safe-mode` which disables a lot of optimisation that may cause problems. See Section A.4.1 [Crashing], page 859.

If `mysqld` doesn't want to start, you should check that you don't have any '`my.cnf`' files that interfere with your setup! You can check your '`my.cnf`' arguments with `mysqld --print-defaults` and avoid using them by starting with `mysqld --no-defaults ...`.

If `mysqld` starts to eat up CPU or memory or if it "hangs", you can use `mysqladmin processlist status` to find out if someone is executing a query that takes a long time. It may be a good idea to run `mysqladmin -i10 processlist status` in some window if you are experiencing performance problems or problems when new clients can't connect.

The command `mysqladmin debug` will dump some information about locks in use, used memory and query usage to the mysql log file. This may help solve some problems. This command also provides some useful information even if you haven't compiled MySQL for debugging!

If the problem is that some tables are getting slower and slower you should try to optimise the table with `OPTIMIZE TABLE` or `myisamchk`. See Chapter 4 [MySQL Database Administration], page 195. You should also check the slow queries with `EXPLAIN`.

You should also read the OS-specific section in this manual for problems that may be unique to your environment. See Section 2.6 [Operating System Specific Notes], page 122.

E.1.1 Compiling MYSQL for Debugging

If you have some very specific problem, you can always try to debug MySQL. To do this you must configure MySQL with the `--with-debug` or the `--with-debug=full` option. You can check whether MySQL was compiled with debugging by doing: `mysqld --help`. If the `--debug` flag is listed with the options then you have debugging enabled. `mysqladmin ver` also lists the `mysqld` version as `mysql ... --debug` in this case.

If you are using gcc or egcs, the recommended configure line is:

```
CC=gcc CFLAGS="-O2" CXX=gcc CXXFLAGS="-O2 -felide-constructors \
   -fno-exceptions -fno-rtti" ./configure --prefix=/usr/local/mysql \
   --with-debug --with-extra-charsets=complex
```

This will avoid problems with the `libstdc++` library and with C++ exceptions (many compilers have problems with C++ exceptions in threaded code) and compile a MySQL version with support for all character sets.

If you suspect a memory overrun error, you can configure MySQL with `--with-debug=full`, which will install a memory allocation (`SAFEMALLOC`) checker. However, running with `SAFEMALLOC` is quite slow, so if you get performance problems you should start `mysqld` with the `--skip-safemalloc` option. This will disable the memory overrun checks for each call to `malloc()` and `free()`.

If `mysqld` stops crashing when you compile it with `--with-debug`, you have probably found a compiler bug or a timing bug within MySQL. In this case you can try to add `-g` to the `CFLAGS` and `CXXFLAGS` variables above and not use `--with-debug`. If `mysqld` now dies, you can at least attach to it with `gdb` or use `gdb` on the core file to find out what happened.

When you configure MySQL for debugging you automatically enable a lot of extra safety check functions that monitor the health of `mysqld`. If they find something "unexpected," an entry will be written to `stderr`, which `safe_mysqld` directs to the error log! This also means that if you are having some unexpected problems with MySQL and are using a source distribution, the first thing you should do is to configure MySQL for debugging! (The second thing, of course, is to send mail to a MySQL mailing list and ask for help. See Section 1.6.1.1 [Mailing-list], page 25. Please use the `mysqlbug` script for all bug reports or questions regarding the MySQL version you are using!

In the Windows MySQL distribution, `mysqld.exe` is by default compiled with support for trace files.

E.1.2 Creating Trace Files

If the `mysqld` server doesn't start or if you can cause the `mysqld` server to crash quickly, you can try to create a trace file to find the problem.

To do this you have to have a `mysqld` that is compiled for debugging. You can check this by executing `mysqld -V`. If the version number ends with `-debug`, it's compiled with support for trace files.

Start the `mysqld` server with a trace log in '`/tmp/mysqld.trace`' (or '`C:\mysqld.trace`' on Windows):

```
mysqld --debug
```

On Windows you should also use the `--standalone` flag to not start `mysqld` as a service:

In a console window do:

```
mysqld --debug --standalone
```

After this you can use the `mysql.exe` command-line tool in a second console window to reproduce the problem. You can take down the above `mysqld` server with `mysqladmin shutdown`.

Note that the trace file will get **very big**! If you want to have a smaller trace file, you can use something like:

```
mysqld --debug=d,info,error,query,general,where:O,/tmp/mysqld.trace
```

which only prints information with the most interesting tags in '`/tmp/mysqld.trace`'.

If you make a bug report about this, please only send the lines from the trace file to the appropriate mailing list where something seems to go wrong! If you can't locate the wrong place, you can ftp the trace file, together with a full bug report, to

`ftp://support.mysql.com/pub/mysql/secret/` so that a MySQL developer can take a look a this.

The trace file is made with the **DBUG** package by Fred Fish. See Section E.3 [The DBUG package], page 1013.

E.1.3 Debugging mysqld under gdb

On most systems you can also start `mysqld` from `gdb` to get more information if `mysqld` crashes.

With some older `gdb` versions on Linux you must use `run --one-thread` if you want to be able to debug `mysqld` threads. In this case you can only have one thread active at a time. We recommend you to upgrade to gdb 5.1 ASAP as thread debugging works much better with this version!

When running `mysqld` under gdb, you should disable the stack trace with `--skip-stack-trace` to be able to catch segfaults within gdb.

In MySQL 4.0.14 and above you should use the `--gdb` option to mysqld. This will install an interrupt handler for `SIGINT` (needed to stop mysqld with `^C` to set breakpoints) and disable stack tracing and core file handling.

It's very hard to debug MySQL under `gdb` if you do a lot of new connections the whole time as `gdb` doesn't free the memory for old threads. You can avoid this problem by starting `mysqld` with `-O thread_cache_size= 'max_connections +1'`. In most cases just using `-O thread_cache_size=5'` will help a lot!

If you want to get a core dump on Linux if `mysqld` dies with a SIGSEGV signal, you can start `mysqld` with the `--core-file` option. This core file can be used to make a backtrace that may help you find out why `mysqld` died:

```
shell> gdb mysqld core
gdb>   backtrace full
gdb>   exit
```

See Section A.4.1 [Crashing], page 859.

If you are using gdb 4.17.x or above on Linux, you should install a '`.gdb`' file, with the following information, in your current directory:

```
set print sevenbit off
handle SIGUSR1 nostop noprint
handle SIGUSR2 nostop noprint
handle SIGWAITING nostop noprint
handle SIGLWP nostop noprint
handle SIGPIPE nostop
handle SIGALRM nostop
handle SIGHUP nostop
handle SIGTERM nostop noprint
```

If you have problems debugging threads with gdb, you should download gdb 5.x and try this instead. The new gdb version has very improved thread handling!

Here is an example how to debug mysqld:

```
shell> gdb /usr/local/libexec/mysqld
gdb> run
...
backtrace full # Do this when mysqld crashes
```

Include the above output in a mail generated with `mysqlbug` and mail this to the general MySQL mailing list. See Section 1.6.1.1 [Mailing-list], page 25.

If `mysqld` hangs you can try to use some system tools like `strace` or `/usr/proc/bin/pstack` to examine where `mysqld` has hung.

```
strace /tmp/log libexec/mysqld
```

If you are using the Perl `DBI` interface, you can turn on debugging information by using the `trace` method or by setting the `DBI_TRACE` environment variable. See Section 11.5.2 [Perl `DBI` Class], page 817.

E.1.4 Using a Stack Trace

On some operating systems, the error log will contain a stack trace if `mysqld` dies unexpectedly. You can use this to find out where (and maybe why) `mysqld` died. See Section 4.10.1 [Error log], page 350. To get a stack trace, you must not compile `mysqld` with the `-fomit-frame-pointer` option to gcc. See Section E.1.1 [Compiling for debugging], page 1007.

If the error file contains something like the following:

```
mysqld got signal 11;
The manual section 'Debugging a MySQL server' tells you how to use a
stack trace and/or the core file to produce a readable backtrace that may
help in finding out why mysqld died
Attemping backtrace. You can use the following information to find out
where mysqld died.  If you see no messages after this, something went
terribly wrong
stack range sanity check, ok, backtrace follows
0x40077552
0x81281a0
0x8128f47
0x8127be0
0x8127995
0x8104947
0x80ff28f
0x810131b
0x80ee4bc
0x80c3c91
0x80c6b43
0x80c1fd9
0x80c1686
```

you can find where `mysqld` died by doing the following:

1. Copy the above numbers to a file, for example '`mysqld.stack`'.
2. Make a symbol file for the `mysqld` server:

```
nm -n libexec/mysqld > /tmp/mysqld.sym
```

Note that most MySQL binary distributions (except for the "debug" packages, where this information is included inside of the binaries themselves) already ship with the above file, named `mysqld.sym.gz`. In this case you can simply unpack it by doing:

```
gunzip < bin/mysqld.sym.gz > /tmp/mysqld.sym
```

3. Execute `resolve_stack_dump -s /tmp/mysqld.sym -n mysqld.stack`.

   This will print out where `mysqld` died. If this doesn't help you find out why `mysqld` died, you should make a bug report and include the output from the above command with the bug report.

   Note however that in most cases it will not help us to just have a stack trace to find the reason for the problem. To be able to locate the bug or provide a workaround, we would in most cases need to know the query that killed `mysqld` and preferable a test case so that we can repeat the problem! See Section 1.6.1.3 [Bug reports], page 27.

E.1.5 Using Log Files to Find Cause of Errors in mysqld

Note that before starting `mysqld` with `--log` you should check all your tables with `myisamchk`. See Chapter 4 [MySQL Database Administration], page 195.

If `mysqld` dies or hangs, you should start `mysqld` with `--log`. When `mysqld` dies again, you can examine the end of the log file for the query that killed `mysqld`.

If you are using `--log` without a file name, the log is stored in the database directory as 'hostname'.log In most cases it's the last query in the log file that killed `mysqld`, but if possible you should verify this by restarting `mysqld` and executing the found query from the `mysql` command-line tools. If this works, you should also test all complicated queries that didn't complete.

You can also try the command `EXPLAIN` on all `SELECT` statements that takes a long time to ensure that `mysqld` is using indexes properly. See Section 5.2.1 [EXPLAIN], page 399.

You can find the queries that take a long time to execute by starting `mysqld` with `--log-slow-queries`. See Section 4.10.5 [Slow query log], page 354.

If you find the text `mysqld restarted` in the error log file (normally named '`hostname.err`') you have probably found a query that causes `mysqld` to fail. If this happens you should check all your tables with `myisamchk` (see Chapter 4 [MySQL Database Administration], page 195), and test the queries in the MySQL log files to see if one doesn't work. If you find such a query, try first upgrading to the newest MySQL version. If this doesn't help and you can't find anything in the `mysql` mail archive, you should report the bug to a MySQL mailing list. The mailing lists are described at `http://lists.mysql.com/`, which also has links to online list archives.

If you have started `mysqld` with `myisam-recover`, MySQL will automatically check and try to repair `MyISAM` tables if they are marked as 'not closed properly' or 'crashed'. If this happens, MySQL will write an entry in the `hostname.err` file '`Warning: Checking table ...`' which is followed by `Warning: Repairing table` if the table needs to be repaired. If you get a lot of these errors, without `mysqld` having died unexpectedly just before, then something is wrong and needs to be investigated further. See Section 4.1.1 [Command-line options], page 195.

It's of course not a good sign if `mysqld` did died unexpectedly, but in this case one shouldn't investigate the `Checking table...` messages but instead try to find out why `mysqld` died.

E.1.6 Making a Test Case If You Experience Table Corruption

If you get corrupted tables or if `mysqld` always fails after some update commands, you can test if this bug is reproducible by doing the following:

- Take down the MySQL daemon (with `mysqladmin shutdown`).
- Make a backup of the tables (to guard against the very unlikely case that the repair will do something bad).
- Check all tables with `myisamchk -s database/*.MYI`. Repair any wrong tables with `myisamchk -r database/table.MYI`.
- Make a second backup of the tables.
- Remove (or move away) any old log files from the MySQL data directory if you need more space.
- Start `mysqld` with `--log-bin`. See Section 4.10.4 [Binary log], page 351. If you want to find a query that crashes `mysqld`, you should use `--log --log-bin`.
- When you have gotten a crashed table, stop the `mysqld server`.
- Restore the backup.
- Restart the `mysqld` server **without** `--log-bin`
- Re-execute the commands with `mysqlbinlog update-log-file | mysql`. The update log is saved in the MySQL database directory with the name `hostname-bin.#`.
- If the tables are corrupted again or you can get `mysqld` to die with the above command, you have found reproducible bug that should be easy to fix! FTP the tables and the binary log to `ftp://support.mysql.com/pub/mysql/secret/` and enter it into our bugs system at `http://bugs.mysql.com/`. If you are a support customer), you can also `support@mysql.com` to alert the MySQL team about the problem and have it fixed as soon as possible.

You can also use the script `mysql_find_rows` to just execute some of the update statements if you want to narrow down the problem.

E.2 Debugging a MySQL client

To be able to debug a MySQL client with the integrated debug package, you should configure MySQL with `--with-debug` or `--with-debug=full`. See Section 2.3.3 [configure options], page 91.

Before running a client, you should set the `MYSQL_DEBUG` environment variable:

```
shell> MYSQL_DEBUG=d:t:O,/tmp/client.trace
shell> export MYSQL_DEBUG
```

This causes clients to generate a trace file in '`/tmp/client.trace`'.

If you have problems with your own client code, you should attempt to connect to the server and run your query using a client that is known to work. Do this by running `mysql` in debugging mode (assuming you have compiled MySQL with debugging on):

```
shell> mysql --debug=d:t:O,/tmp/client.trace
```

This will provide useful information in case you mail a bug report. See Section 1.6.1.3 [Bug reports], page 27.

If your client crashes at some 'legal' looking code, you should check that your '`mysql.h`' include file matches your mysql library file. A very common mistake is to use an old '`mysql.h`' file from an old MySQL installation with new MySQL library.

E.3 The DBUG Package

The MySQL server and most MySQL clients are compiled with the DBUG package originally made by Fred Fish. When one has configured MySQL for debugging, this package makes it possible to get a trace file of what the program is debugging. See Section E.1.2 [Making trace files], page 1008.

One uses the debug package by invoking the program with the `--debug="..."` or the `-#...` option.

Most MySQL programs has a default debug string that will be used if you don't specify an option to `--debug`. The default trace file is usually `/tmp/programname.trace` on Unix and `\programname.trace` on Windows.

The debug control string is a sequence of colon-separated fields as follows:

```
<field_1>:<field_2>:...:<field_N>
```

Each field consists of a mandatory flag character followed by an optional "," and comma-separated list of modifiers:

```
flag[,modifier,modifier,...,modifier]
```

The currently recognised flag characters are:

Flag	Description
d	Enable output from DBUG_<N> macros for the current state. May be followed by a list of keywords which selects output only for the DBUG macros with that keyword. An empty list of keywords implies output for all macros.
D	Delay after each debugger output line. The argument is the number of tenths of seconds to delay, subject to machine capabilities. That is, `-#D,20` is delay two seconds.
f	Limit debugging and/or tracing, and profiling to the list of named functions. Note that a null list will disable all functions. The appropriate "d" or "t" flags must still be given, this flag only limits their actions if they are enabled.
F	Identify the source file name for each line of debug or trace output.
i	Identify the process with the PID or thread ID for each line of debug or trace output.
g	Enable profiling. Create a file called 'dbugmon.out' containing information that can be used to profile the program. May be followed by a list of keywords that select profiling only for the functions in that list. A null list implies that all functions are considered.
L	Identify the source file line number for each line of debug or trace output.
n	Print the current function nesting depth for each line of debug or trace output.
N	Number each line of dbug output.
o	Redirect the debugger output stream to the specified file. The default output is stderr.

O As `o` but the file is really flushed between each write. When needed the file is closed and reopened between each write.

p Limit debugger actions to specified processes. A process must be identified with the DBUG_PROCESS macro and match one in the list for debugger actions to occur.

P Print the current process name for each line of debug or trace output.

r When pushing a new state, do not inherit the previous state's function nesting level. Useful when the output is to start at the left margin.

S Do function _sanity(_file_,_line_) at each debugged function until _sanity() returns something that differs from 0. (Mostly used with safemalloc to find memory leaks)

t Enable function call/exit trace lines. May be followed by a list (containing only one modifier) giving a numeric maximum trace level, beyond which no output will occur for either debugging or tracing macros. The default is a compile time option.

Some examples of debug control strings which might appear on a shell command-line (the "-#" is typically used to introduce a control string to an application program) are:

```
-#d:t
-#d:f,main,subr1:F:L:t,20
-#d,input,output,files:n
-#d:t:i:O,\\mysqld.trace
```

In MySQL, common tags to print (with the `d` option) are: `enter`,`exit`,`error`,`warning`,`info` and `loop`.

E.4 Locking methods

Currently MySQL only supports table locking for `ISAM`/`MyISAM` and `HEAP` tables, page-level locking for `BDB` tables and row-level locking for `InnoDB` tables. See Section 5.3.1 [Internal locking], page 418. With `MyISAM` tables one can freely mix `INSERT` and `SELECT` without locks, if the `INSERT` statements are non-conflicting (that is, whenever they append to the end of the table file rather than filling freespace from deleted rows/data).

Starting in version 3.23.33, you can analyse the table lock contention on your system by checking `Table_locks_waited` and `Table_locks_immediate` environment variables.

To decide if you want to use a table type with row-level locking, you will want to look at what the application does and what the select/update pattern of the data is.

Pros for row locking:

- Fewer lock conflicts when accessing different rows in many threads.
- Fewer changes for rollbacks.
- Makes it possible to lock a single row a long time.

Cons:

- Takes more memory than page level or table locks.
- Is slower than page level or table locks when used on a big part of the table, because one has to do many more locks.
- Is definitely much worse than other locks if you do often do `GROUP BY` on a large part of the data or if one has to often scan the whole table.
- With higher level locks one can also more easily support locks of different types to tune the application as the lock overhead is less notable as for row level locks.

Table locks are superior to page level / row level locks in the following cases:

- Mostly reads
- Read and updates on strict keys; this is where one updates or deletes a row that can be fetched with one key read:

```
UPDATE table_name SET column=value WHERE unique_key#
DELETE FROM table_name WHERE unique_key=#
```

- `SELECT` combined with `INSERT` (and very few `UPDATE` and `DELETE` statements).
- Many scans / `GROUP BY` on the whole table without any writers.

Other options than row / page level locking:

Versioning (like we use in MySQL for concurrent inserts) where you can have one writer at the same time as many readers. This means that the database/table supports different views for the data depending on when one started to access it. Other names for this are time travel, copy on write or copy on demand.

Copy on demand is in many case much better than page or row level locking; the worst case does, however, use much more memory than when using normal locks.

Instead of using row level locks one can use application level locks (like get_lock/release_lock in MySQL). This works of course only in well-behaved applications.

In many cases one can do an educated guess which locking type is best for the application, but generally it's very hard to say that a given lock type is better than another; everything depends on the application and different part of the application may require different lock types.

Here are some tips about locking in MySQL:

Most web applications do lots of selects, very few deletes, updates mainly on keys, and inserts in some specific tables. The base MySQL setup is very well tuned for this.

Concurrent users are not a problem if one doesn't mix updates with selects that need to examine many rows in the same table.

If one mixes inserts and deletes on the same table then `INSERT DELAYED` may be of great help.

One can also use `LOCK TABLES` to speed up things (many updates within a single lock is much faster than updates without locks). Splitting thing to different tables will also help.

If you get speed problems with the table locks in MySQL, you may be able to solve these by converting some of your tables to `InnoDB` or `BDB` tables. See Section 7.5 [InnoDB], page 606. See Section 7.6 [BDB], page 654.

The optimisation section in the manual covers a lot of different aspects of how to tune applications. See Section 5.2.13 [Tips], page 415.

E.5 Comments about RTS threads

I have tried to use the RTS thread packages with MySQL but stumbled on the following problems:

They use an old version of a lot of POSIX calls and it is very tedious to make wrappers for all functions. I am inclined to think that it would be easier to change the thread libraries to the newest POSIX specification.

Some wrappers are already written. See '`mysys/my_pthread.c`' for more info.

At least the following should be changed:

`pthread_get_specific` should use one argument. `sigwait` should take two arguments. A lot of functions (at least `pthread_cond_wait`, `pthread_cond_timedwait`) should return the error code on error. Now they return -1 and set `errno`.

Another problem is that user-level threads use the `ALRM` signal and this aborts a lot of functions (`read`, `write`, `open`...). MySQL should do a retry on interrupt on all of these but it is not that easy to verify it.

The biggest unsolved problem is the following:

To get thread-level alarms I changed '`mysys/thr_alarm.c`' to wait between alarms with `pthread_cond_timedwait()`, but this aborts with error `EINTR`. I tried to debug the thread library as to why this happens, but couldn't find any easy solution.

If someone wants to try MySQL with RTS threads I suggest the following:

- Change functions MySQL uses from the thread library to POSIX. This shouldn't take that long.
- Compile all libraries with the `-DHAVE_rts_threads`.
- Compile `thr_alarm`.
- If there are some small differences in the implementation, they may be fixed by changing '`my_pthread.h`' and '`my_pthread.c`'.
- Run `thr_alarm`. If it runs without any "warning", "error" or aborted messages, you are on the right track. Here is a successful run on Solaris:

```
Main thread: 1
Thread 0 (5) started
Thread: 5  Waiting
process_alarm
Thread 1 (6) started
Thread: 6  Waiting
process_alarm
process_alarm
thread_alarm
Thread: 6  Slept for 1 (1) sec
Thread: 6  Waiting
process_alarm
process_alarm
thread_alarm
Thread: 6  Slept for 2 (2) sec
Thread: 6  Simulation of no alarm needed
Thread: 6  Slept for 0 (3) sec
Thread: 6  Waiting
process_alarm
process_alarm
thread_alarm
Thread: 6  Slept for 4 (4) sec
Thread: 6  Waiting
```

```
process_alarm
thread_alarm
Thread: 5  Slept for 10 (10) sec
Thread: 5  Waiting
process_alarm
process_alarm
thread_alarm
Thread: 6  Slept for 5 (5) sec
Thread: 6  Waiting
process_alarm
process_alarm

...
thread_alarm
Thread: 5  Slept for 0 (1) sec
end
```

E.6 Differences between different thread packages

MySQL is very dependent on the thread package used. So when choosing a good platform for MySQL, the thread package is very important.

There are at least three types of thread packages:

- User threads in a single process. Thread switching is managed with alarms and the threads library manages all non-thread-safe functions with locks. Read, write and select operations are usually managed with a thread-specific select that switches to another thread if the running threads have to wait for data. If the user thread packages are integrated in the standard libs (FreeBSD and BSDI threads) the thread package requires less overhead than thread packages that have to map all unsafe calls (MIT-pthreads, FSU Pthreads and RTS threads). In some environments (for example, SCO), all system calls are thread-safe so the mapping can be done very easily (FSU Pthreads on SCO). Downside: All mapped calls take a little time and it's quite tricky to be able to handle all situations. There are usually also some system calls that are not handled by the thread package (like MIT-pthreads and sockets). Thread scheduling isn't always optimal.
- User threads in separate processes. Thread switching is done by the kernel and all data are shared between threads. The thread package manages the standard thread calls to allow sharing data between threads. LinuxThreads is using this method. Downside: Lots of processes. Thread creating is slow. If one thread dies the rest are usually left hanging and you must kill them all before restarting. Thread switching is somewhat expensive.
- Kernel threads. Thread switching is handled by the thread library or the kernel and is very fast. Everything is done in one process, but on some systems, `ps` may show the different threads. If one thread aborts, the whole process aborts. Most system calls are thread-safe and should require very little overhead. Solaris, HP-UX, AIX and OSF/1 have kernel threads.

In some systems kernel threads are managed by integrating user level threads in the system libraries. In such cases, the thread switching can only be done by the thread library and the kernel isn't really "thread aware".

Appendix F Environment Variables

Here is a list of all the environment variables that are used directly or indirectly by MySQL. Most of these can also be found in other places in this manual.

Note that any options on the command-line take precedence over values specified in configuration files and environment variables, and values in configuration files take precedence over values in environment variables.

In many cases it's preferable to use a configure file instead of environment variables to modify the behaviour of MySQL. See Section 4.1.2 [Option files], page 203.

Variable	Description
CCX	Set this to your C++ compiler when running configure.
CC	Set this to your C compiler when running configure.
CFLAGS	Flags for your C compiler when running configure.
CXXFLAGS	Flags for your C++ compiler when running configure.
DBI_USER	The default user name for Perl DBI.
DBI_TRACE	Used when tracing Perl DBI.
HOME	The default path for the `mysql` history file is '`$HOME/.mysql_history`'.
LD_RUN_PATH	Used to specify where your '`libmysqlclient.so`' is.
MYSQL_DEBUG	Debug-trace options when debugging.
MYSQL_HISTFILE	The path to the `mysql` history file.
MYSQL_HOST	Default host name used by the `mysql` command-line client.
MYSQL_PS1	Command prompt to use in the `mysql` command-line client. See Section 4.9.2 [mysql], page 327.
MYSQL_PWD	The default password when connecting to `mysqld`. Note that use of this is insecure!
MYSQL_TCP_PORT	The default TCP/IP port.
MYSQL_UNIX_PORT	The default socket; used for connections to `localhost`.
PATH	Used by the shell to finds the MySQL programs.
TMPDIR	The directory where temporary tables/files are created.
TZ	This should be set to your local time zone. See Section A.4.6 [Timezone problems], page 864.
UMASK_DIR	The user-directory creation mask when creating directories. Note that this is ANDed with `UMASK`!
UMASK	The user-file creation mask when creating files.
USER	The default user on Windows to use when connecting to `mysqld`.

Appendix G MySQL Regular Expressions

A regular expression (regex) is a powerful way of specifying a complex search.

MySQL uses Henry Spencer's implementation of regular expressions, which is aimed at conformance with POSIX 1003.2. MySQL uses the extended version.

This is a simplistic reference that skips the details. To get more exact information, see Henry Spencer's `regex(7)` manual page that is included in the source distribution. See Appendix C [Credits], page 878.

A regular expression describes a set of strings. The simplest regexp is one that has no special characters in it. For example, the regexp `hello` matches `hello` and nothing else.

Non-trivial regular expressions use certain special constructs so that they can match more than one string. For example, the regexp `hello|word` matches either the string `hello` or the string `word`.

As a more complex example, the regexp `B[an]*s` matches any of the strings `Bananas`, `Baaaaas`, `Bs`, and any other string starting with a `B`, ending with an `s`, and containing any number of `a` or `n` characters in between.

A regular expression may use any of the following special characters/constructs:

`^` Match the beginning of a string.

```
mysql> SELECT "fo\nfo" REGEXP "^fo$";            -> 0
mysql> SELECT "fofo" REGEXP "^fo";               -> 1
```

`$` Match the end of a string.

```
mysql> SELECT "fo\no" REGEXP "^fo\no$";          -> 1
mysql> SELECT "fo\no" REGEXP "^fo$";             -> 0
```

`.` Match any character (including newline).

```
mysql> SELECT "fofo" REGEXP "^f.*";              -> 1
mysql> SELECT "fo\nfo" REGEXP "^f.*";            -> 1
```

`a*` Match any sequence of zero or more `a` characters.

```
mysql> SELECT "Ban" REGEXP "^Ba*n";              -> 1
mysql> SELECT "Baaan" REGEXP "^Ba*n";            -> 1
mysql> SELECT "Bn" REGEXP "^Ba*n";               -> 1
```

`a+` Match any sequence of one or more `a` characters.

```
mysql> SELECT "Ban" REGEXP "^Ba+n";              -> 1
mysql> SELECT "Bn" REGEXP "^Ba+n";               -> 0
```

`a?` Match either zero or one `a` character.

```
mysql> SELECT "Bn" REGEXP "^Ba?n";               -> 1
mysql> SELECT "Ban" REGEXP "^Ba?n";              -> 1
mysql> SELECT "Baan" REGEXP "^Ba?n";             -> 0
```

`de|abc` Match either of the sequences `de` or `abc`.

```
mysql> SELECT "pi" REGEXP "pi|apa";              -> 1
mysql> SELECT "axe" REGEXP "pi|apa";             -> 0
mysql> SELECT "apa" REGEXP "pi|apa";             -> 1
```

```
mysql> SELECT "apa" REGEXP "^(pi|apa)$";        -> 1
mysql> SELECT "pi" REGEXP "^(pi|apa)$";         -> 1
mysql> SELECT "pix" REGEXP "^(pi|apa)$";        -> 0
```

`(abc)*` Match zero or more instances of the sequence `abc`.

```
mysql> SELECT "pi" REGEXP "^(pi)*$";            -> 1
mysql> SELECT "pip" REGEXP "^(pi)*$";           -> 0
mysql> SELECT "pipi" REGEXP "^(pi)*$";          -> 1
```

`{1}`
`{2,3}` The is a more general way of writing regexps that match many occurrences of the previous atom.

`a*` Can be written as `a{0,}`.

`a+` Can be written as `a{1,}`.

`a?` Can be written as `a{0,1}`.

To be more precise, an atom followed by a bound containing one integer `i` and no comma matches a sequence of exactly `i` matches of the atom. An atom followed by a bound containing one integer `i` and a comma matches a sequence of `i` or more matches of the atom. An atom followed by a bound containing two integers `i` and `j` matches a sequence of `i` through `j` (inclusive) matches of the atom.

Both arguments must be in the range from `0` to `RE_DUP_MAX` (default 255), inclusive. If there are two arguments, the second must be greater than or equal to the first.

`[a-dX]`
`[^a-dX]` Matches any character which is (or is not, if `^` is used) either `a`, `b`, `c`, `d` or `X`. To include a literal `]` character, it must immediately follow the opening bracket `[`. To include a literal `-` character, it must be written first or last. So `[0-9]` matches any decimal digit. Any character that does not have a defined meaning inside a `[]` pair has no special meaning and matches only itself.

```
mysql> SELECT "aXbc" REGEXP "[a-dXYZ]";         -> 1
mysql> SELECT "aXbc" REGEXP "^[a-dXYZ]$";       -> 0
mysql> SELECT "aXbc" REGEXP "^[a-dXYZ]+$";      -> 1
mysql> SELECT "aXbc" REGEXP "^[^a-dXYZ]+$";     -> 0
mysql> SELECT "gheis" REGEXP "^[^a-dXYZ]+$";    -> 1
mysql> SELECT "gheisa" REGEXP "^[^a-dXYZ]+$";   -> 0
```

`[[.characters.]]`
The sequence of characters of that collating element. The sequence is a single element of the bracket expression's list. A bracket expression containing a multi-character collating element can thus match more than one character, for example, if the collating sequence includes a `ch` collating element, then the regular expression `[[.ch.]]*c` matches the first five characters of `chchcc`.

`[=character_class=]`
An equivalence class, standing for the sequences of characters of all collating elements equivalent to that one, including itself.

For example, if `o` and `(+)` are the members of an equivalence class, then `[[=o=]]`, `[[=(+)=]]`, and `[o(+)]` are all synonymous. An equivalence class may not be an endpoint of a range.

`[:character_class:]`

Within a bracket expression, the name of a character class enclosed in `[:` and `:]` stands for the list of all characters belonging to that class. Standard character class names are:

Name	Name	Name
alnum	digit	punct
alpha	graph	space
blank	lower	upper
cntrl	print	xdigit

These stand for the character classes defined in the `ctype(3)` manual page. A locale may provide others. A character class may not be used as an endpoint of a range.

```
mysql> SELECT "justalnums" REGEXP "[[:alnum:]]+";       -> 1
mysql> SELECT "!!" REGEXP "[[:alnum:]]+";               -> 0
```

`[[:<:]]`

`[[:>:]]` These match the null string at the beginning and end of a word respectively. A word is defined as a sequence of word characters which is neither preceded nor followed by word characters. A word character is an alnum character (as defined by `ctype(3)`) or an underscore (_).

```
mysql> SELECT "a word a" REGEXP "[[:<:]]word[[:>:]]";      -> 1
mysql> SELECT "a xword a" REGEXP "[[:<:]]word[[:>:]]";     -> 0
```

```
mysql> SELECT "weeknights" REGEXP "^(wee|week)(knights|nights)$"; -> 1
```

Appendix H GNU General Public License

Version 2, June 1991

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Version 2.1, February 1999

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That's all there is to it!

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