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# murach's MySQL

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**4TH EDITION**

**Joel Murach**

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# Introduction

Since its release in 2000, MySQL has become the world's most popular open-source database. It has been used by everyone from hobbyists to the world's largest companies to deliver cost-effective, high-performance, scalable database applications, the type of applications that the web is built on. So knowing MySQL is a plus for any developer today.

## Who this book is for

This book is designed for developers who are new to MySQL, as well as developers who have been using MySQL for years but still aren't getting the most from it. It shows how to code all the SQL statements that developers need for their applications, and it shows how to code these statements so they run efficiently.

This book is also a good choice for anyone who wants to learn standard SQL. Since SQL is a standard language for accessing database data, most of the SQL statements in this book will work with any relational database. As a result, once you use this book to learn how to use SQL to work with a MySQL database, you can transfer most of what you have learned to another database such as Oracle or SQL Server.

This book is also the right *first* book for anyone who wants to become a database administrator. Although this book doesn't present all of the advanced skills that are needed by a DBA, it will get you started. Then, when you complete this book, you'll be prepared for more advanced books on the subject

## 5 reasons why you'll learn faster with this book

- This book starts by showing you how to query an existing database rather than how to create a new database. Why? Because that's what you're most likely to need to do first on the job.

- It has hundreds of examples that range from the simple to the complex. That way, you can quickly get the idea of how a feature works from the simple examples and also see how the feature is used in the real world from the more complex ones.
- The exercises at the end of each chapter provide a way for you to gain valuable hands-on experience without extra busywork.
- All of the information is presented in *paired pages*, with the essential syntax, guidelines, and examples on the right page and clear explanations on the left page. This helps you learn faster by reading less.
- The paired-pages format is ideal for reference when you need to refresh your memory about how to do something.

## What you'll learn in this book

In section 1, you'll learn the concepts and terms you need for working with any database. You'll learn how to use MySQL Workbench to work with a database and run SQL statements. You'll also learn all the SQL skills for retrieving data from a database and for adding, updating, and deleting that data. These skills are the critical SQL skills that you'll need to get started.

In section 2, you can learn more SQL skills as you need them. You can learn how to summarize the data that you retrieve. You can learn how to code subqueries. You can learn about the types of data that MySQL supports. And you can learn how to use MySQL functions in your SQL statements. These advanced skills are sure to raise your expertise even if you already have SQL experience.

In section 3, you'll learn how to design a database. This includes learning how to use MySQL Workbench to create an EER (enhanced entity-relationship) model for your database. Then, you'll learn how to implement that design by using the DDL (Data Definition Language) statements that are a part of SQL. When you're done, you'll be able to design and implement your own database. In addition, you'll gain valuable perspective that will make you a better SQL programmer, even if you never need to design a database.

In section 4, you'll learn how to use MySQL to create stored procedures, functions, triggers, and events. In addition, you'll learn how to manage transactions and locking. These features allow you to store multiple SQL statements in the database and access them as needed, either to run on their own or to use in application programs. So, once you master these features, you'll have a powerful set of MySQL skills.

In section 5, you'll learn a starting set of skills for becoming a database administrator (DBA). These skills include how to secure a database, how to back up a database, and how to restore a database. To start, this section shows how to implement these skills on a local database. Then, it shows how to use Amazon Web Services (AWS) to host a MySQL database in the cloud. This can make your database more affordable, flexible, and scalable.

## What software you need for this book

Although you should be able to use this book with most versions of MySQL, we recommend that you use:

- MySQL Community Server 8.0 or higher
- MySQL Workbench 8.0 or higher

This software can be downloaded for free from MySQL's website. And appendixes A (Windows) and B (macOS) provide complete instructions for installing it.

The SQL statements presented in this book have been tested against MySQL Community Server 8.0 and 8.1. As a result, if you're using one of these versions, the SQL statements in this book should work exactly as described. Since MySQL is backwards compatible, these SQL statements should also work with future versions of MySQL. In addition, most statements presented in this book work with earlier versions of MySQL, and we have done our best to identify any statements that don't.

If you use MySQL Workbench 8.0, all of the skills presented in this book should work exactly as described. However, when a new version of Workbench becomes available, you should be able to use it with this book. In that case, the skills presented in this book may not work exactly as described, but they should work similarly.

## What you can download from our website

You can download all the files for this book from our website. These files include:

- A script that creates the three databases used by this book
- The SQL statements for all examples in this book
- Solutions for the exercises at the end of each chapter

Again, appendixes A (Windows) and B (macOS) provide complete instructions for installing these items on your computer.

## Support materials for trainers and instructors

If you're a corporate trainer or a college instructor who would like to use this book for a course, we offer support materials that will help you set up and run your course as effectively as possible. These materials include instructional objectives, test banks, additional exercises, and PowerPoint slides.

To learn more, please go to our website at www.murachforinstructors.com if you're an instructor. If you're a trainer, please go to www.murach.com and click on the *Courseware for Trainers* link, or contact Kelly at 1-800-221-5528 or kelly@murach.com.

## Please let me know how this book works for you

When I started writing the 1st edition of book, I had two goals. First, I wanted to show you how to get started with MySQL as quickly and easily as possible. Second, I wanted to raise your database development skills to a professional level.

For the 4th edition of this book, our editorial team worked hard to update and streamline this book to make it easier than ever to get started with MySQL. This included adding a new chapter on hosting a MySQL database on AWS. Now, I wish you all the best with learning MySQL. If you have any comments about this book, I'd love to hear from you.

Joel Murach

Joel Murach
joel@murach.com

# Section 1

## An introduction to MySQL

Before you learn to code MySQL statements, you need to understand some concepts and terms related to SQL and relational databases. So, that's what you'll learn in chapter 1. In addition, you'll need to know how to use the tools for working with a MySQL database. That's what you'll learn in chapter 2.

After that, you'll be ready to learn how to code basic SQL statements. In chapter 3, you'll learn how to code SELECT statements to retrieve data from a single table. In chapter 4, you'll learn how to retrieve data from two or more tables. And in chapter 5, you'll learn how to add, update, and delete rows from a table.

Once you're done reading the chapters in this section, you'll have all of the basic skills you need to use MySQL. Then, you can learn more SQL skills by reading the chapters in section 2.

# 1

# An introduction to relational databases

This chapter introduces the concepts and terms that you need to know before you learn how to use SQL to work with a relational database such as MySQL. If you've never worked with relational databases before, this chapter will teach you what they are and how they work. It also shows you some examples of SQL statements that you'll be able to code yourself after completing section 1.

# An introduction to client/server systems

If this is your first time working with client/server systems, the topics that follow introduce you to their essential hardware and software components. When you use SQL to access a MySQL database, that system is most often a client/server system.

## The hardware components of a client/server system

Figure 1-1 presents the three main hardware components of a client/server system: the clients, the network, and the server. The *clients* are usually personal computers or mobile devices, but they may be any device that sends information to or requests information from the server.

The *network* is the cabling, communication lines, network interface cards, hubs, routers, and other components that connect the clients and the server. Because you don't need to understand how it works to use it, most diagrams use a cloud symbol to represent the network.

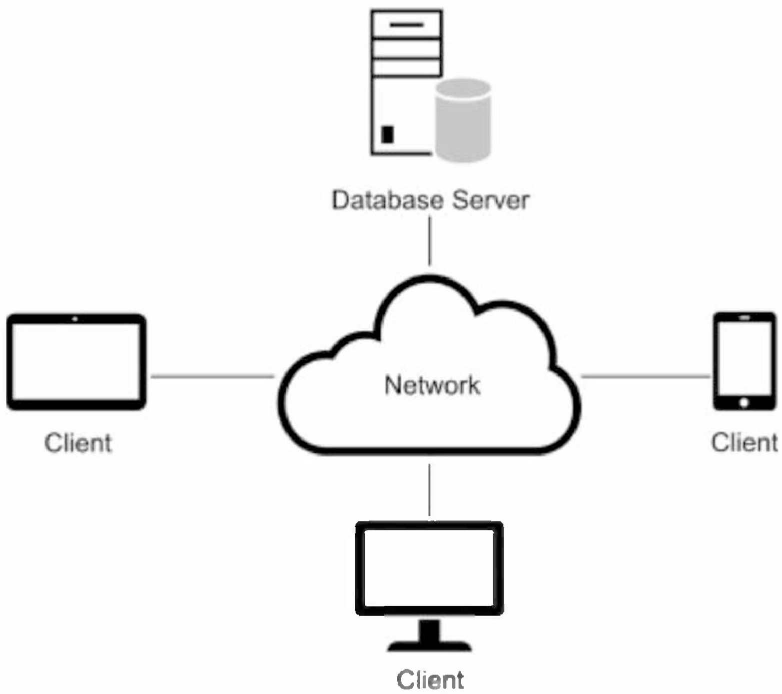
The *server* is a computer that has enough processor speed, memory, and disk storage to store the files and databases of the system and provide services to the clients of the system. When its primary purpose is to store databases, the server is often referred to as a *database server*.

In a simple client/server system, the clients and the server may be part of a *local area network (LAN)* that connects computers that are near each other. However, two or more LANs that reside at separate geographical locations may be connected as part of a larger network such as a *wide area network (WAN)*. In addition, individual systems or networks can be connected over the internet.

When a server is available from the internet, it's known as being in the *cloud*. Today, many companies offer servers that you can use to host your server-side data and run services from almost anywhere in the world. These are known as *cloud computing platforms*. With this approach, you use an online interface to interact with servers that are maintained by another company. Two of the biggest cloud computing platforms are Amazon Web Services and Microsoft Azure. You'll learn more about Amazon's platform and some of the services it provides in chapter 20.

When a client/server system consists of private networks and servers, often spread throughout the country or world, it is commonly referred to as an *enterprise system*. Enterprise systems can consist of on-site resources, cloud resources, or a combination of the two.

### A simple client/server system




### The three hardware components of a client/server system

- The *clients* are the computers or mobile devices of the system.
- The *server* is a specialized computer that stores the files and databases of the system and provides services to the clients. When it is primarily used to store databases, it's often referred to as a *database server*.
- The *network* consists of the cabling, communication lines, routers, and other components that connect the clients and servers of the system. In diagrams, it is usually represented by a cloud to indicate the unknown nature of the network.

### Client/server system implementations

- A simple *client/server system* like the one shown above may use a *local area network (LAN)*, which is a network that directly connects computers that are near each other.
- Individual systems and LANs can be connected and share data over large private networks, such as a *wide area network (WAN)*, or over a public network like the internet.
- When a server is available from the internet, it is known as being in the *cloud*. A server in the cloud may be distributed across multiple computers or share a computer with other servers.
- A server can be available from a *cloud computing platform*. With this approach, you use an online interface to interact with servers that are maintained by another company.
- When a system consists of a private network and servers over a wide area, it is commonly called an *enterprise system*.

Figure 1-1 The hardware components of a client/server system

## The software components of a client/server system

Figure 1-2 presents the software components of a typical client/server system that uses a database server. In addition to a *network operating system* that manages the functions of the network, the server requires a *database management system (DBMS)* like MySQL. This DBMS manages the databases that are stored on the server.

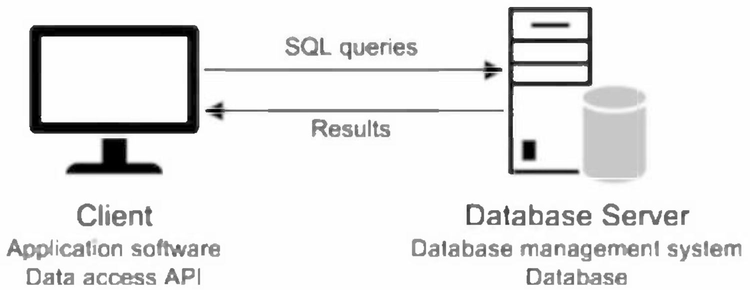
In contrast to a server, each client requires *application software* to perform useful work. This can be a purchased software package like a financial accounting package, or it can be custom software that's developed for a specific application.

Although the application software runs on the client, it uses data that's stored on the server. To do that, it uses a *data access API* (*application programming interface*). Since the technique you use to work with an API depends on both the programming language and API you're using, this book doesn't show how to do that. Instead, it shows how to use a standard language called *SQL* (*Structured Query Language*) that lets any application communicate with any DBMS. In conversation, SQL is pronounced as either "S-Q-L" or "sequel".

Once the software for the clients and the server has been installed, the clients communicate with the server via *SQL queries* (or just *queries*) that are sent to the DBMS through the API. After a client sends a query to the DBMS, the DBMS processes the query and sends the results back to the client. This processing is typically referred to as *back-end processing*, and the database server is referred to as the *back end*. Conversely, processing done by the clients is called *front-end processing*.

The processing done by a client/server system is divided between the clients and the server. In this figure, the DBMS on the server is processing requests made by the application running on the client. This balances the workload between the clients and the server so the system works more efficiently.

## Client software, server software, and the SQL interface




### Server software

- To store and manage the databases of the client/server system, each server requires a *database management system (DBMS)* like MySQL.
- The processing that's done by the DBMS is typically referred to as *back-end processing*, and the database server is referred to as the *back end*.

### Client software

- The *application software* does the work that the user wants to do. This type of software can be purchased or developed.
- The *data access API (application programming interface)* provides the interface between the application program and the DBMS. For example, for Java applications, the most common data access API for MySQL is JDBC (Java Database Connectivity).
- The processing that's done by the client software is typically referred to as *front-end processing*, and the client is typically referred to as the *front end*.

### The SQL interface

- *SQL* stands for *Structured Query Language*, which is the standard language for working with a relational database.
- The application software communicates with the DBMS by sending *SQL queries* through the data access API. When the DBMS receives a query that requests data, it processes the query and returns the requested data (the *query results*) to the client.

Figure 1-2 The software components of a client/server system

## Other client/server architectures

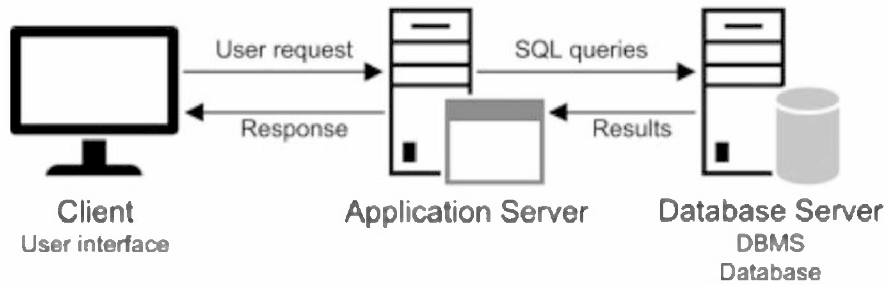
In its simplest form, a client/server system consists of a single database server and one or more clients. However, many client/server systems include additional servers. For example, figure 1-3 presents two diagrams that show how an additional server can be used between the clients and a database server.

The first diagram is for an application that runs on a simple networked system. With this system, the user interface for the application runs on the client. However, the processing that's done by the application takes place on the *application server*. Then, if the application server needs to access the database, it uses SQL to query the database server. Next, the database server sends the results of the query back to the application server. At this point, the application server may further process the results and send an appropriate response back to the client, or it may send another query to the database.

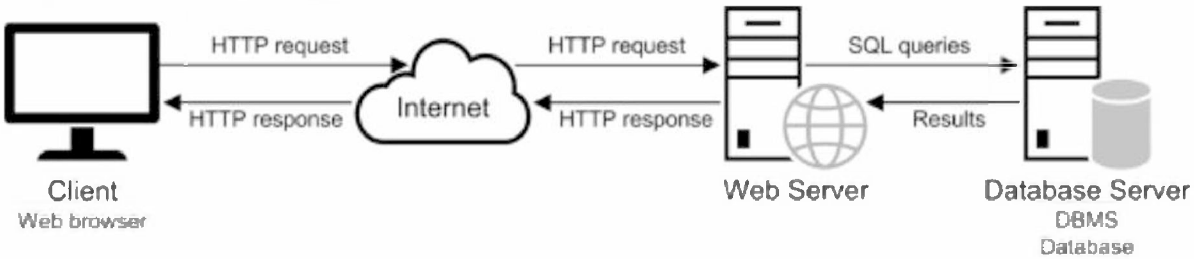
A web-based system like the one shown in the second diagram works similarly. In this diagram, the client, which is typically a web browser such as Chrome, uses a protocol known as HTTP (Hypertext Transfer Protocol) to send a request to a *web server* that's typically running somewhere on the internet. Then, if the web server needs to access data from the database, it uses SQL to send a request for that data to the database server. Next, the database server sends the results of the query back to the web server. At this point, the web server may do additional processing, send another query to the database server, or send a response back to the web browser.

Although this figure should give you an idea of how client/server systems can be configured, these systems can be much more complicated than what's shown here. For example, it's common for a web server to send requests to one or more application servers that in turn send requests to one or more database servers. In most cases, though, it's not necessary for you to know how a system is configured to use SQL.

### A networked system that uses an application server




### A simple web-based system




### Description

- In addition to a database server, a client/server system can include additional servers, such as *application servers* and *web servers*.
- An *application server* handles the processing for an application and uses SQL to communicate with the database server.
- A *web server* uses a protocol known as HTTP (Hypertext Transfer Protocol) to communicate with the client. It can also use SQL to communicate with the database server.
- In a web-based system, it's common for the client to use a web browser to communicate with a web server that's running somewhere on the internet.
- Complex system architectures can include many application servers, web servers, and database servers.

Figure 1-3 Other client/server architectures

# An introduction to the relational database model

In 1970, Dr. E. F. Codd developed a model for a new type of database called a *relational database*. This type of database eliminated some of the problems that were associated with standard files and other database designs. By using the relational model, you can reduce data redundancy, which saves disk storage and leads to efficient data retrieval. You can also view and manipulate data in a way that is both intuitive and efficient. Today, relational databases are the standard for database applications.

## How a table is organized

A relational database stores data in one or more *tables*. Each table can be viewed as a two-dimensional matrix consisting of *rows* and *columns*. This is illustrated by the table in figure 1-4. Each row in this table contains information about a single vendor.

In practice, the rows and columns of a relational database table are often referred to by the more traditional terms, *records* and *fields*. Some software packages use one set of terms, some use the other, and some use a combination. In this book, I use the terms *rows* and *columns* because those are the terms used by MySQL, and because they make the structure of a table easy to visualize.

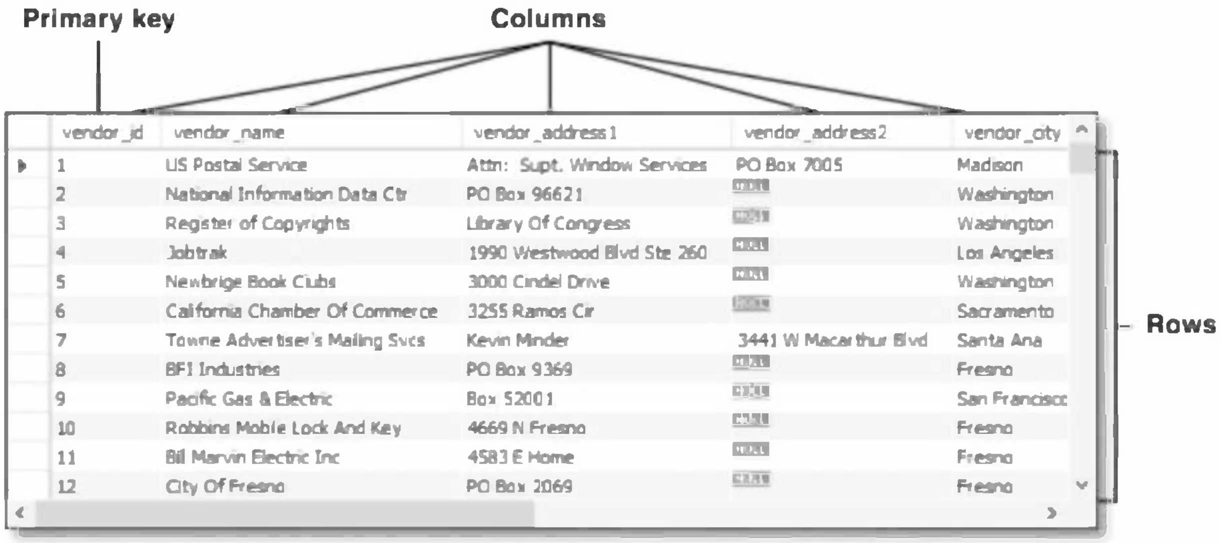
In general, each table is modeled after a real-world entity such as a vendor or an invoice. Then, the columns of the table represent the attributes of the entity such as name, address, and phone number. Each row of the table represents one instance of the entity. A value stored at the intersection of each row and column is sometimes called a *cell*.

If a table contains a column that uniquely identifies each row in the table, you can define this column as the *primary key* of the table. For instance, the primary key of the Vendors table in this figure is the vendor_id column. A primary key can also consist of two or more columns that together uniquely identify a row. In that case, the key is called a *composite primary key*.

In addition to primary keys, some database management systems let you define additional keys that uniquely identify each row in a table. If, for example, the vendor_name column in the Vendors table contains unique data, it can be defined as a *non-primary key*. In MySQL, this is called a *unique key*.

*Indexes* provide an efficient way of accessing the rows in a table based on the values in one or more columns. Because applications typically access the rows in a table by referring to their key values, an index is automatically created for each key you define. However, you can define indexes for other columns as well. If, for example, you frequently need to sort the Vendor rows by zip code, you can set up an index for that column. Like a key, an index can consist of one or more columns.

### The Vendors table in an Accounts Payable database




| vendor_id | vendor_name | vendor_address1 | vendor_address2 | vendor_city |
|---|---|---|---|---|
| 1 | US Postal Service | Attn: Supt. Window Services | PO Box 7005 | Madison |
| 2 | National Information Data Ctr | PO Box 96621 | NULL | Washington |
| 3 | Register of Copyrights | Library Of Congress | NULL | Washington |
| 4 | Jobtrak | 1990 Westwood Blvd Ste 260 | NULL | Los Angeles |
| 5 | Newbrige Book Clubs | 3000 Cindel Drive | NULL | Washington |
| 6 | California Chamber Of Commerce | 3255 Ramos Cir | NULL | Sacramento |
| 7 | Towne Advertiser's Mailing Svcs | Kevin Minder | 3441 W Macarthur Blvd | Santa Ana |
| 8 | BFI Industries | PO Box 9369 | NULL | Fresno |
| 9 | Pacific Gas & Electric | Box 52001 | NULL | San Francisco |
| 10 | Robbins Mobile Lock And Key | 4669 N Fresno | NULL | Fresno |
| 11 | Bill Marvin Electric Inc | 4583 E Home | NULL | Fresno |
| 12 | City Of Fresno | PO Box 2069 | NULL | Fresno |

### Description

- A *relational database* consists of *tables*. Tables consist of *rows* and *columns*, which can also be referred to as *records* and *fields*.
- A table is typically modeled after a real-world entity, such as an invoice or a vendor.
- A column represents some attribute of the entity, such as the amount of an invoice or a vendor's address.
- A row contains a set of values for a single instance of the entity, such as one invoice or one vendor.
- The intersection of a row and a column is sometimes called a *cell*. A cell stores a single *value*.
- Most tables have a *primary key* that uniquely identifies each row in the table. The primary key is usually a single column, but it can also consist of two or more columns. If a primary key uses two or more columns, it's called a *composite primary key*.
- In addition to primary keys, some database management systems let you define one or more *non-primary keys*. In MySQL, these keys are called *unique keys*. Like a primary key, a non-primary key uniquely identifies each row in the table.
- A table can also be defined with one or more *indexes*. An index provides an efficient way to access data from a table based on the values in specific columns. An index is automatically created for a table's primary and non-primary keys.

Figure 1-4 How a database table is organized

## How tables are related

The tables in a relational database can be related to other tables by values in specific columns. The two tables shown in figure 1-5 illustrate this concept. Here, each row in the Vendors table can be related to one or more rows in the Invoices table. This is called a *one-to-many relationship*. That's because one vendor can be related to many invoices, but each invoice can only be related to one vendor.

Typically, relationships exist between the primary key in one table and a *foreign key* in another table. A foreign key is one or more columns in a table that refer to a primary key in another table. In this figure, for example, the vendor_id column in the Invoices column is a foreign key that refers to the primary key of the Vendors table.

Although one-to-many relationships are the most common, two tables can also have a one-to-one or many-to-many relationship. If a table has a *one-to-one relationship* with another table, the data in the two tables could be stored in a single table. However, it's often useful to store large objects such as images, sound, and videos in a separate table. Then, you can join the two tables with the one-to-one relationship only when the large objects are needed.

In contrast, a *many-to-many relationship* is usually implemented by using an intermediate table that has a one-to-many relationship with the two tables in the many-to-many relationship. In other words, a many-to-many relationship can usually be broken down into two one-to-many relationships.

## The relationship between the Vendors and Invoices tables in the database

**Primary key**

| vendor_id | vendor_name | vendor_address1 | vendor_address2 | vendor_city |
|---|---|---|---|---|
| 112 | Office Depot | File No 81901 | NULL | Los Angeles |
| 113 | Pollstar | 4697 W Jacquelyn Ave | NULL | Fresno |
| 114 | Postmaster | Postage Due Technician | 1900 E Street | Fresno |
| 115 | Roadway Package System, Inc | Dept La 21095 | NULL | Pasadena |
| 116 | State of California | Employment Development Dept | PO Box 826276 | Sacramento |
| 117 | Suburban Propane | 2874 S Cherry Ave | NULL | Fresno |
| 118 | Unocal | P.O. Box 860070 | NULL | Pasadena |
| 119 | Yesmed, Inc | PO Box 2061 | NULL | Fresno |
| 120 | Dataforms/West | 1617 W. Shaw Avenue | Suite F | Fresno |
| 121 | Zylka Design | 3467 W Shaw Ave #103 | NULL | Fresno |
| 122 | United Parcel Service | P.O. Box 505820 | NULL | Reno |
| 123 | Federal Express Corporation | P.O. Box 1140 | Dept A | Memphis |

| invoice_id | vendor_id | invoice_number | invoice_date | invoice_total | payment_total | credit_total | terms_id | invoice_d |
|---|---|---|---|---|---|---|---|---|
| [illegible] | 123 | 963253245 | 2022-06-10 | 40.75 | 40.75 | 0.00 | 3 | 2022-07-1 |
| 56 | 86 | 367447 | 2022-06-11 | 2433.00 | 2433.00 | 0.00 | 1 | 2022-06-2 |
| 57 | 103 | 75C-90227 | 2022-06-11 | 1367.50 | 1367.50 | 0.00 | 5 | 2022-07-1 |
| [illegible] | 123 | 963253256 | 2022-06-11 | 53.25 | 53.25 | 0.00 | 3 | 2022-07-1 |
| [illegible] | 123 | 4-314-3057 | 2022-06-11 | 13.75 | 13.75 | 0.00 | 3 | 2022-07-1 |
| 60 | 122 | 989319-497 | 2022-06-12 | 2312.20 | 2312.20 | 0.00 | 3 | 2022-07-1 |
| 61 | 115 | 24946731 | 2022-06-15 | 25.67 | 25.67 | 0.00 | 4 | 2022-07-2 |
| [illegible] | 123 | 963253269 | 2022-06-15 | 26.75 | 26.75 | 0.00 | 3 | 2022-07-1 |
| 63 | 122 | 989319-427 | 2022-06-16 | 2115.81 | 2115.81 | 0.00 | 3 | 2022-07-1 |
| [illegible] | 123 | 963253267 | 2022-06-17 | 23.50 | 23.50 | 0.00 | 3 | 2022-07-1 |
| 65 | 99 | 509786 | 2022-06-18 | 6940.25 | 6940.25 | 0.00 | 3 | 2022-07-1 |

**Foreign key**

### Description

- The tables in a relational database are related to each other through their key columns. For example, the vendor_id column is used to relate the Vendors and Invoices tables.
- The vendor_id column in the Invoices table is called a *foreign key* because it identifies a related row in the Vendors table. A table may contain one or more foreign keys.
- The relationships between the tables in a database correspond to the relationships between the entities they represent. The most common type of relationship is a *one-to-many relationship* as illustrated by the Vendors and Invoices tables. A table can also have a *one-to-one relationship* or a *many-to-many relationship* with another table.

Figure 1-5    How tables are related

## How columns are defined

When you create a table, you must define the table's columns. To do that, you assign properties to each column as indicated by the design of the Invoices table in figure 1-6.

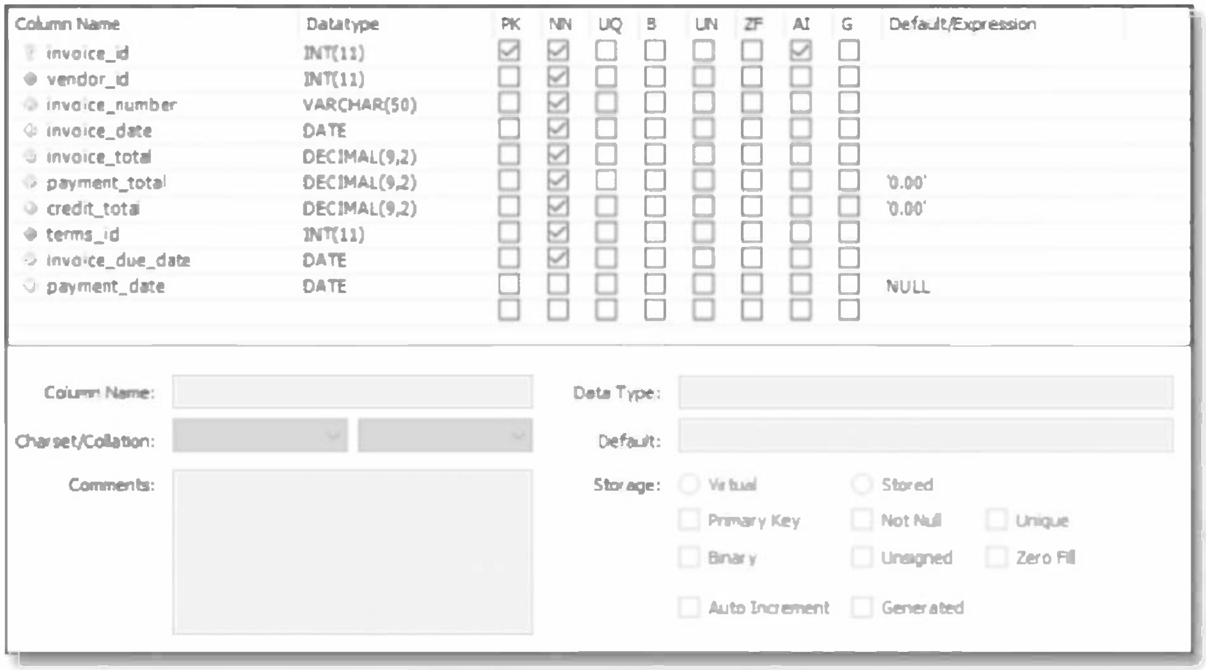
The most important property for a column is its *data type*, which determines the type of information that can be stored in the column. With MySQL, you can use one of the basic data types listed in this figure, as well as others. In most cases, it's best to assign a data type that minimizes disk storage because that will improve the performance of the queries.

In addition to a data type, you must identify whether a column can store *null values* (or just *nulls*). Null represents a value that's unknown, unavailable, or not applicable. In this figure, the columns that have the NN (not null) box checked don't allow null values. If you don't allow null values for a column, the column must store a value or its row can't be stored in the table. That's the case for all of the columns of the Invoices table except for the payment_date column.

You can also assign a *default value* to each column. Then, that value is assigned to the column if another value isn't provided when you create a new row. Three of the columns of the Invoices table have a default value.

Each table can also contain a numeric column whose value is generated automatically by the DBMS. In MySQL, this kind of column is called an *auto increment column*. In the Invoices table, the invoice_id column is an auto increment column.

### The columns of the Invoices table




### Common MySQL data types

| Type | Description |
|---|---|
| **CHAR, VARCHAR** | A string of letters, symbols, and numbers. |
| **INT, DECIMAL** | Integer and decimal numbers that contain an exact value. |
| **FLOAT** | Floating-point numbers that contain an approximate value. |
| **DATE** | Dates and times. |

### Description

- The *data type* that's assigned to a column determines the type of information that can be stored in the column.
- Each column definition indicates whether or not it can contain *null values*. A null value indicates that a value is unknown, unavailable, or not applicable.
- A column can be defined with a *default value*. Then, that value is used if a value isn't provided when a row is added to the table.
- A column can also be defined as an *auto increment column*. An auto increment column is a numeric column whose value is generated automatically when a row is added to the table.

Figure 1-6 How columns are defined

## How to read a database diagram

When working with relational databases, you can use an *enhanced entity-relationship (EER) diagram* to show how the tables in a database are defined and related. In figure 1-7, for example, you can see an EER diagram for the AP (Accounts Payable) database that's used throughout this book. This diagram shows that the database contains five related tables: Vendors, Terms, Invoices, Invoice_Line_Items, and General_Ledger_Accounts.

For each table, this diagram shows how the columns are defined. For example, it shows that the Vendors table has 12 columns. It shows the name and data type for each column. It uses a yellow key icon to show that the primary key for this table is the vendor_id column. And it uses a pink diamond icon to show that the table has two columns that are foreign keys: default_terms_id and default_account_number.

This diagram also shows how the tables are related. To do that, it places connectors between the tables with symbols at the endpoints that identify the type of relationship. The two most common symbols are shown in the table in this figure. These symbols identify the "one" and "many" sides of a relationship.

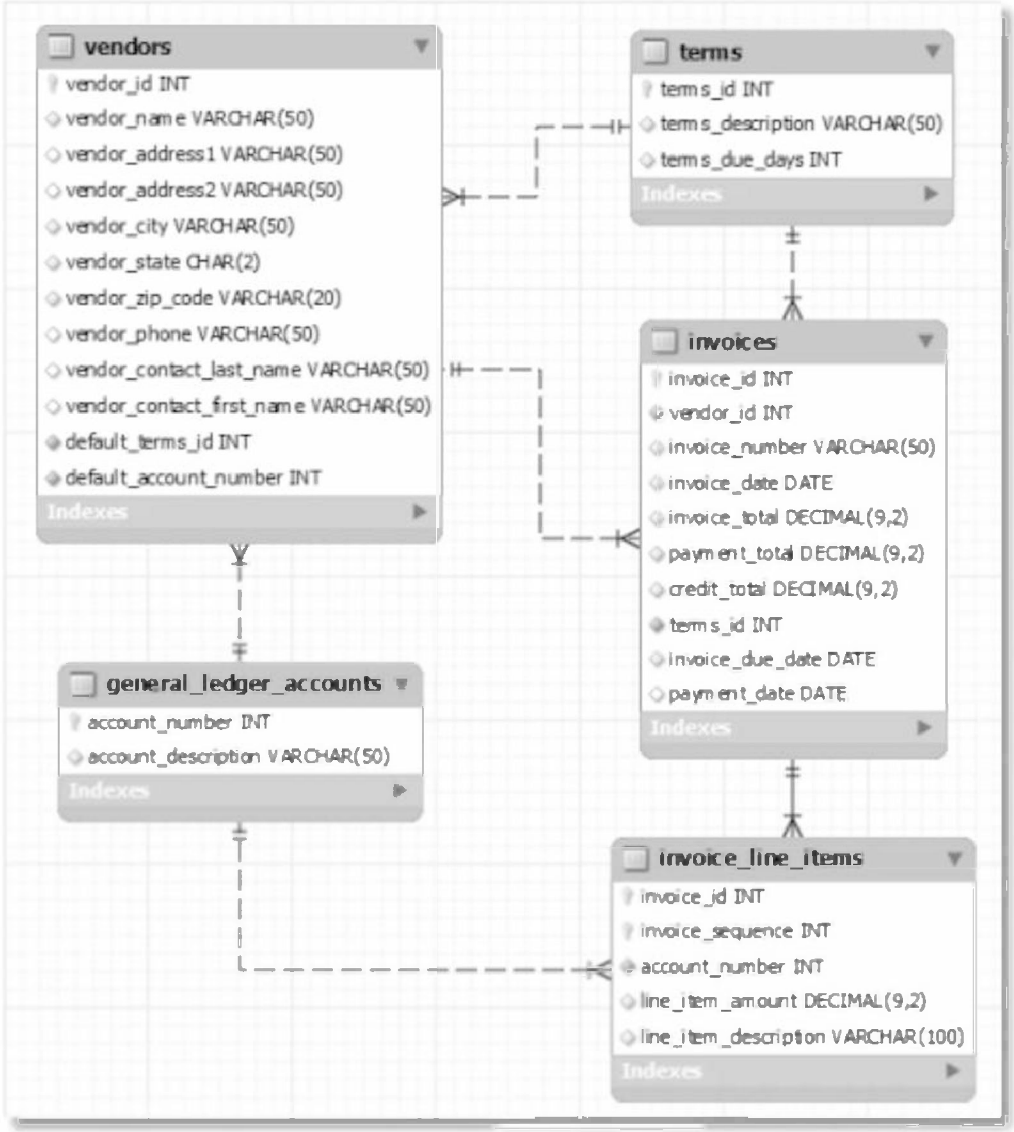
For example, the connector between the Vendors and Invoices table shows that these tables have a one-to-many relationship. The symbol on the endpoint closest to the Invoices table indicates that many invoices can exist for each vendor, and the symbol on the endpoint closest to the Vendors table indicates that only one vendor can exist for each invoice. In this case, these tables are related by the primary key of the Vendors table (the vendor_id column) and a foreign key of the Invoices table (also the vendor_id column).

Similarly, this diagram shows that there's a one-to-many relationship between the Terms and Vendors tables. In other words, each terms of payment can have many vendors, but each vendor can only have one default terms of payment. These tables are related by the primary key of the Terms table (the terms_id column) and a foreign key of the Vendors table (the default_terms_id column).

Note that, unlike the other tables, the primary key for the Invoice_Line_Items table consists of two columns: invoice_id and invoice_sequence. Since the Invoice_Line_Items table can contain more than one row for each row in the Invoices table, the invoice_id column alone doesn't uniquely identify a line item. So, the invoice_sequence column must also be included in the primary key.

In chapter 10, you'll learn how to use MySQL Workbench to create and work with EER diagrams. For now, you just need to understand how to read the diagram presented in this figure so you can understand the relationships between the tables in the AP database.

### An EER diagram for the AP (Accounts Payable) database




### Common relationship symbols

| Symbol | Meaning |
|---|---|
| ┼ | One |
| ¥ | Many |

### Description

- An *enhanced entity-relationship (EER) diagram* can be used to show how the tables in a database are defined and related.

Figure 1-7 How to read a database diagram

# An introduction to SQL and SQL-based systems

In the topics that follow, you'll learn how SQL and SQL-based database management systems evolved. In addition, you'll learn how four of the most popular SQL-based systems compare.

## A brief history of SQL

Prior to the release of the first *relational database management system (RDBMS)*, each database had a unique physical structure and a unique programming language that the programmer had to understand. That all changed with the advent of SQL and the relational database management system.

Figure 1-8 lists the important events in the history of SQL. In 1970, Dr. E. F. Codd published an article that described the relational database model he had been working on with a research team at IBM. By 1978, the IBM team had developed a database system based on this model, called System/R, along with a query language called SEQUEL (Structured English Query Language). Although the database and query language were never officially released, IBM remained committed to the relational model.

The following year, Relational Software, Inc. released the first relational database management system, called Oracle. This RDBMS ran on a minicomputer and used SQL as its query language. This product was widely successful, and the company later changed its name to Oracle to reflect that success.

During the 1980s, other SQL-based database systems, including DB2 and SQL Server, were developed. Although each of these systems used SQL as its query language, each implementation was unique. That began to change in 1989, when the *American National Standards Institute* (*ANSI*) published its first set of standards for a database query language. These standards have been revised a few times since then, most recently in 2019. As each database manufacturer has attempted to comply with these standards, their implementations of SQL have become more similar. However, each database still has its own *dialect* of SQL that includes additions, or *extensions*, to the standards.

Although you should be aware of the SQL standards, they will have little effect on your job as a MySQL programmer. The main benefit of the standards is that the basic SQL statements are the same in each dialect. As a result, once you've learned one dialect, it's relatively easy to learn another. On the other hand, porting applications that use SQL from one type of database to another often requires substantial changes.

MySQL was first released in 1995 and was used internally by the company that developed it, MySQL AB. Then, in 2000, MySQL became an open-source database. Since that time, MySQL has become one of the most popular databases, especially for web applications. In 2008, MySQL was acquired by Sun Microsystems, and in 2010, Oracle acquired Sun.

Soon after Oracle's acquisition of MySQL, many of the original developers of MySQL left and began working on a fork of the open-source code named

### Important events in the history of SQL

| Year | Event |
|---|---|
| 1970 | Dr. E. F. Codd develops the relational database model. |
| 1978 | IBM develops the predecessor to SQL, called Structured English Query Language (SEQUEL). |
| 1979 | Relational Software, Inc. (later renamed Oracle) releases the first relational database, Oracle. |
| 1985 | IBM releases DB2 (Database 2). |
| 1987 | Microsoft releases SQL Server. |
| 1989 | The American National Standards Institute (ANSI) publishes the first set of standards for a database query language, called ANSI/ISO SQL-89, or SQL 1. |
| 1992 | ANSI publishes revised standards (ANSI/ISO SQL-92, or SQL 2) that are more stringent than SQL 1. These standards introduce levels of conformance that indicate the extent to which a dialect meets the standards. |
| 1995 | MySQL AB releases MySQL for internal use. |
| 1999 | ANSI publishes SQL 3 (ANSI/ISO SQL:1999), which replaces levels of conformance with a core specification along with specifications for nine additional packages. |
| 2000 | MySQL is released as an open-source database. |
| 2003 | ANSI publishes SQL:2003. |
| 2006 | ANSI publishes SQL:2006. |
| 2008 | ANSI publishes SQL:2008. |
| | Sun Microsystems acquires MySQL. |
| 2010 | Oracle acquires Sun Microsystems and MySQL. |
| | Many of the original developers of MySQL leave and begin working on a fork of the open-source code named MariaDB. |
| 2011 | ANSI publishes SQL:2011. |
| 2016 | ANSI publishes SQL:2016. |
| 2019 | ANSI publishes SQL:2019. |

### Description

- Although SQL is a standard language, each vendor has its own *SQL dialect*, or *variant*, that may include extensions to the standards.

### How knowing "standard SQL" helps you

- The most basic SQL statements are the same for all SQL dialects.
- Once you have learned one SQL dialect, you can easily learn other dialects.

### How knowing "standard SQL" does not help you

- Any non-trivial application will require modification to the SQL statements when moved from one relational database to another.

Figure 1-8 A brief history of SQL

MariaDB. One of MariaDB's stated goals is to remain free and open-source while maintaining high compatibility with MySQL so it can be used as a drop-in replacement for MySQL. As a result, most of the SQL statements for working with MySQL work the same for MariaDB.

## A comparison of four relational databases

Although this book is about MySQL, you may want to know about some of the other SQL-based relational database management systems. Figure 1-9 compares MySQL with three other popular databases: Oracle, DB2, and Microsoft (MS) SQL Server.

Oracle has a huge installed base of customers and continues to dominate the marketplace, especially for servers running the Unix or Linux operating system. Oracle works well for large systems and has a reputation for being extremely reliable.

DB2 was originally designed to run on IBM mainframe systems and continues to be the premier database for those systems. It also dominates in hybrid environments where IBM mainframes and newer servers must coexist. Although it is expensive, it also has a reputation for being reliable and easy to use.

SQL Server was designed by Microsoft to run on Windows and is widely used for both small and medium-sized systems. SQL Server 2017 and later also run on Linux. SQL Server has a reputation for being inexpensive and easy to use.

MySQL runs on all major operating systems and is widely used for web applications. MySQL is an *open-source database*, which means that any developer can view and modify its source code. In addition, the MySQL Community Server is free for most users, although Oracle also sells other editions of MySQL that include customer support and advanced features.

Dozens of other relational database products are also available from various vendors. These include proprietary databases like Amazon Aurora, as well as open-source databases like PostgreSQL, SQLite, and MariaDB. In addition, you'll find that most of these databases are offered as a service from various cloud computing platforms. This is known as *DBaaS* (*database as a service*). Today, Amazon Web Services (AWS), Microsoft Azure, and Oracle Cloud are among the top DBaaS providers.

### Oracle

- Released in 1979.
- Runs on Unix, z/OS, Windows, Linux, and macOS.
- Typically used for large, mission-critical systems that run on one or more Unix servers.

### DB2

- Released in 1985.
- Runs on OS/390, z/OS, AIX, Unix, Windows, Linux, and macOS.
- Typically used for large, mission-critical systems that run on legacy IBM mainframe systems using the z/OS or OS/390 operating system.

### SQL Server

- Released in 1987.
- Runs on Windows and Linux.
- Typically used for small- to medium-sized systems that run on one or more Windows or Linux servers.

### MySQL

- Released in 2000.
- Runs on Unix, Linux, Windows, and macOS.
- A popular *open-source database* that runs on all major operating systems and is commonly used for web applications.

### Description

- *Unix* is a family of proprietary operating systems. It was originally developed by Bell Labs in 1969.
- *Linux* is a family of open-source operating systems. It was originally released by Linus Torvalds in 1991. Since Linux was originally based on Unix, it's known as a Unix-like operating system.
- MySQL is a popular *open-source database* that runs on all major operating systems and is commonly used for web applications.
- These are just four of the most popular relational databases. Many other relational databases exist.
- Some databases are offered by cloud providers as services, so you don't have to handle setup or maintenance yourself. This is known as *DBaaS* (*database as a service*).

Figure 1-9 A comparison of four relational databases

# The SQL statements

In the topics that follow, you'll learn about some of the SQL statements provided by MySQL. You can use some of these statements to manipulate the data in a database, and you can use others to work with database objects. Although you may not feel comfortable coding these statements on your own after reading these figures, you should have a good idea of what they can do. Then, you'll be better prepared to learn the details of coding these statements when they're presented later in this book.

## An introduction to the SQL statements

Figure 1-10 summarizes some of the most common SQL statements. These statements can be divided into two categories. The statements that work with the data in a database are called the *data manipulation language* (*DML*). These statements are presented in the first table in this figure, and they're the ones that application programmers use the most.

The statements that create and work with database objects are called the *data definition language* (*DDL*). On large systems, these statements are used exclusively by *database administrators* (*DBAs*). It's a DBA's job to maintain existing databases, fine-tune them for faster performance, and create new databases. On smaller systems, though, a SQL programmer may also use some of these statements.

### SQL statements used to work with data (DML)

| Statement | Description |
|---|---|
| `SELECT` | Retrieves data from one or more tables. |
| `INSERT` | Adds new rows to a table. |
| `UPDATE` | Changes existing rows in a table. |
| `DELETE` | Deletes existing rows from a table. |

### SQL statements used to work with database objects (DDL)

| Statement | Description |
|---|---|
| `CREATE DATABASE` | Creates a new database on the server. |
| `CREATE TABLE` | Creates a new table in a database. |
| `CREATE INDEX` | Creates a new index for a table. |
| `ALTER TABLE` | Changes the definition of an existing table. |
| `ALTER INDEX` | Changes the structure of an existing index. |
| `DROP DATABASE` | Deletes an existing database. |
| `DROP TABLE` | Deletes an existing table. |
| `DROP INDEX` | Deletes an existing index. |

### Description

- *Data manipulation language (DML)* statements let you work with the data in a database.
- *Data definition language (DDL)* statements let you work with the objects in the database.
- SQL programmers typically work with DML statements, while *database administrators* (*DBAs*) use the DDL statements.

Figure 1-10 An introduction to the SQL statements

## How to work with database objects

To give you an idea of how you use the DDL statements shown in the previous figure, figure 1-11 presents some examples. The first statement creates an accounts payable database named AP. This is the database that's used in many of the examples throughout this book. Then, the second example selects that database. As a result, the rest of the statements in this figure are run against the AP database.

The third example creates the Invoices table that's used throughout this chapter. If you don't understand all of this code right now, don't worry. For now, just realize that this statement defines each column in the table, including its data type, whether or not it allows null values, and its default value if it has one. In addition, it defines an auto increment column, a primary key column, and two foreign key columns.

The fourth example changes the Invoices table by adding a column to it. Like the statement that created the table, this statement specifies the attributes of the new column. Then, the fifth example deletes the column that was just added.

The sixth example creates an index on the Invoices table. In this case, the index is for the vendor_id column, which is used frequently to access the table. Then, the last example deletes the index that was just added.

### A statement that creates a new database

```
CREATE DATABASE ap
```

### A statement that selects the current database

```
USE ap
```

### A statement that creates a new table

```
CREATE TABLE invoices
(
  invoice_id          INT            PRIMARY KEY   AUTO_INCREMENT,
  vendor_id           INT            NOT NULL,
  invoice_number      VARCHAR(50)    NOT NULL,
  invoice_date        DATE           NOT NULL,
  invoice_total       DECIMAL(9,2)   NOT NULL,
  payment_total       DECIMAL(9,2)                 DEFAULT 0,
  credit_total        DECIMAL(9,2)                 DEFAULT 0,
  terms_id            INT            NOT NULL,
  invoice_due_date    DATE           NOT NULL,
  payment_date        DATE,
  CONSTRAINT invoices_fk_vendors
    FOREIGN KEY (vendor_id)
    REFERENCES vendors (vendor_id),
  CONSTRAINT invoices_fk_terms
    FOREIGN KEY (terms_id)
    REFERENCES terms (terms_id)
)
```

### A statement that adds a new column to a table

```
ALTER TABLE invoices
ADD balance_due DECIMAL(9,2)
```

### A statement that deletes the new column

```
ALTER TABLE invoices
DROP COLUMN balance_due
```

### A statement that creates an index on the table

```
CREATE INDEX invoices_vendor_id_index
  ON invoices (vendor_id)
```

### A statement that deletes the new index

```
DROP INDEX invoices_vendor_id_index
  ON invoices
```

Figure 1-11 Typical statements for working with database objects

## How to query a single table

Figure 1-12 shows how to use a SELECT statement to query a single table in a database. To start, this figure shows some of the columns and rows of the Invoices table. Then, in the SELECT statement that follows, the SELECT clause names the columns to be retrieved, and the FROM clause names the table that contains the columns, called the *base table*. In this case, six columns will be retrieved from the Invoices table.

Note that the last column, balance_due, is calculated from three other columns in the table. In other words, a column by the name of balance_due doesn't exist in the table. This type of column is called a *calculated value*, and it exists only in the results of the query.

In addition to the SELECT and FROM clauses, this SELECT statement includes a WHERE clause and an ORDER BY clause. The WHERE clause gives the criteria for the rows to be selected. In this case, a row is selected only if it has a balance due that's greater than zero. And the ORDER BY clause sorts the rows by the invoice_date column.

This figure also shows the *result set* (or *result table*) that's returned by the SELECT statement. A result set is a logical table that's created temporarily within the database. When an application requests data from a database, it receives a result set.

### The Invoices base table

| invoice_id | vendor_id | invoice_number | invoice_date | invoice_total | payment_total | credit_total | terms_id | invoice_du |
|---|---|---|---|---|---|---|---|---|
| 1 | 122 | 989319-457 | 2022-04-08 | 3813.33 | 3813.33 | 0.00 | 3 | 2022-05-0 |
| 2 | 123 | 263253241 | 2022-04-10 | 40.20 | 40.20 | 0.00 | 3 | 2022-05-1 |
| 3 | 123 | 963253234 | 2022-04-13 | 138.75 | 138.75 | 0.00 | 3 | 2022-05-1 |
| 4 | 123 | 2-000-2993 | 2022-04-16 | 144.70 | 144.70 | 0.00 | 3 | 2022-05-1 |
| 5 | 123 | 963253251 | 2022-04-16 | 15.50 | 15.50 | 0.00 | 3 | 2022-05-1 |
| 6 | 123 | 963253261 | 2022-04-16 | 42.75 | 42.75 | 0.00 | 3 | 2022-05-1 |
| 7 | 123 | 963253237 | 2022-04-21 | 172.50 | 172.50 | 0.00 | 3 | 2022-05-2 |
| 8 | 89 | 125520-1 | 2022-04-24 | 95.00 | 95.00 | 0.00 | 1 | 2022-05-0 |

### A SELECT statement that retrieves and sorts selected columns and rows from the Invoices table

```
SELECT invoice_number, invoice_date, invoice_total,
    payment_total, credit_total,
    invoice_total - payment_total - credit_total AS balance_due
FROM invoices
WHERE invoice_total - payment_total - credit_total > 0
ORDER BY invoice_date
```

### The result set defined by the SELECT statement

| invoice_number | invoice_date | invoice_total | payment_total | credit_total | balance_due |
|---|---|---|---|---|---|
| 39104 | 2022-07-10 | 85.31 | 0.00 | 0.00 | 85.31 |
| 963253264 | 2022-07-18 | 52.25 | 0.00 | 0.00 | 52.25 |
| 31361833 | 2022-07-21 | 579.42 | 0.00 | 0.00 | 579.42 |
| 263253268 | 2022-07-21 | 59.97 | 0.00 | 0.00 | 59.97 |
| 263253270 | 2022-07-22 | 67.92 | 0.00 | 0.00 | 67.92 |
| 263253273 | 2022-07-22 | 30.75 | 0.00 | 0.00 | 30.75 |
| P-0608 | 2022-07-23 | 20551.18 | 0.00 | 1200.00 | 19351.18 |
| 9982771 | 2022-07-24 | 503.20 | 0.00 | 0.00 | 503.20 |
| 134116 | 2022-07-28 | 90.36 | 0.00 | 0.00 | 90.36 |

### Description

- You use a SELECT statement to retrieve selected columns and rows from a table, called the *base table*. The result of a SELECT statement is a *result table*, or *result set*.
- A result set can include *calculated values* that are calculated from columns in the table.
- A SELECT statement is commonly referred to as a *query*.

Figure 1-12 How to query a single table

## How to join data from two or more tables

Figure 1-13 presents a SELECT statement that retrieves data from two tables. This type of operation is called a *join* because the data from the two tables is joined together into a single result set. For example, the SELECT statement in this figure joins data from the Vendors and Invoices tables.

An *inner join* is the most common type of SQL join. When you use an inner join, rows from the two tables in the join are included in the result table only if their related columns match. These matching columns are specified in the FROM clause of the SELECT statement. In the SELECT statement in this figure, for example, rows from the Vendors and Invoices tables are included only if the value of the vendor_id column in the Vendors table matches the value of the vendor_id column in one or more rows in the Invoices table. If there aren't any invoices for a particular vendor, that vendor won't be included in the result set.

Although this figure shows how to join data from two tables, you can extend this syntax to join data from three or more tables. If, for example, you want to include line item data from a table named Invoice_Line_Items in the results shown in this figure, you can code the FROM clause of the SELECT statement like this:

```
FROM vendors
    INNER JOIN invoices
        ON vendors.vendor_id = invoices.vendor_id
    INNER JOIN invoice_line_items
        ON invoices.invoice_id = invoice_line_items.invoice_id
```

Then, in the SELECT clause, you can include any of the columns in the Invoice_Line_Items table.

In addition to inner joins, most relational databases including MySQL support other types of joins such as *outer joins*. An outer join lets you include all rows from a table even if the other table doesn't have a matching row.

### A SELECT statement that joins data from the Vendors and Invoices tables

```
SELECT vendor_name, invoice_number, invoice_date, invoice_total
FROM vendors
    INNER JOIN invoices
        ON vendors.vendor_id = invoices.vendor_id
WHERE invoice_total >= 500
ORDER BY vendor_name, invoice_total DESC
```

### The result set defined by the SELECT statement

| vendor_name | invoice_number | invoice_date | invoice_total |
|---|---|---|---|
| Bertelsmann Industry Svcs. Inc | 509786 | 2022-06-18 | 6940.25 |
| Cahners Publishing Company | 587056 | 2022-06-30 | 2184.50 |
| Computerworld | 367447 | 2022-06-11 | 2433.00 |
| Data Reproductions Corp | 40318 | 2022-06-01 | 21842.00 |
| Dean Witter Reynolds | 75C-90227 | 2022-06-11 | 1367.50 |
| Digital Dreamworks | P02-3772 | 2022-05-21 | 7125.34 |
| Federal Express Corporation | 963253230 | 2022-07-07 | 739.20 |
| Ford Motor Credit Company | 9982771 | 2022-07-24 | 503.20 |
| Franchise Tax Board | RTR-72-3662-X | 2022-05-25 | 1600.00 |

### Description

- A *join* lets you combine data from two or more tables into a single result set.
- The most common type of join in SQL is an *inner join*. This type of join returns rows from both tables only if their related columns match.
- An *outer join* returns rows from one table in the join even if the other table doesn't contain a matching row.

Figure 1-13 How to join data from two or more tables

## How to add, update, and delete data in a table

Figure 1-14 shows how you can use the INSERT, UPDATE, and DELETE statements to modify the data in a table. In this figure, for example, the first statement is an INSERT statement that adds a row to the Invoices table. To do that, the INSERT clause names the columns whose values are supplied in the VALUES clause.

The two UPDATE statements in this figure show how to change the data in one or more rows of a table. The first statement, for example, assigns a value of 35.89 to the credit_total column of the invoice in the Invoices table with invoice number 367447. The second statement adds 30 days to the invoice due date for each row in the Invoices table whose terms_id column has a value of 4.

To delete rows from a table, you use the DELETE statement. For example, the first DELETE statement in this figure deletes the invoice with invoice number 4-342-8069 from the Invoices table. The second DELETE statement deletes all invoices with a balance due of zero.

### A statement that adds a row to the Invoices table

```
INSERT INTO invoices
  (vendor_id, invoice_number, invoice_date,
   invoice_total, terms_id, invoice_due_date)
VALUES
  (12, '3289175', '2022-07-18', 165, 3, '2022-08-17')
```

### A statement that changes the value of the credit_total column for a selected row in the Invoices table

```
UPDATE invoices
SET credit_total = 35.89
WHERE invoice_number = '367447'
```

### A statement that changes the values in the invoice_due_date column for all invoices with the specified terms_id

```
UPDATE invoices
SET invoice_due_date = DATE_ADD(invoice_due_date, INTERVAL 30 DAY)
WHERE terms_id = 4
```

### A statement that deletes a selected invoice from the Invoices table

```
DELETE FROM invoices
WHERE invoice_number = '4-342-8069'
```

### A statement that deletes all paid invoices from the Invoices table

```
DELETE FROM invoices
WHERE invoice_total - payment_total - credit_total = 0
```

### Description

- You use an INSERT statement to add rows to a table.
- You use an UPDATE statement to change the values in one or more rows of a table based on the condition you specify.
- You use a DELETE statement to delete one or more rows from a table based on the condition you specify.

### Warning

- If you're new to SQL, don't execute the statements above until you understand the effect that they can have on the database.

Figure 1-14 How to add, update, and delete data in a table

## SQL coding guidelines

SQL is a freeform language. That means that you can include line breaks, spaces, and indentation without affecting the way the database interprets the code. In addition, SQL is not case-sensitive like some languages. That means that you can use uppercase or lowercase letters or a combination of the two without affecting the way the database interprets the code.

Although you can code SQL statements with a freeform style, I suggest that you follow the coding recommendations presented in figure 1-15. The examples in this figure illustrate the value of these coding recommendations. The first example presents an unformatted SELECT statement that's difficult to read. In contrast, this statement is much easier to read after our coding recommendations are applied, as shown in the second example.

The third and fourth examples show how to use *comments* in your code. The third example illustrates how to code a *block comment*. A block comment begins with /* and ends with */. Any text inside the comment isn't executed by the system. This type of comment is typically coded at the beginning of a group of statements and is used to document the entire group. Block comments can also be used within a statement to describe blocks of code, but that's not common.

The fourth example includes a *single-line comment*. A single-line comment starts with -- and can be coded on a separate line as shown in this example, or it can be coded at the end of a line of code. In either case, the comment ends at the end of the line.

Although many programmers sprinkle their code with comments, that shouldn't be necessary if you write your code so it's easy to read and understand. Instead, you should use comments only to clarify portions of code that are hard to understand. Then, if you change the code, you should be sure to change the comments too. That way, the comments will accurately represent what the code does.

### A SELECT statement that's difficult to read

```
select invoice_number, invoice_date, invoice_total,
payment_total, credit_total, invoice_total - payment_total -
credit_total as balance_due from invoices where invoice_total -
payment_total - credit_total > 0 order by invoice_date
```

### A SELECT statement that's coded with a readable style

```
SELECT invoice_number, invoice_date, invoice_total,
    payment_total, credit_total,
    invoice_total - payment_total - credit_total AS balance_due
FROM invoices
WHERE invoice_total - payment_total - credit_total > 0
ORDER BY invoice_date
```

### A SELECT statement with a block comment

```
/*
Author: Joel Murach
Date: 8/22/2023
*/
SELECT invoice_number, invoice_date, invoice_total,
    invoice_total - payment_total - credit_total AS balance_due
FROM invoices
```

### A SELECT statement with a single-line comment

```
-- The fourth column calculates the balance due
SELECT invoice_number, invoice_date, invoice_total,
    invoice_total - payment_total - credit_total AS balance_due
FROM invoices
```

### Coding recommendations

- Capitalize all keywords, and use lowercase for the other code in a SQL statement.
- Separate the words in names with underscores, as in invoice_number.
- Start each clause on a new line.
- Break long clauses into multiple lines and indent continued lines.
- Use *comments* to document code that is difficult to understand.

### How to code a comment

- To code a *block comment*, type /* at the start of the block and */ at the end.
- To code a *single-line comment*, type -- followed by the comment.

### Description

- Line breaks, white space, indentation, and capitalization have no effect on how MySQL processes statements.
- Comments can be used to document what a statement does or what specific parts of the code do. They are not executed by the system.

Figure 1-15 SQL coding guidelines

# Perspective

To help you understand how SQL is used, this chapter has introduced you to the hardware and software components of a client/server system. It has also described how relational databases are organized and how you use some SQL statements to work with the data in a relational database. With that as background, you're now ready to start using MySQL.

## Terms

client
server
database server
network
client/server system
local area network (LAN)
wide area network (WAN)
cloud
cloud computing platform
enterprise system
database management system (DBMS)
back end
application software
data access API (application programming interface)
front end
SQL (Structured Query Language)
query
query results
network operating system
application server
web server
relational database
table
row
column
record
field
cell
primary key
composite primary key
non-primary key
unique key
index
foreign key
one-to-many relationship
one-to-one relationship
many-to-many relationship
data type
null value
default value
auto increment column
enhanced entity-relationship (EER) diagram
relational database management system (RDBMS)
American National Standards Institute (ANSI)
Oracle
DB2
SQL Server
database as a service (DBaaS)
SQL dialect
SQL extension
open-source database
data manipulation language (DML)
data definition language (DDL)
database administrator (DBA)
base table
result table
result set
calculated value
join
inner join
outer join
comment
block comment
single-line comment

2

# How to use MySQL Workbench and other development tools

In the last chapter, you learned about some of the SQL statements that you can use to work with the data in a relational database. Before you learn the details of coding these statements, however, you need to learn how to use MySQL Workbench to enter and execute SQL statements. In addition, you should learn how to use the MySQL Reference Manual, and you should at least be familiar with the MySQL Command Line Client.

# An introduction to MySQL Workbench

*MySQL Workbench* is a free graphical tool that makes it easy to work with MySQL. We recommend using Workbench as you work through this book. This chapter shows how to use version 8.0 of MySQL Workbench. However, with some minor variations, the skills presented in this chapter should work for later versions as well.

## The Home page of MySQL Workbench

When you start MySQL Workbench, it displays its Home page as shown in figure 2-1. This page is divided into three tabs: Connections, Models, and Migration.

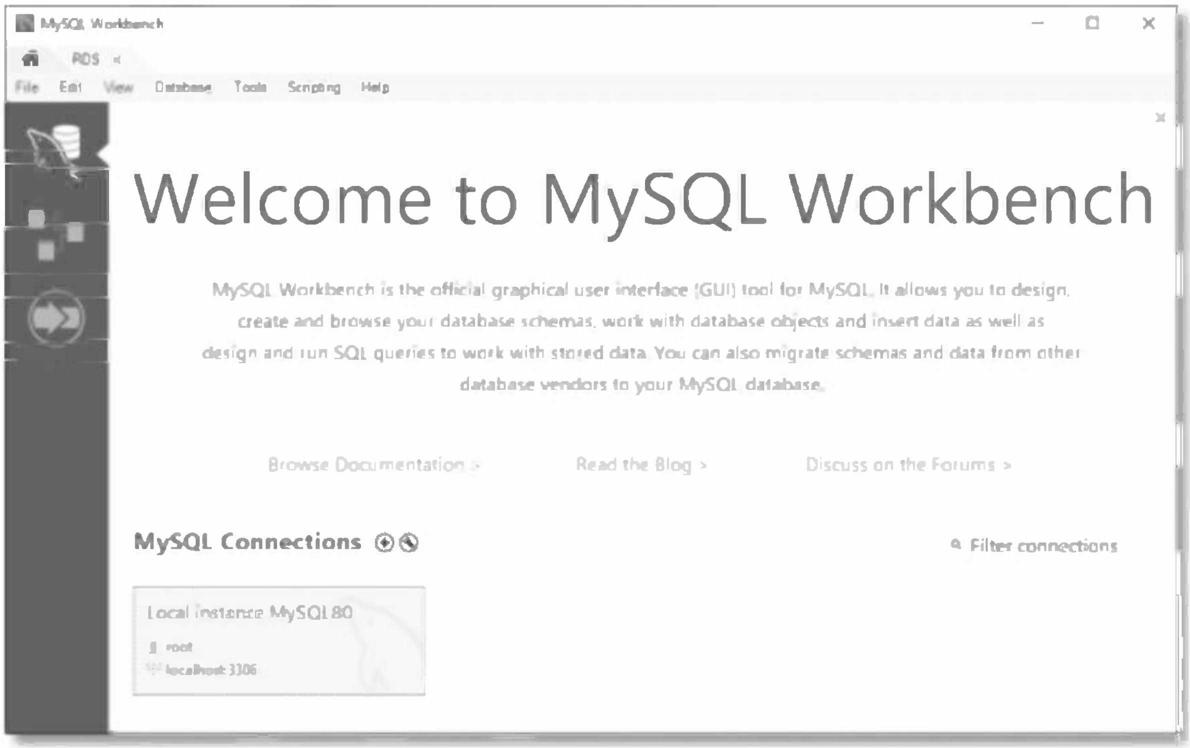
The Connections tab contains links that you can use to open a connection to a MySQL server. Then, you can use that connection to code and run SQL statements. If you installed MySQL Community Server as described in appendix A or B, this tab will contain one connection that allows you to connect as the root user to a local instance of MySQL Server that's running on your computer. However, if necessary, you can click the ⊕ icon to the right of MySQL Connections to create other connections.

The Connections tab also contains links to MySQL Workbench documentation, blogs, and forums. This book doesn't show how to use these links, but you may find them useful, especially after you have learned the basic skills for working with MySQL that are described in this book.

The Models tab contains links that let you create database diagrams from a type of data model known as an EER model. You can also use this tab to open existing EER models or to create new ones. Then, you can work with EER diagrams that correspond to these models. To learn more about EER models and diagrams, you can read chapter 10.

Once you connect to a MySQL server, you can use Workbench to work with that server and the databases on the server. Then, if you need to return to the Home page, you can do that by clicking on the tab with the house icon on it near the top left of the Workbench window. In this figure, the Home tab is the only tab that's shown, but you'll see some other tabs in the next few figures.

## The Home page of MySQL Workbench




### Description

- The Home page of MySQL Workbench is divided into the three tabs displayed at the left side of the window: Connections, Models, and Migration.
- You can use the Connections tab to code and run SQL statements.
- You can use the Models tab to create and work with EER models.
- You can use the Migration tab to migrate other databases to MySQL and to copy a database from one instance of MySQL to another.
- The Home page also includes links that you can use to view the documentation for using MySQL Workbench, view the MySQL Workbench blog, and view and join in the MySQL Workbench forum.
- You can return to the Home page by clicking the tab with the house icon. This tab is always displayed in the top left corner of the Workbench window.

Figure 2-1 The Home page of MySQL Workbench

## How to open a database connection

Before you can work with a database, you need to connect to the server that hosts that database. When you start MySQL Workbench, the MySQL Connections tab displays a list of saved connections.

By default, MySQL Workbench has one saved connection in this list. Here, the connection is named "Local instance MySQL80", and it connects as the root user to a MySQL server that's running on port 3306 of the local host computer. This assumes that you're using MySQL version 8.0 and that you've followed the instructions for installing the instance as described in appendix A (Windows) or appendix B (macOS). If you want to rename the connection, you can do that by editing the connection parameters as described in figure 2-2.

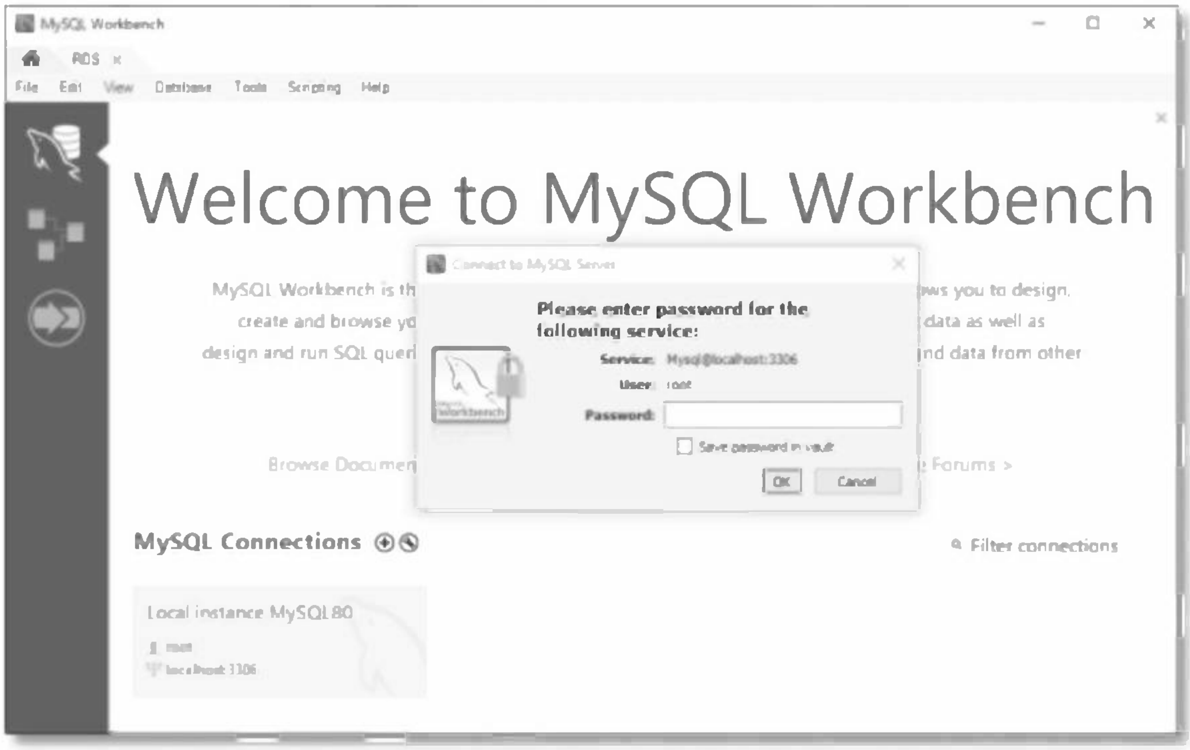
Since you typically want to connect as the root user when you're first getting started, you typically use this default connection to connect to the server. To do that, click the connection and enter the password for the root user if you're prompted for it. This is the password that you created when installing the MySQL Server.

This figure shows the dialog box that MySQL Workbench displays to prompt for a password. This dialog box shows that it's attempting to use the root user to connect to a MySQL server running on port 3306 of the local host. In addition to entering a password in this dialog box, you can select the "Save password in vault" option to save the password so you don't have to enter it every time you connect to this server. Then, if you ever want to clear the password from the vault, you can right-click the connection, select Edit Connection, and click the Clear button.

In some cases, you may need to connect as another user or connect to a MySQL server running on a different computer. To do that, you can use the Manage Server Connections dialog box to edit the parameters for a connection as described in this figure. This dialog box lets you specify the parameters for the connection such as the connection name, username, hostname, and port number.

If you want to add a new connection to the Connections tab, you can click the ⊕ icon to the right of MySQL Connections, enter a name for the connection, and specify the parameters for the connection. Then, this connection appears in the list of connections, and you can click on it to use it.

## The dialog box for opening database connections




## Description

- To connect as the root user to an instance of MySQL that's running on the local host computer, click the stored connection for the local instance and enter the password for the root user if prompted.
- To save the password for a connection so you don't have to enter it every time, check the "Save password in vault" option when you're prompted for your password.
- To clear the password from the vault so you are prompted for your password, right-click the connection, select Edit Connection, click the Clear button for the password and click the Close button.
- To edit the connection parameters for a connection, right-click the connection and select Edit Connection to display the Manage Server Connections dialog box. Then, enter the connection parameters and click the Close button. This lets you specify the connection name, the username, the hostname, the port number, and other connection parameters.
- To add a connection to another MySQL server, click the ⊕ icon to the right of MySQL Connections, enter the connection parameters, and click the OK button. Then, the connection appears in the list of connections.
- If you get a warning that MySQL Workbench is incompatible with the server version and that some features may not work properly, don't be alarmed. You can click Continue Anyway and the features described in this book should still work.

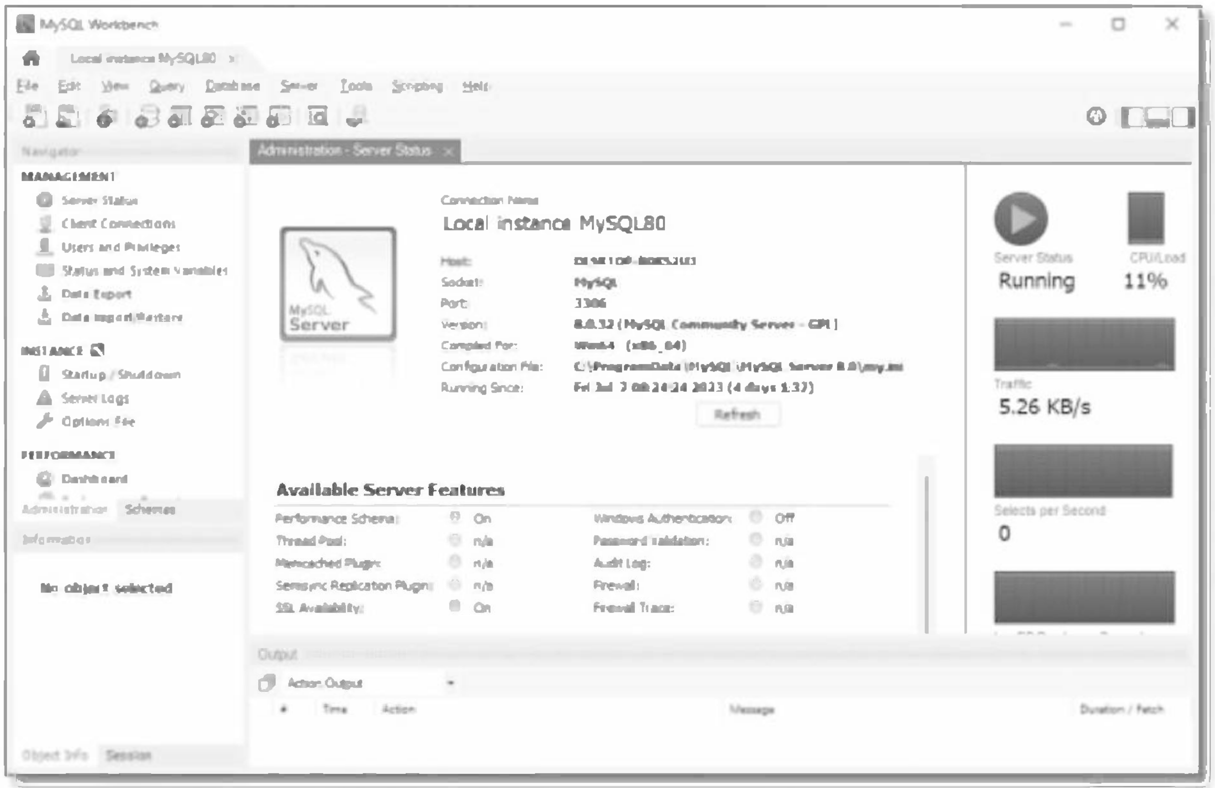
Figure 2-2 How to open a database connection

## How to view the status of the database server

If you installed MySQL on your computer as described in appendix A (Windows) or B (macOS), the *database server* should start automatically when you start your computer. This piece of software is sometimes referred to as the *database service* or *database engine*. It receives SQL statements that are passed to it, processes them, and returns the results.

To check whether the MySQL database server is running on your computer, you can display the Server Status tab of MySQL Workbench as shown in figure 2-3. Then, if the server isn't already running, you can use the Services app for Windows or the System Preferences dialog box for macOS to start it. For more information, see figure A-1 in appendix A (Windows) or figure B-1 in appendix B (macOS).

## The Server Status option of MySQL Workbench




## How to view the status of the database server

1. Display the Connections tab of the MySQL Workbench Home page.
2. Click the connection to the local server. This should connect you to the local MySQL server as the root user. If necessary, enter the password for the root user.
3. If the Administration tab of the Navigator window isn't displayed, click on it to display it. Then, select the Server Status option from the Management category. This will display information about the database server, including whether it is running.

## Description

- After you install MySQL, the *database server* usually starts automatically each time you start your computer. You can confirm that's it's running by displaying the Server Status tab.
- The database server can also be referred to as the *database service* or the *database engine*.
- If you need to start or stop the database server, appendix A provides instructions for Windows, and appendix B provides instructions for macOS.

Figure 2-3 How to view the status of the database server

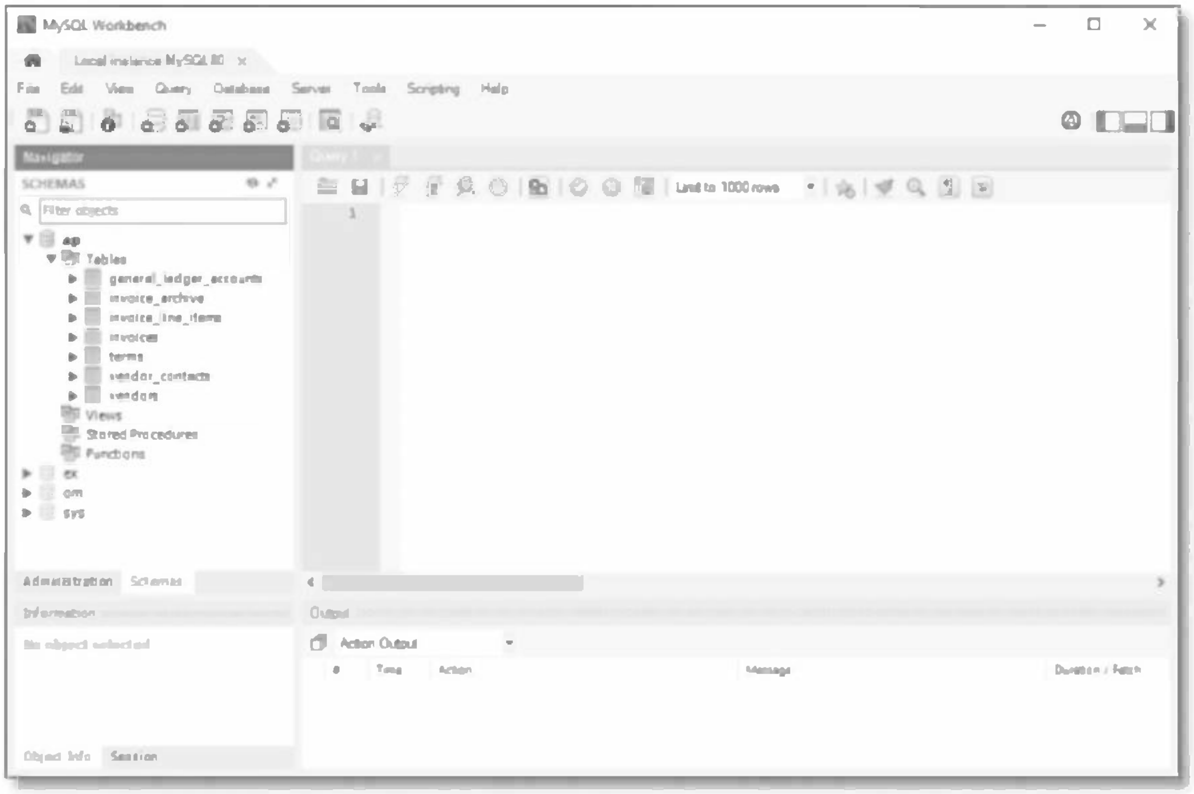
## How to navigate through the database objects

After you connect to a database server, you can use the Schemas category of the Navigator window to navigate through the *database objects* in the databases on the server, as shown in figure 2-4. As you can see, these objects include tables, views, stored procedures, and functions. For this chapter, however, you can focus on the tables. Later in this book, you'll learn more about views, stored procedures, and functions.

In this figure, I double-clicked the node for the AP database (*schema*) in the Schemas tab of the Navigator window to select it and view the database objects it contains (tables, views, stored procedures, and functions). Then, I expanded the Tables node to view all of the tables in the AP database.

To work with a node or an object, you can right-click it to display a context-sensitive menu. Then, you can select an item from that menu. For example, you can right-click the node for the AP database to display a list of items for working with that database.

### The tables available for the AP database




## Description

- Each database (or *schema*) provides access to the *database objects* that are available. These database objects include tables, views, stored procedures, and functions.
- On some systems, the Navigator window provides Administration and Schemas tabs that you can use to display the Administration and Schemas categories. On other systems, the Navigator window displays the Administration category above the Schemas category.
- To display the databases for the current connection, you can use the Navigator window to view the Schemas category.
- To navigate through the database objects for a database, click the arrows to the left of each of the nodes in the Navigator window to expand or collapse the node.
- To work with a node or an object, right-click the node or object and select an item from the resulting menu.

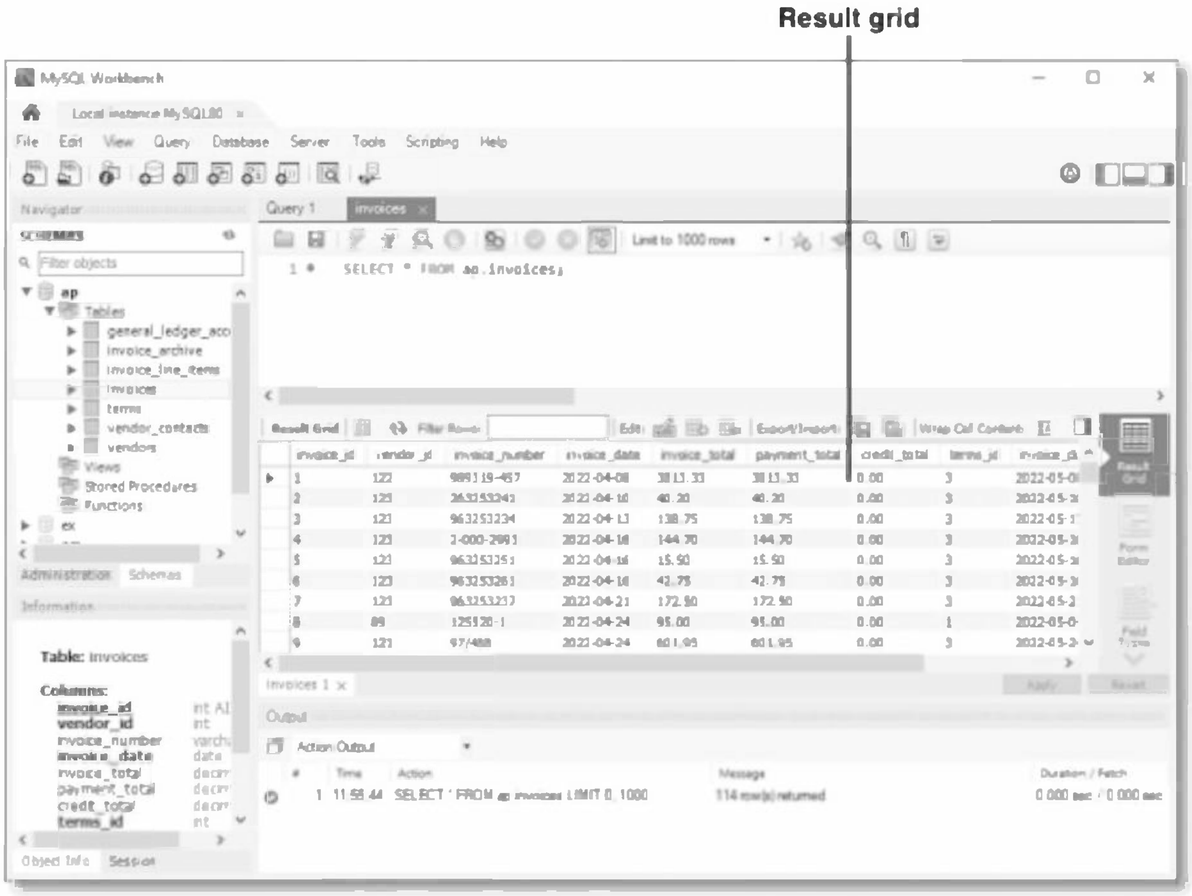
Figure 2-4 How to navigate through the database objects

## How to view and edit the data for a table

To view the data for a table, you can right-click the table name and select Select Rows - Limit 1000. In figure 2-5, for example, I selected this command for the Invoices table. This displayed the data for the table in a Result grid. In addition, it displayed information about the SELECT statement that was used to retrieve the data in the Output tab.

To insert, edit, and delete the rows in the table, you can use the buttons at the top of the Result grid. Then, to apply the changes to the table, you can click the Apply button at the bottom of the Result grid. Or, if you want to cancel the changes, you can click the Revert button.

## The data for the Invoices table displayed in the Result grid




## Description

- To view the data for a table, right-click the table in the Navigator window and select Select Rows - Limit 1000 to display it in a Result grid.
- To edit the data for a table, view the data. Then, you can use the buttons at the top of the Result grid to insert, update, and delete rows.
- To apply the changes to the table, click the Apply button at the bottom of the tab. To cancel the changes, click the Revert button.

Figure 2-5 How to view and edit the data for a table

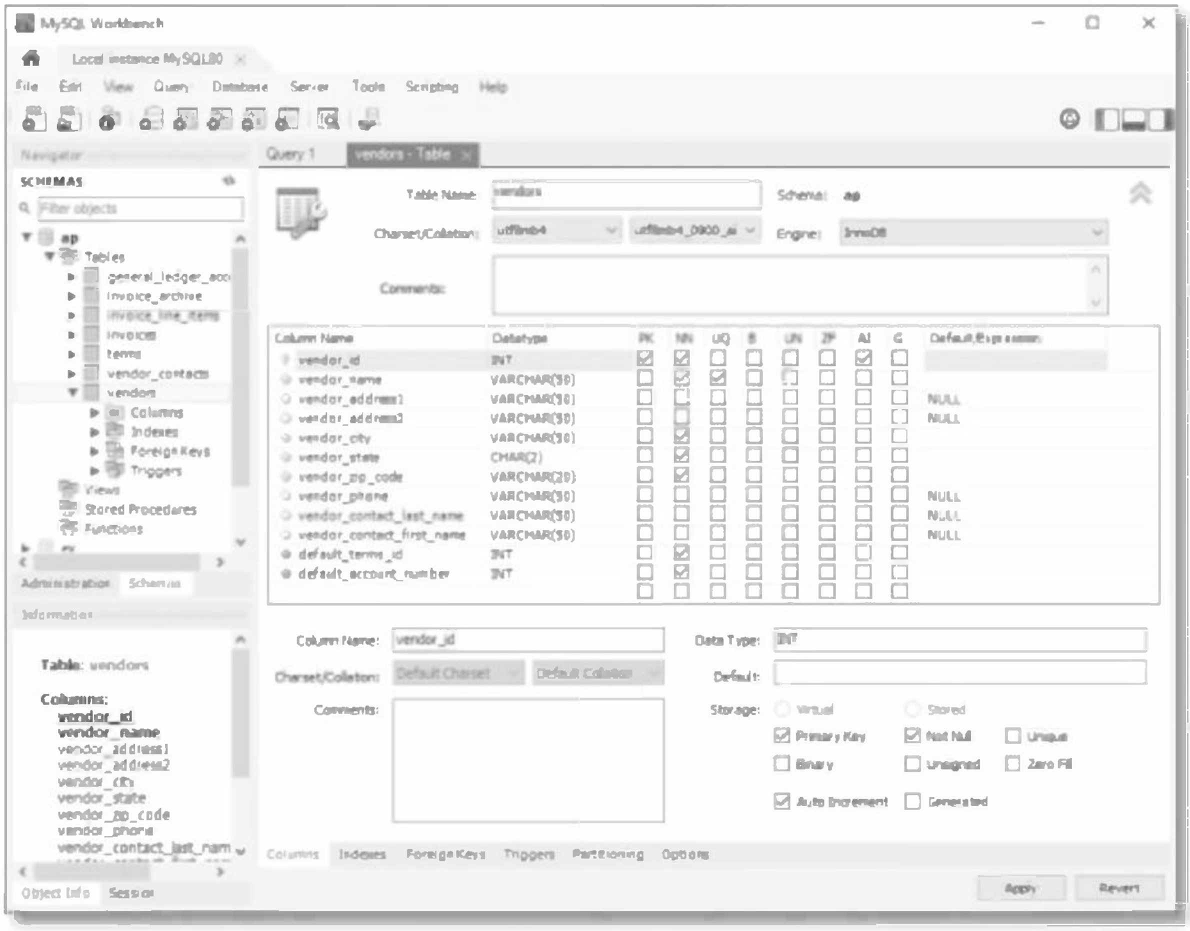
## How to view and edit the column definitions for a table

If you want to view or edit the column definitions for a table, you can use the techniques described in figure 2-6. In this figure, for example, the column definitions for the Vendors table are displayed. At this point, you can view information about each column of the table such as its name and data type. You can also select a column to display the information about that column in the Columns tab at the bottom of the window.

Once you display the column definitions for a table, you can add a column, delete one or more columns, or modify a column. To add a new column, you enter its information in the row at the bottom of the list. To delete one or more columns, you select the columns using standard techniques, and then right-click on one of the selected columns and select the Delete Selected command. To change the name of a column, you select the column and then click on the name and edit it. To change the data type of a column, you select the column and then click on its data type and select another data type from the drop-down list that appears. And so on.

Most of the time, you won't want to use MySQL Workbench to edit the column definitions for a table. Instead, you'll want to edit the scripts that create the database so you can easily recreate the database later. In chapter 11, you'll learn more about creating and modifying the column definitions for a table using both techniques.

## The column definitions for the Vendors table



## Description

- To view the column definitions for a table, right-click the table name in the Navigator window and select Alter Table.
- To edit the column definitions for a table, view the column definitions. Then, you can use the resulting window to add new columns and modify and delete existing columns.

Figure 2-6 How to view and edit the column definitions for a table

# How to use MySQL Workbench to run SQL statements

Although you can use MySQL Workbench to view and edit the column definitions and data in a database, it's most useful for running SQL statements against a database. This topic presents the basic skills you need to do that.

## How to enter and execute a SQL statement

When you first connect to a MySQL server in MySQL Workbench, a SQL Editor tab with the name "Query 1" is automatically opened. Figure 2-7 shows how to use this tab to enter and execute a SQL statement. If necessary, you can also open additional SQL Editor tabs by clicking the Create New SQL Tab button in the SQL Editor toolbar or pressing Ctrl+T.

You can enter or edit a SQL statement in any open SQL tab. As you enter statements, you'll notice that MySQL Workbench automatically applies colors to various elements. For example, it displays keywords in blue. This makes your statements easier to read and can help you identify coding errors.

To execute a single SQL statement like the one in this figure, you can press Ctrl+Enter or click the Execute Statement button in the SQL Editor toolbar. If the statement returns data, that data is displayed below the SQL editor in a corresponding Result grid. In this figure, for example, the result set returned by the SELECT statement is displayed. If necessary, you can adjust the height of the Result grid by dragging the bar that separates the SQL Editor tab from the Result grid.

Before you execute a SQL statement, make sure you've selected a database by double-clicking the database in the Navigator window. Otherwise, you'll get an error message like this:

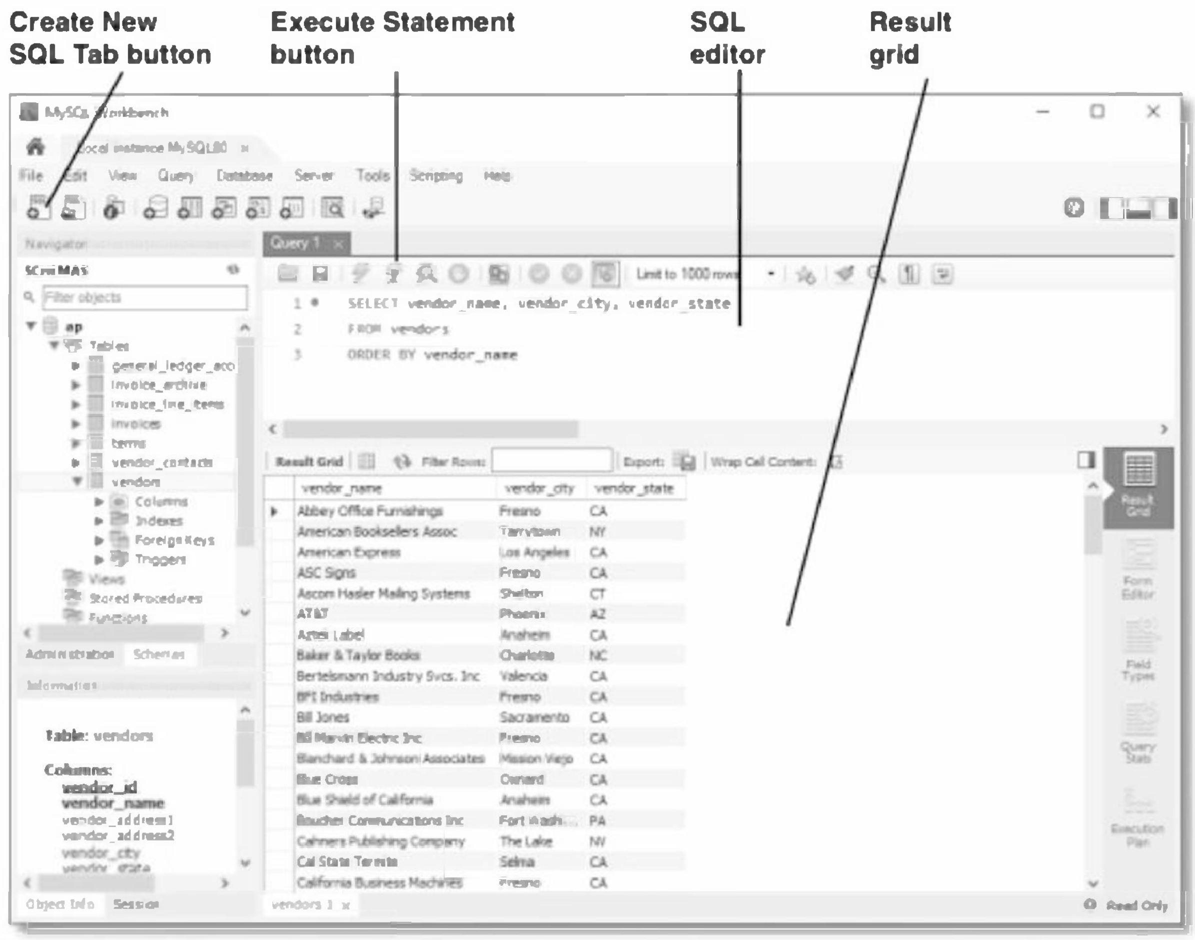
```
Error Code: 1046. No database selected
```

Similarly, if you haven't selected the correct database, you'll get an error message that says the table doesn't exist. For example, if the EX database is selected when you attempt to retrieve data from the Vendors table in the AP database, you'll get an error message like this:

```
Error Code: 1146. Table 'ex.vendors' doesn't exist
```

To fix this, you can double-click the AP database to select it.

## A SELECT statement and its results




## Description

- To open a new SQL tab, press Ctrl+T or click the Create New SQL Tab button ( ) in the SQL Editor toolbar.
- To select the current database, double-click its name in the Schemas tab of the Navigator window. This displays the database in bold.
- To enter a SQL statement, type it into the SQL editor.
- As you enter the text for a statement, the SQL editor applies color to various elements, such as SQL keywords, to make them easy to identify.
- To execute a SQL statement, press Ctrl+Enter or click the Execute Statement button ( ) in the SQL Editor toolbar. If the statement retrieves data, the data is displayed in a Result grid below the SQL Editor tab.

Figure 2-7 How to enter and execute a SQL statement

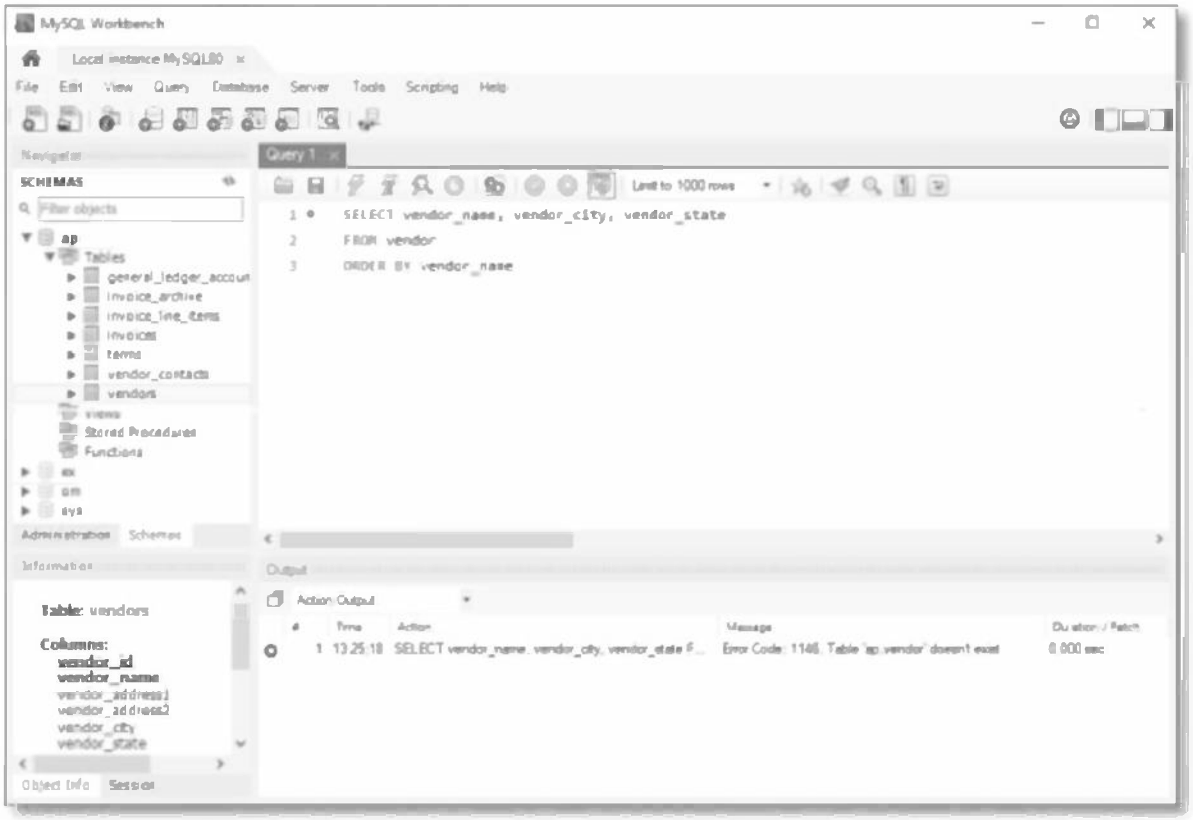
## How to handle syntax errors

If an error occurs during the execution of a SQL statement, MySQL Workbench displays a message that includes the error number and a brief description of the error. In figure 2-8, for example, the message displays an error number of 1146 and a brief description that says "Table ap.vendor doesn't exist."

In this example, the problem is that a table named Vendor doesn't exist in the AP database. To fix this problem, you need to edit the SQL statement so the table is Vendors instead of Vendor. Then, you should be able to successfully run the SQL statement.

This figure also lists some other common causes of errors. As you can see, most errors are caused by incorrect syntax. However, it's also common to get an error if you have selected the wrong database. If, for example, you have selected the EX database and you try to run a statement that refers to tables in the AP database, you will get an error. Regardless of what's causing the problem, you can usually identify and correct the problem without much trouble. In some cases, though, it may be difficult to figure out the cause of an error. Then, you can usually get more information about the error by searching the internet or by searching the MySQL Reference Manual as described later in this chapter.

## How to handle syntax errors




## Common causes of errors

- Having the wrong database selected
- Misspelling the name of a table or column
- Misspelling a keyword
- Omitting the closing quotation mark for a character string

## Description

- If an error occurs during the execution of a SQL statement, MySQL Workbench displays a message in the Output tab that includes an error code and a brief description of the error.
- Most errors are caused by incorrect syntax and can be corrected without any additional assistance. Otherwise, you can usually get more information about an error by searching for the error code or description in the MySQL Reference Manual or on the internet.

Figure 2-8 How to handle syntax errors

## How to open and save SQL scripts

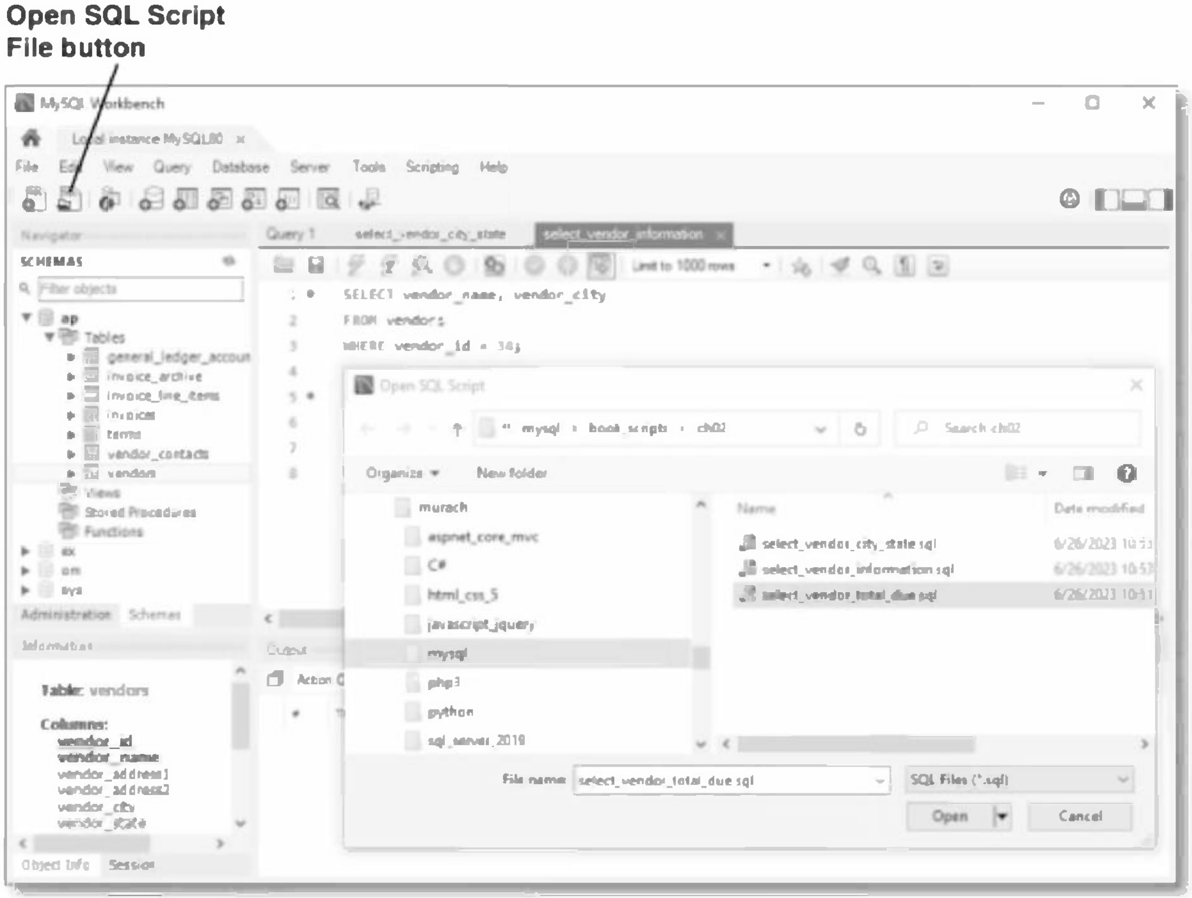
In MySQL, a *script* is a file that contains one or more SQL statements. To create a script, you enter the statements you want it to include into a SQL Editor tab as shown in the next figure. Then, you can click the Save button or press Ctrl+S to save the script as described in figure 2-9.

Once you've saved a script, you can open it again later. To do that, you can click the Open SQL Script File button in the SQL Editor toolbar, or you can press Ctrl+Shift+O to display the Open SQL Script dialog box. In this figure, the dialog box that's displayed shows the script files that have been saved for chapter 2. These files are created when you download and install the source code for this book. Note that the names of these files have the .sql extension. (If you're using Windows and the file extensions aren't displayed, you can display them by opening the File Explorer, displaying the View tab, and selecting the "File name extensions" option in the Show/hide group.)

Once you open a script, you can run it as shown in the next figure. You can also use it as the basis for a new SQL script. To do that, just modify it any way you want. Then, you can save it as a new script by pressing the Ctrl+Shift+S keys or selecting File→Save Script As.

The screen in this figure shows the tabs for two script files that have been opened. After you open two or more scripts, you can switch between them by clicking on the appropriate tab. Then, you can cut, copy, and paste code from one script to another.

## The Open SQL Script dialog box




## Description

- A *SQL script* is a file that contains one or more SQL statements.
- To open a SQL script, click the Open SQL Script File button in the SQL Editor toolbar or press Ctrl+Shift+O. Then, use the Open SQL Script dialog box to locate and open the SQL script.
- When you open a SQL script, MySQL Workbench displays it in its own SQL Editor tab. To switch between open scripts, select the appropriate tab.
- To cut, copy, and paste code from one SQL script to another, use the standard techniques.
- To save a SQL statement to a script file, click the Save button in the SQL Editor toolbar or press Ctrl+S. Then, use the Save SQL Script dialog box that's displayed to specify a location and name for the file.
- To save a script you've modified to a new file, press Ctrl+Shift+S or select File→Save Script As.

Figure 2-9 How to open and save SQL scripts

## How to enter and execute SQL scripts

In the last topic, you saw a SQL script that contained a single SQL statement. However, a SQL script typically contains multiple statements. Figure 2-10 shows how to enter and execute scripts like that.

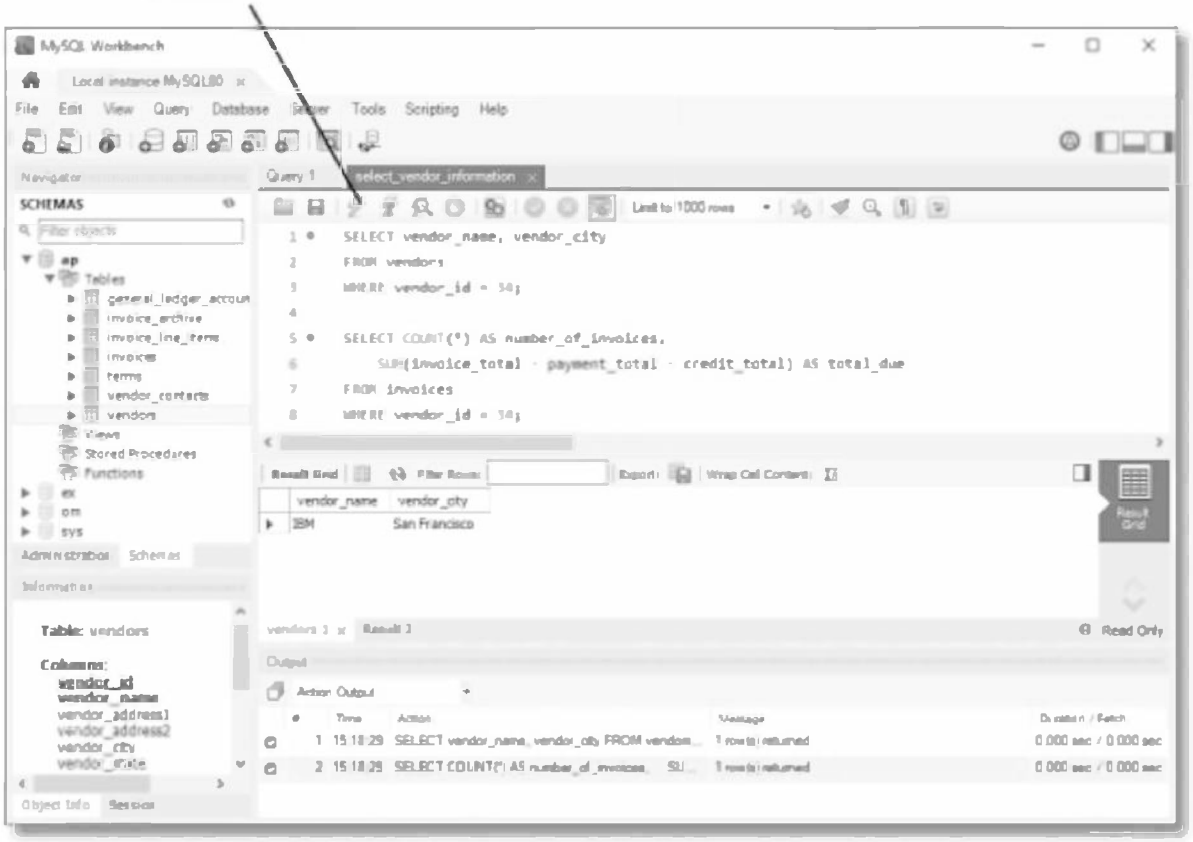
When you code multiple SQL statements within a script, you must code a semicolon at the end of each statement. For example, this figure shows a script that contains two SELECT statements. To execute both of these statements, you can press the Ctrl+Shift+Enter keys, or you can click the Execute Script button in the SQL Editor toolbar. When you do, the results of each script are displayed in a separate Result grid. To switch between Result grids, you can click on the tabs that are displayed below the current Result grid.

If you want to execute a single SQL statement that's stored within a script, you can do that by moving the insertion point into the statement and pressing the Ctrl+Enter keys or clicking the Execute Statement button. Then, if the statement retrieves data, the data is displayed in a single Result grid.

If you need to, you can also execute two or more statements in a script. To do that, you select the statements and then press the Ctrl+Shift+Enter keys or click the Execute Script button. This is useful if a script contains many statements and you just want to execute some of them.

## A SQL script and its results

**Execute Script button**




## Description

- When you code a script that contains more than one statement, you must code a semicolon at the end of each statement.
- To run an entire SQL script, press Ctrl+Shift+Enter or click the Execute Script button ( ) that's located just to the left of the Execute Statement button in the SQL Editor toolbar.
- When you run a SQL script, the results of each statement that returns data are displayed in a separate Result grid. To switch between these Result grids, you can click on the tabs that are displayed below the current Result grid.
- To execute one SQL statement within a script, move the insertion point into that statement and press Ctrl+Enter or click the Execute Statement button ( ). If the statement retrieves data, the data is displayed in a Result grid.
- To execute two or more statements within a script, select them in the editor and then press Ctrl+Shift+Enter or click the Execute Script button.

Figure 2-10 How to enter and execute SQL scripts

# How to use the MySQL Reference Manual

Figure 2-11 shows how to use another useful tool for working with MySQL: the *MySQL Reference Manual*. In most cases, you'll use a web browser to view this manual directly from the internet. That way, you can be sure that the information is always up to date. However, you can also download this manual and save it on your hard drive. Either way, you can use the MySQL Reference Manual to quickly look up detailed technical information about the MySQL database, including information about SQL statements and functions.

## How to view the manual

You can view the MySQL Reference Manual by using a web browser to go to the web address shown at the top of this figure. Here, the Reference Manual for version 8.0 of MySQL is displayed. However, you can easily select another version by selecting it from the drop-down list at the right side of the page.

## How to look up information

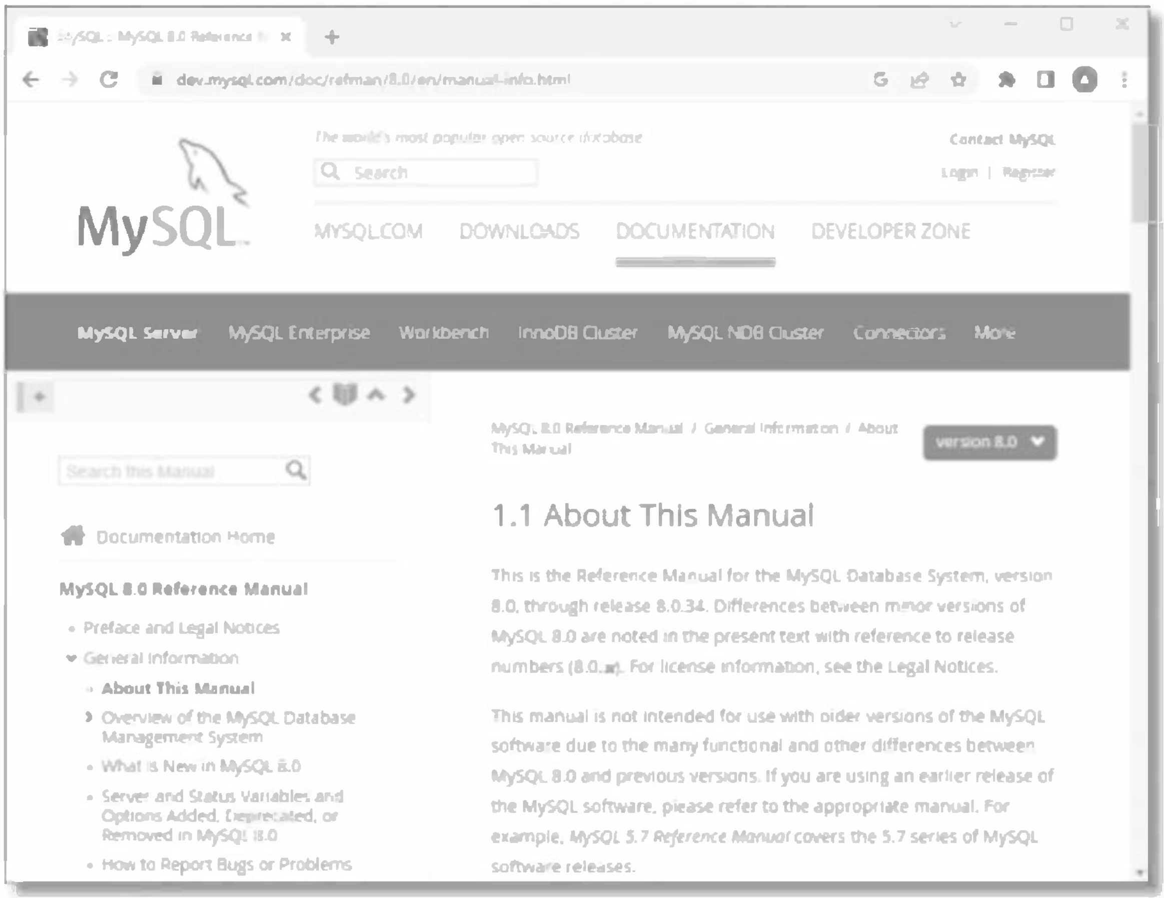
Once you've navigated to the correct version of the MySQL Reference Manual, it's easy to look up information. To do that, you can use the table of contents in the left sidebar to drill down to the information that you're looking for. When you find the topic you want, you can click it to display it in the main part of the window. Then, if you want to navigate back up the hierarchy of information, you can use the breadcrumb links across the top of the page. In this figure, for example, you can click the "MySQL 8.0 Reference Manual" link to return to the Home page for the manual. Or, you can click the "General Information" link to navigate to that page.

Another easy way to look up information is to search for a specific word or phrase. To do that, you can use the search bar near the top of the left sidebar. When you do, the search results are displayed in the main window. Then, you can click any of the links in the results to view information about the search terms.

### The web address for the MySQL 8.0 Reference Manual

https://dev.mysql.com/doc/refman/8.0/en/

### A web page from the MySQL Reference Manual




### Description

- To view the *MySQL Reference Manual*, go to the MySQL website and select the correct version of the manual.
- To view a topic, click on it in the table of contents in the left sidebar.
- To return to the Home page for the manual, click the Start icon ( ) for the manual that's displayed at the top of the left sidebar.
- To search for a particular word or phrase, use the search bar near the top of the left sidebar. Then, you can scroll through the results that are displayed and click any link to get more information.
- You can also download the MySQL Reference Manual for offline use by clicking on one of the links below the table of contents. However, it typically makes sense to use the manual online.

Figure 2-11 How to use the MySQL Reference Manual

# How to use the MySQL Command Line Client

Before MySQL Workbench was available, programmers used a command-line tool known as the *MySQL Command Line Client* to connect to a MySQL server and work with it. This tool is also known as the *MySQL command line*. Although you may never need this tool, you should at least be aware that it exists. This tool is installed with MySQL, and it can be useful if MySQL Workbench isn't installed on the system that you're using.

## How to start and stop the MySQL Command Line Client

Figure 2-12 shows how to start and stop the MySQL Command Line Client in Windows and macOS. At the top of this figure, you can see the Command Prompt window that the MySQL Command Line Client uses on Windows. On macOS, you use the Terminal window instead.

When you use Windows, there's an easy way to start the MySQL Command Line Client if you want to log in as the root user for the database server that's running on the local computer. To do that, you just click the button for the Start menu, type "mysql 8.0 command", and then click Open. Then, the MySQL Command Line Client starts and prompts you for a password. If you enter the password correctly, you will be logged on to the database server as the root user.

In some cases, you'll need to use a command line to start the MySQL Command Line Client instead of using the Start menu. For example, you may need to do that if you want to log into a database that's running on a different computer or if you want to log in as a user other than the root user. You also need to do that if you're using another operating system such as macOS. In those cases, you can open a command line and change the directory to the bin directory for the MySQL installation. Then, you can execute the mysql command and supply the parameters that are needed to connect to the database server.

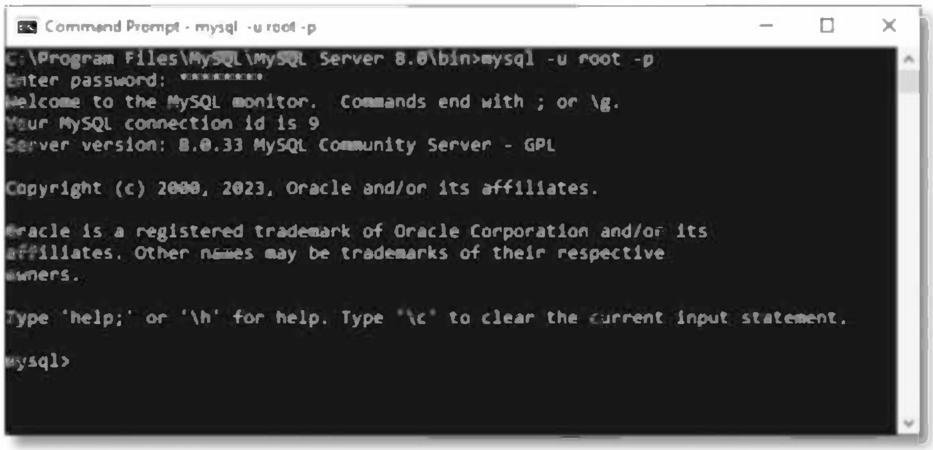
If the MySQL server is located on a remote computer, you can specify -h, followed by the host name of the computer, and -u, followed by a valid username. In addition, you specify -p so MySQL prompts you for a valid password. Although it can take some experimentation to get these connection parameters right, you only need to figure this out once.

Once you enter a valid password for the specified username, the MySQL Command Line Client displays a welcome message and a command line that looks like this:

```
mysql>
```

From this prompt, you can enter any statement that works with MySQL. When you're done, you can exit the MySQL Command Line Client by entering "exit" or "quit" followed by a semicolon.

## The MySQL Command Line Client displayed by Windows




## How to start the MySQL Command Line Client from the command line

### For Windows

```
cd \Program Files\MySQL\MySQL Server 8.0\bin
mysql -u root -p
```

### For macOS

```
cd /usr/local/mysql/bin
./mysql -u root -p
```

## How the mysql command works

### The syntax

```
mysql -h hostname -u username -p
```

### Examples

```
mysql -u ap_tester -p
mysql -h localhost -u root -p
mysql -h murach.com -u ap_tester -p
```

## How to exit from the MySQL Command Line Client

```
mysql> exit;
```

## Description

- MySQL provides a command-line client program called the *MySQL Command Line Client* that lets you enter SQL statements that work with MySQL databases. This program is also known as the *MySQL command line*.
- For Windows, the easiest way to start the MySQL Command Line Client is to display the Start menu, enter "mysql 8.0 command", and click Open. However, you can also use a Command Prompt window to start the MySQL Command Line Client.
- For macOS, use a Terminal window to start the MySQL Command Line Client.
- To stop the MySQL Command Line Client, enter "exit" or "quit" at the command line, followed by a semicolon.
- MySQL 8.0 also includes a Unicode version of the command-line client program. For more information on this program, you can refer to section 4.5.1.6.2 of the reference manual.

Figure 2-12 How to start and stop the MySQL Command Line Client

## How to use the MySQL Command Line Client to work with a database

Once the MySQL Command Line Client is connected to a database server, you can use it to run SQL statements that work with the databases that are available from that server. When you enter a statement, you must end it with a semicolon. Otherwise, the mysql command line displays a second line when you press the Enter key like this:

```
mysql> show databases
    ->
```

This shows that the MySQL Command Line Client is waiting for you to finish your statement. To finish a statement and execute it, just type a semicolon and press the Enter key.

Figure 2-13 shows how to execute three SQL statements. Here, I entered all three of these statements in lowercase letters. That's because SQL isn't case-sensitive, and lowercase letters are easier to type.

To list the names of the databases stored on a server, you use the SHOW DATABASES statement as illustrated by the first example. Here, the "ap", "ex", and "om" databases are the databases that are created when you install our downloadable databases as described in appendixes A and B. The "information_schema", "performance_schema", and "mysql" databases are internal databases that are used by the MySQL server. And the "sys" database is a database that comes with MySQL and can be used to interpret data in the "performance_schema" database.

To select the database that you want to work with, you can enter a USE statement as illustrated by the second example. Here, the AP database is selected, and the message after this statement says "Database changed" to indicate that the statement was successful. After you select a database, the commands and statements that you enter will work with that database.

To retrieve data from the database, you use a SELECT statement as illustrated by the third example. Here, the vendor_name column from the Vendors table is displayed. Note, however, that the result set is limited to the first five rows. When you successfully execute a SELECT statement, the MySQL Command Line Client displays a message giving the number of rows that are included in the result set and the amount of time it took to run the query. In this case, it took less than 1/100 of a second to run the query.

### How to list the names of all databases managed by the server

```
mysql> show databases;
+--------------------+
| Database           |
+--------------------+
| ap                 |
| ex                 |
| information_schema |
| mysql              |
| om                 |
| performance_schema |
| sys                |
+--------------------+
7 rows in set (0.00 sec)
```

### How to select a database for use

```
mysql> use ap;
Database changed
```

### How to select data from a database

```
mysql> select vendor_name from vendors limit 5;
+-----------------------------+
| vendor_name                 |
+-----------------------------+
| Abbey Office Furnishings    |
| American Booksellers Assoc  |
| American Express            |
| ASC Signs                   |
| Ascom Hasler Mailing Systems|
+-----------------------------+
5 rows in set (0.00 sec)
```

### Description

- You can use the MySQL Command Line Client to work with any of the databases running on the database server. To do that, you can use any SQL statement that works with a MySQL database.
- To execute a SQL statement, type the statement on the command line, followed by a semicolon. Then, press Enter.
- To show a list of all available databases, you can use the SHOW DATABASES statement.
- To select the database that you want to work with, you can use the USE statement.
- SQL statements aren't case-sensitive. As a result, when using the MySQL Command Line Client, most programmers enter their statements in lowercase letters because they're easier to type.

Figure 2-13 How to use the MySQL Command Line Client to work with a database

# Perspective

In this chapter, you learned how to use MySQL Workbench to start and stop a MySQL server, enter and execute SQL statements, and work with SQL scripts. With that as background, you're ready to go on to the next chapter, where you'll start learning the details of coding your own SQL statements.

## Terms

MySQL Workbench
database server
database service
database engine
database object
schema
SQL script
MySQL Reference Manual
MySQL Command Line Client

## Before you start the exercises...

Before you start the exercises for this chapter, you need to install MySQL Server and MySQL Workbench. In addition, you need to download and install the source files for this book, and you need to create the databases and tables for this book. The procedures for doing these tasks are provided in appendix A (Windows) and appendix B (macOS).

## Exercises

In these exercises, you'll use MySQL Workbench to review the tables in the AP database. In addition, you'll use MySQL Workbench to enter SQL statements and run them against these tables.

### Make sure the MySQL server is running

1. Start MySQL Workbench and open a connection for the root user.
2. Check whether the MySQL server is running. If it isn't, use the procedure in figure A-1 of appendix A (Windows) or figure B-1 of appendix B (macOS) to start it.

### Use MySQL Workbench to review the Accounts Payable (AP) database

3. In the Schemas tab of the Navigator window, expand the node for the AP database so you can see all of the database objects it contains.
4. View the data for the Vendors and Invoices tables.
5. Navigate through the database objects and view the column definitions for at least the Vendors and Invoices tables.

## Use MySQL Workbench to enter and run SQL statements

6. Double-click the AP database to select it. When you do that, MySQL Workbench should display the database in bold.

7. Open a SQL Editor tab. Then, enter and run this SQL statement:

```
SELECT vendor_name FROM vendors
```

8. Delete the *e* at the end of vendor_name and run the statement again. Note the error number and the description of the error.

9. Open another SQL Editor tab. Then, enter and run this statement:

```
SELECT COUNT(*) AS number_of_invoices,
    SUM(invoice_total) AS grand_invoice_total
FROM invoices
```

## Use MySQL Workbench to open and run scripts

10. Open the select_vendor_city_state script that's in the murach/mysql/book_scripts/ch02 directory. Note that this script contains just one SQL statement. Then, run the statement.

11. Open the select_vendor_total_due script that's in the ch02 directory. Note that this opens another SQL Editor tab.

12. Open the select_vendor_information script that's in the ch02 directory. Notice that this script contains two SQL statements that end with semicolons (scroll down if you need to).

13. Press the Ctrl+Shift+Enter keys or click the Execute SQL Script button to run both of the statements in this script. Note that this displays the results in two Result grids. Make sure to view the results of both SELECT statements.

14. Move the insertion point into the first statement and press Ctrl+Enter to run just that statement.

15. Move the insertion point into the second statement and press Ctrl+Enter to run just that statement.

16. Exit from MySQL Workbench.

# 3

# How to retrieve data from a single table

In this chapter, you'll learn how to code SELECT statements that retrieve data from a single table. The skills covered here are the essential ones that apply to any SELECT statement you code, no matter how many tables it operates on, no matter how complex the retrieval. So you'll want to be sure you have a good understanding of the material in this chapter before you go on to the chapters that follow.

# An introduction to the SELECT statement

To get you started quickly, this chapter begins by presenting the basic syntax of the SELECT statement. Then, it presents several examples that should give you an overview of how this statement works.

## The basic syntax of the SELECT statement

Figure 3-1 presents the basic syntax of the SELECT statement. The syntax summary at the top of this figure uses conventions that are similar to those used in other programming manuals. Capitalized words are *keywords* that you have to type exactly as shown. In contrast, you have to provide replacements for the lowercase words. For example, you can enter a list of columns in place of select_list, and you can enter a table name in place of table_source.

Beyond that, you can omit the clauses enclosed in brackets ( [ ] ), and you can choose between the items enclosed in braces ( { } ) and separated by pipes ( | ). If you have a choice between two or more optional items, the default item is underlined. And if an element can be coded multiple times in a statement, it's followed by an ellipsis (...).

This syntax summary has been simplified so you can focus on the five main clauses of the SELECT statement: SELECT, FROM, WHERE, ORDER BY, and LIMIT. Most SELECT statements contain the first four of these clauses. However, only the SELECT clause is required.

The SELECT clause is always the first clause in a SELECT statement. It identifies the columns in the result set. These columns are retrieved from the *base tables* named in the FROM clause. Since this chapter focuses on retrieving data from a single table, the examples in this chapter use FROM clauses that name a single base table. In the next chapter, though, you'll learn how to retrieve data from two or more tables.

The WHERE, ORDER BY, and LIMIT clauses are optional. The ORDER BY clause determines how the rows in the result set are sorted, and the WHERE clause determines which rows in the base table are included in the result set. The WHERE clause specifies a *search condition* that's used to *filter* the rows in the base table. When this condition is true, the row is included in the result set.

The LIMIT clause limits the number of rows in the result set. In contrast to the WHERE clause, which uses a search condition, the LIMIT clause simply returns a specified number of rows, regardless of the size of the full result set. Of course, if the result set has fewer rows than are specified by the LIMIT clause, all the rows in the result set are returned.

### The syntax used in this book

| Syntax | Meaning |
|---|---|
| `KEYWORD` | Keywords have each letter capitalized. |
| `element_name` | Words in lowercase should be replaced with the appropriate element, such as a list or columns or the name of a table. |
| `{A\|B\|C}` | Choose only one of the elements in the brackets separated by the pipes. |
| `[A]` | The element in brackets is optional. |
| `DEFAULT` | Default elements are underlined. |
| `...` | More elements can be added to the clause. |

### The basic syntax of the SELECT statement

```
SELECT select_list
[FROM table_source]
[WHERE search_condition]
[ORDER BY order_by_list]
[LIMIT row_limit]
```

### The five clauses of the basic SELECT statement

| Clause | Description |
|---|---|
| `SELECT` | Describes the columns in the result set. |
| `FROM` | Names the base table from which the query retrieves the data. |
| `WHERE` | Specifies the conditions for a row to be included in the result set. |
| `ORDER BY` | Specifies how to sort the rows in the result set. |
| `LIMIT` | Specifies the number of rows to return. |

### Description

- The SELECT statement retrieves the columns specified in the SELECT clause from the *base table* specified in the FROM clause and stores them in a result set.
- The WHERE clause is used to *filter* the rows in the base table so that only those rows that match the search condition are included in the result set. If you omit the WHERE clause, all of the rows in the base table are included.
- The search condition of a WHERE clause consists of one or more *Boolean expressions* that result in a true, false, or null value. If the combination of all the expressions is a true value, the row being tested is included in the result set. Otherwise, it's not.
- If you include the ORDER BY clause, the rows in the result set are sorted in the specified sequence. Otherwise, the sequence of the rows is not guaranteed by MySQL.
- If you include the LIMIT clause, the result set that's retrieved is limited to a specified number of rows. If you omit this clause, all rows that match are returned.
- You must code the clauses in the order shown or you'll get a syntax error.

### Note

- The syntax shown above does not include all of the clauses of the SELECT statement. You'll learn about the other clauses later in this book.

Figure 3-1 The basic syntax of the SELECT statement

## SELECT statement examples

Figure 3-2 presents five SELECT statement examples. All of these statements retrieve data from the Invoices table in the AP database that you experimented with in the last chapter. After each statement, you can see its result set as displayed by MySQL Workbench. In these examples, a horizontal or vertical scroll bar indicates that the result set contains more rows or columns than can be displayed at one time.

The first statement in this figure retrieves all of the rows and columns from the Invoices table. Here, an asterisk (*) indicates that all of the columns should be retrieved, and the WHERE and LIMIT clauses are omitted so all of the rows in the table are retrieved. In addition, this statement doesn't include an ORDER BY clause, so the rows are in primary key sequence.

The second statement retrieves selected columns from the Invoices table. These columns are listed in the SELECT clause. Like the first statement, this statement doesn't include a WHERE or a LIMIT clause, so all the rows are retrieved. Then, the ORDER BY clause causes the rows to be sorted by the invoice_total column in descending order, from largest to smallest.

The third statement also lists the columns to be retrieved. In this case, though, the last column is calculated from two columns in the base table, credit_total and payment_total, and the resulting column is given the name total_credits. In addition, the WHERE clause specifies that only the invoice whose invoice_id column has a value of 17 should be retrieved.

The fourth SELECT statement includes a WHERE clause whose condition specifies a range of values. In this case, only invoices with invoice dates between 06/01/2022 and 06/30/2022 are retrieved. In addition, the rows in the result set are sorted by invoice date.

The last statement in this figure shows another example of the WHERE clause. In this case, only those rows with invoice totals greater than 50,000 are retrieved. Since none of the rows in the Invoices table satisfy this condition, the result set is empty.

### Retrieve all rows and columns from the Invoices table

```
SELECT * FROM invoices
```

| invoice_id | vendor_id | invoice_number | invoice_date | invoice_total | payment_total | credit_total | terms_id | invoice_d |
|---|---|---|---|---|---|---|---|---|
| 1 | 122 | 989319-457 | 2022-04-08 | 3813.33 | 3813.33 | 0.00 | 3 | 2022-05-0 |
| 2 | 123 | 263253241 | 2022-04-10 | 40.20 | 40.20 | 0.00 | 3 | 2022-05-1 |
| 3 | 123 | 963253234 | 2022-04-13 | 138.75 | 138.75 | 0.00 | 3 | 2022-05-1 |
| 4 | 123 | 2-000-2993 | 2022-04-16 | 144.70 | 144.70 | 0.00 | 3 | 2022-05-1 |

(114 rows)

### Retrieve three columns and sort the rows by invoice total

```
SELECT invoice_number, invoice_date, invoice_total
FROM invoices
ORDER BY invoice_total DESC
```

| invoice_number | invoice_date | invoice_total |
|---|---|---|
| 0-2058 | 2022-05-28 | 37966.19 |
| P-0259 | 2022-07-19 | 26881.40 |
| 0-2060 | 2022-07-24 | 23517.58 |
| 40318 | 2022-06-01 | 21842.00 |
| P-0608 | 2022-07-23 | 20551.18 |

(114 rows)

### Retrieve two columns and a calculated value for one row

```
SELECT invoice_id, invoice_total,
       credit_total + payment_total AS total_credits
FROM invoices
WHERE invoice_id = 17
```

| invoice_id | invoice_total | total_credits |
|---|---|---|
| 17 | 10.00 | 10.00 |

### Retrieve three columns for rows between given dates

```
SELECT invoice_number, invoice_date, invoice_total
FROM invoices
WHERE invoice_date BETWEEN '2022-06-01' AND '2022-06-30'
ORDER BY invoice_date
```

| invoice_number | invoice_date | invoice_total |
|---|---|---|
| 989319-437 | 2022-06-01 | 2765.36 |
| 111-92R-10094 | 2022-06-01 | 19.67 |
| 40318 | 2022-06-01 | 21842.00 |
| 1-202-2978 | 2022-06-03 | 33.00 |
| 31359783 | 2022-06-03 | 1575.00 |

(37 rows)

### A SELECT statement that returns an empty result set

```
SELECT invoice_number, invoice_date, invoice_total
FROM invoices
WHERE invoice_total > 50000
```

| invoice_number | invoice_date | invoice_total |
|---|---|---|

Figure 3-2 SELECT statement examples

# How to code the SELECT clause

Now that you have a general idea of how the main clauses of a SELECT statement work, you're ready to learn the details for coding the first clause, the SELECT clause. You can use this clause to specify the columns for a result set.

## How to code column specifications

Figure 3-3 begins by presenting a more detailed syntax for the SELECT clause. Then, it continues by summarizing four techniques you can use to specify the columns for a result set. First, you can code an asterisk in the SELECT clause to retrieve all of the columns in the base table. When you use this technique, MySQL returns the columns in the order that they are defined in the base table.

Second, you can code a list of column names from the base table separated by commas. In this figure, for instance, the second example specifies three columns that are in the Vendors table.

Third, you can code an *expression* that uses arithmetic operators. The result of an expression is a single value. In this figure, for instance, the third example uses an expression to subtract the payment_total and credit_total columns from the invoice_total column and return the balance due.

Fourth, you can code an expression that uses functions. In this figure, for instance, the fourth example uses the CONCAT function to join a column named first_name, a space, and a column named last_name. Here, two single quotes are used to identify the literal value for the space.

When you code the SELECT clause, you should include only the columns you need. For example, you shouldn't code an asterisk to retrieve all the columns unless you need all the columns. That's because the amount of data that's retrieved can affect system performance. This is particularly important if you're developing SQL statements that will be used by application programs.

For now, don't worry if you don't completely understand all four techniques. In the next four figures, you'll learn more about how they work.

## The expanded syntax of the SELECT clause

```
SELECT [ALL|DISTINCT]
       column_specification [[AS] result_column]
    [, column_specification [[AS] result_column]]...
```

## Four ways to code column specifications

| Source | Option | Syntax |
|---|---|---|
| Base table value | All columns | * |
| | Column name | column_name |
| Calculated value | Result of a calculation | Arithmetic expressions (see figure 3-5) |
| | Result of a function | Functions (see figures 3-6 and 3-7) |

## Column specifications that use base table values

### Retrieve all columns

```
SELECT *
```

### Retrieve specific columns

```
SELECT vendor_name, vendor_city, vendor_state
```

## Column specifications that use calculated values

### An arithmetic expression that calculates the balance due

```
SELECT invoice_total - payment_total - credit_total AS balance_due
```

### A function that returns the full name

```
SELECT CONCAT(first_name, ' ', last_name) AS full_name
```

## Description

- Use SELECT * only when you need to retrieve all of the columns from a table. Otherwise, list the names of the columns you need.
- An *expression* is a combination of column names and operators that evaluate to a single value. In the SELECT clause, you can code expressions that include one or more arithmetic operators and expressions that include one or more functions.
- After each column specification, you can code an AS clause to specify the name for the column in the result set. See figure 3-4 for details.

## Note

- The ALL and DISTINCT keywords specify whether or not duplicate rows are returned. See figure 3-9 for details.

Figure 3-3 How to code column specifications

## How to name the columns in a result set using aliases

By default, MySQL gives a column in a result set the same name as the column in the base table. If the column is based on a calculated value, it's assigned a name based on the expression for the value. However, whenever you want, you can specify a different name known as a *column alias* as shown in figure 3-4.

To assign a column alias, you code the column specification followed by the AS keyword and the new name as shown by the first example in this figure. Here, the statement creates an alias of "Invoice Number" for the invoice_number column, "Date" for the invoice_date column, and "Total" for the invoice_total column. To include a space in the alias for the first column, this statement encloses that alias in double quotes ( " ).

The second example in this figure shows what happens when you don't assign an alias to a calculated column. In that case, MySQL automatically assigns the column an alias that's the same as the column's expression. Since the expressions for many calculated values are cumbersome, you typically assign a shorter alias for calculated values as shown throughout the rest of this chapter.

### A SELECT statement that renames the columns in the result set

```
SELECT invoice_number AS "Invoice Number", invoice_date AS Date,
       invoice_total AS Total
FROM invoices
```

| Invoice Number | Date | Total |
|---|---|---|
| 989319-457 | 2022-04-08 | 3813.33 |
| 263253241 | 2022-04-10 | 40.20 |
| 963253234 | 2022-04-13 | 138.75 |
| 2-000-2993 | 2022-04-16 | 144.70 |

```
(114 rows)
```

### A SELECT statement that doesn't name a calculated column

```
SELECT invoice_number, invoice_date, invoice_total,
       invoice_total - payment_total - credit_total
FROM invoices
```

| invoice_number | invoice_date | invoice_total | invoice_total - payment_total - credit_total |
|---|---|---|---|
| 989319-457 | 2022-04-08 | 3813.33 | 0.00 |
| 263253241 | 2022-04-10 | 40.20 | 0.00 |
| 963253234 | 2022-04-13 | 138.75 | 0.00 |
| 2-000-2993 | 2022-04-16 | 144.70 | 0.00 |

```
(114 rows)
```

### Description

- By default, a column in the result set is given the same name as the column in the base table. If that's not what you want, you can specify a substitute name, or *column alias*, for the column.
- To specify an alias for a column, use the AS phrase. Although the AS keyword is optional, I recommend you code it for readability.
- If you don't specify an alias for a column that's based on a calculated value, MySQL uses the expression for the calculated value as the column name.
- To include spaces or special characters in an alias, enclose the alias in double quotes ( " ) or single quotes ( ' ).

Figure 3-4 How to name the columns in a result set using aliases

## How to code arithmetic expressions

Figure 3-5 shows how to code *arithmetic expressions*. To start, it summarizes the *arithmetic operators* you can use in this type of expression. Then, it presents three examples that show how you use these operators.

The SELECT statement in the first example includes an arithmetic expression that calculates the balance due for an invoice. This expression subtracts the payment_total and credit_total columns from the invoice_total column. The resulting column is given an alias of balance_due.

When MySQL evaluates an arithmetic expression, it performs the operations from left to right based on the *order of precedence*. To start, MySQL performs multiplication, division, and modulo operations. Then, it performs addition and subtraction operations.

If that's not what you want, you can use parentheses to specify how an expression is evaluated. Then, MySQL evaluates the expressions in the innermost sets of parentheses first, followed by the expressions in outer sets of parentheses. Within each set of parentheses, MySQL evaluates the expression from left to right in the order of precedence.

If you want, you can also use parentheses to clarify an expression even if they're not needed for the expression to be evaluated properly. However, you should avoid cluttering your SQL statements with unnecessary parentheses.

To show how parentheses and the order of precedence affect the evaluation of an expression, consider the second example in this figure. Here, the expressions in the second and third columns both perform the same operations. These expressions use one column name (invoice_id) that returns a number and two *literal values* for numbers (7 and 3). When you code a literal value for a number, you don't need to enclose it in quotes.

When MySQL evaluates the expression in the second column, it performs the multiplication operation before the addition operation because multiplication comes before addition in the order of precedence. When MySQL evaluates the expression in the third column, though, it performs the addition operation first because it's enclosed in parentheses. Because of this, these two expressions return different values as shown in the result set.

Although you're probably familiar with the addition, subtraction, multiplication, and division operators, you may not be familiar with the MOD (%) or DIV operators. MOD returns the remainder of a division of two integers, and DIV returns the integer quotient of two numbers. These are shown in the third example in this figure. Here, the second column contains the quotient of the two numbers, which MySQL automatically converts from an integer value to a decimal value. Then, the third column uses the DIV operator to return the integer quotient of the same division operation. The fourth column uses the modulo operator to return the remainder of the division operation.

Before going on, you should notice that the second and third SELECT statements include an ORDER BY clause that sorts the result set in ascending sequence by the invoice_id column. Although you might think that this would be the default, that's not the case with MySQL. Instead, the rows in a result set are returned in the most efficient way. If you want the rows returned in a specific sequence, then, you need to include the ORDER BY clause.

### The arithmetic operators in order of precedence

| Operator | Name | Order of precedence |
|---|---|---|
| * | Multiplication | 1 |
| / | Division | 1 |
| DIV | Integer division | 1 |
| % (MOD) | Modulo (remainder) | 1 |
| + | Addition | 2 |
| - | Subtraction | 2 |

### A SELECT statement that calculates the balance due

```
SELECT invoice_total, payment_total, credit_total,
       invoice_total - payment_total - credit_total AS balance_due
FROM invoices
```

| invoice_total | payment_total | credit_total | balance_due |
|---|---|---|---|
| 3813.33 | 3813.33 | 0.00 | 0.00 |
| 40.20 | 40.20 | 0.00 | 0.00 |
| 138.75 | 138.75 | 0.00 | 0.00 |

### Use parentheses to control the sequence of operations

```
SELECT invoice_id,
       invoice_id + 7 * 3 AS multiply_first,
       (invoice_id + 7) * 3 AS add_first
FROM invoices
ORDER BY invoice_id
```

| invoice_id | multiply_first | add_first |
|---|---|---|
| 1 | 22 | 24 |
| 2 | 23 | 27 |
| 3 | 24 | 30 |

### Use the DIV and modulo operators

```
SELECT invoice_id,
       invoice_id / 3 AS decimal_quotient,
       invoice_id DIV 3 AS integer_quotient,
       invoice_id % 3 AS remainder
FROM invoices
ORDER BY invoice_id
```

| invoice_id | decimal_quotient | integer_quotient | remainder |
|---|---|---|---|
| 1 | 0.3333 | 0 | 1 |
| 2 | 0.6667 | 0 | 2 |
| 3 | 1.0000 | 1 | 0 |

### Description

- Unless parentheses are used, the operations in an expression take place from left to right in the *order of precedence*. For arithmetic expressions, MySQL performs multiplication, division, and modulo operations first. Then, it performs addition and subtraction operations.
- When necessary, you can use parentheses to override or clarify the sequence of operations.

Figure 3-5 How to code arithmetic expressions

## How to use the CONCAT function to join strings

Figure 3-6 presents the CONCAT function and shows you how to use it to join, or *concatenate*, strings. In MySQL, a *string* can contain any combination of characters, and a *function* performs an operation and returns a value. To code a function, you begin by entering its name followed by a set of parentheses. If the function requires an *argument*, or *parameter*, you enter it within the parentheses. If the function takes more than one argument, you separate them with commas.

In this figure, the first example shows how to use the CONCAT function to join the vendor_city and vendor_state columns in the Vendors table. Since this example doesn't assign an alias to this column, MySQL automatically assigns the expression formula as the column name. In addition, there isn't a space between the vendor_state and the vendor_city in the result set. Since this makes the data difficult to read, this string should be formatted as shown in the second or third example.

The second example shows how to format a string expression by adding spaces and punctuation. Here, the vendor_city column is concatenated with a literal value for a string that contains a comma and a space. Then, the vendor_state column is concatenated with that result, followed by a literal value for a string that contains a single space and the vendor_zip_code column.

To code a string literal, you can enclose the value in either single quotes ( ' ) or double quotes ( " ). Occasionally, you may need to include a single quote as an apostrophe within a literal value for a string. If you're using single quotes around the literal, however, MySQL will misinterpret the apostrophe as the end of the string. To solve this, you can code two single quotation marks in a row as shown by the third example. Or, you can use double quotes like this:

```
CONCAT(vendor_name, "'s Address: ") AS vendor
```

## The syntax of the CONCAT function

```
CONCAT(string1[, string2]...)
```

## How to concatenate string data

```
SELECT vendor_city, vendor_state, CONCAT(vendor_city, vendor_state)
FROM vendors
```

| vendor_city | vendor_state | CONCAT(vendor_city, vendor_state) |
|---|---|---|
| Madison | WI | MadisonWI |
| Washington | DC | WashingtonDC |

```
(122 rows)
```

## How to format string data using literal values

```
SELECT vendor_name,
       CONCAT(vendor_city, ', ', vendor_state, ' ', vendor_zip_code)
           AS address
FROM vendors
```

| vendor_name | address |
|---|---|
| US Postal Service | Madison, WI 53707 |
| National Information Data Ctr | Washington, DC 20120 |

```
(122 rows)
```

## How to include apostrophes in literal values

```
SELECT CONCAT(vendor_name, '''s Address: ') AS Vendor,
       CONCAT(vendor_city, ', ', vendor_state, ' ', vendor_zip_code)
           AS Address
FROM vendors
```

| Vendor | Address |
|---|---|
| US Postal Service's Address: | Madison, WI 53707 |
| National Information Data Ctr's Address: | Washington, DC 20120 |

```
(122 rows)
```

## Description

- An expression can include any of the *functions* that are supported by MySQL. A function performs an operation and returns a value.
- To code a function, code the function name followed by a set of parentheses. Within the parentheses, code any *parameters*, or *arguments*, required by the function. If a function requires two or more arguments, separate them with commas.
- To code a literal value for a string, enclose one or more characters within single quotes ( ' ) or double quotes ( " ).
- To include a single quote within a literal value for a string, code two single quotes. Or, use double quotes instead of single quotes to start and end the literal value.
- To join, or *concatenate*, two or more string columns or literal values, use the CONCAT function.

Figure 3-6 How to use the CONCAT function to join strings

## How to use functions with strings, dates, and numbers

Figure 3-7 shows how to work with three more functions. The LEFT function operates on strings, the DATE_FORMAT function operates on dates, and the ROUND function operates on numbers. For now, don't worry about the details of how the functions shown here work, because you'll learn more about all of these functions in chapter 9. Instead, just focus on how they're used in column specifications.

The first example in this figure shows how to use the LEFT function to extract the first character of the vendor_contact_first_name and vendor_contact_last_name columns. The first parameter of this function specifies the string value, and the second parameter specifies the number of characters to return. Then, this statement concatenates the results of the two LEFT functions to form initials as shown in the result set.

The second example shows how to use the DATE_FORMAT function to change the format used to display date values. This function requires two parameters. The first parameter is the date value to be formatted and the second is a format string that uses specific values as placeholders for the various parts of the date. The first column in this example returns the invoice_date column in the default MySQL date format, "yyyy-mm-dd". Since this format isn't used as often in the USA, the second column is formatted in the more typical "mm/dd/yy" format. In the third column, the invoice date is in another format that's commonly used. In chapter 9, you'll learn more about specifying the format string for the DATE_FORMAT function.

The third example uses the ROUND function to round the value of the invoice_total column to the nearest dollar and nearest dime. This function can accept either one or two parameters. The first parameter specifies the number to be rounded and the optional second parameter specifies the number of decimal places to keep. If the second parameter is omitted, the function rounds to the nearest integer.

## The syntax of the LEFT, DATE_FORMAT, and ROUND functions

```
LEFT(string, number_of_characters)
DATE_FORMAT(date, format_string)
ROUND(number[, number_of_decimal_places])
```

## A SELECT statement that uses the LEFT function

```
SELECT vendor_contact_first_name, vendor_contact_last_name,
       CONCAT(LEFT(vendor_contact_first_name, 1),
              LEFT(vendor_contact_last_name, 1)) AS initials
FROM vendors
```

| vendor_contact_first_name | vendor_contact_last_name | initials |
|---|---|---|
| Francesco | Alberto | FA |
| Ania | Irvin | AI |
| Lukas | Liana | LL |
| Kenzie | Quinn | KQ |
| Michelle | Marks | MM |

(122 rows)

## A SELECT statement that uses the DATE_FORMAT function

```
SELECT invoice_date,
       DATE_FORMAT(invoice_date, '%m/%d/%y') AS 'MM/DD/YY',
       DATE_FORMAT(invoice_date, '%e-%b-%Y') AS 'DD-Mon-YYYY'
FROM invoices
ORDER BY invoice_date
```

| invoice_date | MM/DD/YY | DD-Mon-YYYY |
|---|---|---|
| 2022-04-08 | 04/08/22 | 8-Apr-2022 |
| 2022-04-10 | 04/10/22 | 10-Apr-2022 |
| 2022-04-13 | 04/13/22 | 13-Apr-2022 |
| 2022-04-16 | 04/16/22 | 16-Apr-2022 |
| 2022-04-16 | 04/16/22 | 16-Apr-2022 |

(114 rows)

## A SELECT statement that uses the ROUND function

```
SELECT invoice_date, invoice_total,
       ROUND(invoice_total) AS nearest_dollar,
       ROUND(invoice_total, 1) AS nearest_dime
FROM invoices
ORDER BY invoice_date
```

| invoice_date | invoice_total | nearest_dollar | nearest_dime |
|---|---|---|---|
| 2022-04-08 | 3813.33 | 3813 | 3813.3 |
| 2022-04-10 | 40.20 | 40 | 40.2 |
| 2022-04-13 | 138.75 | 139 | 138.8 |
| 2022-04-16 | 144.70 | 145 | 144.7 |
| 2022-04-16 | 15.50 | 16 | 15.5 |

(114 rows)

## Description

- When using the DATE_FORMAT function to specify the format of a date, you use the percent sign (%) to identify a format code. For example, a format code of m returns the month number with a leading zero if necessary.

Figure 3-7 How to use functions with strings, dates, and numbers

## How to test expressions by coding statements without FROM clauses

When you use MySQL, you don't have to code FROM clauses in SELECT statements. This makes it easy for you to code SELECT statements that test expressions and functions like those that you've seen in this chapter. Instead of coding column specifications in the SELECT clause, you use literals or functions to supply the test values you need. And you code column aliases to display the results. Then, once you're sure that the code works as you intend it to, you can add the FROM clause and replace the literals or functions with the correct column specifications.

Figure 3-8 shows how to test expressions. Here, the first example tests an arithmetic expression using numeric literals that make it easy to verify the results. The remaining examples test the functions that you saw in figure 3-7. If you compare these statements, you'll see that the second and fourth examples simply replace the column specifications in figure 3-7 with literal values. The third example uses another function, CURRENT_DATE, to supply a date value in place of the invoice_date column that's coded in figure 3-7.

## Four SELECT statements without FROM clauses

### Example 1: Testing a calculation

```
SELECT 1000 * (1 + .1) AS "10% More Than 1000"
```

| 10% More Than 1000 |
|---|
| 1100.0 |

### Example 2: Testing the CONCAT function

```
SELECT "Ed" AS first_name, "Williams" AS last_name,
    CONCAT(LEFT("Ed", 1), LEFT("Williams", 1)) AS initials
```

| first_name | last_name | initials |
|---|---|---|
| Ed | Williams | EW |

### Example 3: Testing the DATE_FORMAT function

```
SELECT CURRENT_DATE,
       DATE_FORMAT(CURRENT_DATE, '%m/%d/%y') AS 'MM/DD/YY',
       DATE_FORMAT(CURRENT_DATE, '%e-%b-%Y') AS 'DD-Mon-YYYY'
```

| CURRENT_DATE | MM/DD/YY | DD-Mon-YYYY |
|---|---|---|
| 2023-06-28 | 06/28/23 | 28-Jun-2023 |

### Example 4: Testing the ROUND function

```
SELECT 12345.6789 AS value,
       ROUND(12345.6789) AS nearest_dollar,
       ROUND(12345.6789, 1) AS nearest_dime
```

| value | nearest_dollar | nearest_dime |
|---|---|---|
| 12345.6789 | 12346 | 12345.7 |

## Description

- With MySQL, you don't have to code a FROM clause. This makes it easy to test expressions that include arithmetic operators and functions.
- The CURRENT_DATE function returns the current date. The parentheses are optional for this function.

Figure 3-8 How to test expressions

## How to eliminate duplicate rows

By default, all of the rows in the base table that satisfy the search condition in the WHERE clause are included in the result set. In some cases, though, that means that the result set will contain duplicate rows, or rows whose column values are identical. If that's not what you want, you can include the DISTINCT keyword in the SELECT clause to eliminate the duplicate rows.

Figure 3-9 shows how this works. Here, both SELECT statements retrieve the vendor_city and vendor_state columns from the Vendors table. The first statement doesn't include the DISTINCT keyword. Because of that, the same city and state can appear in the result set more than once. In the results shown in this figure, for example, you can see that Anaheim CA occurs twice and Boston MA occurs three times. In contrast, the second statement includes the DISTINCT keyword, so each city and state combination is included only once.

## A SELECT statement that returns all rows

```
SELECT vendor_city, vendor_state
FROM vendors
ORDER BY vendor_city
```

| vendor_city | vendor_state |
|---|---|
| Anaheim | CA |
| Anaheim | CA |
| Ann Arbor | MI |
| Auburn Hills | MI |
| Boston | MA |
| Boston | MA |
| Boston | MA |

```
(122 rows)
```

## A SELECT statement that eliminates duplicate rows

```
SELECT DISTINCT vendor_city, vendor_state
FROM vendors
ORDER BY vendor_city
```

| vendor_city | vendor_state |
|---|---|
| Anaheim | CA |
| Ann Arbor | MI |
| Auburn Hills | MI |
| Boston | MA |
| Brea | CA |
| Carol Stream | IL |
| Charlotte | NC |

```
(53 rows)
```

## Description

- The DISTINCT keyword prevents duplicate (identical) rows from being included in the result set. DISTINCTROW is a synonym for DISTINCT.
- The ALL keyword causes all rows matching the search condition to be included in the result set, regardless of whether rows are duplicated. Since this is the default, you'll usually omit the ALL keyword.
- To use the DISTINCT or ALL keyword, code it immediately after the SELECT keyword as shown above.

Figure 3-9 How to eliminate duplicate rows

# How to code the WHERE clause

Earlier in this chapter, I mentioned that to improve performance, you should code your SELECT statements so they retrieve only the columns you need. That goes for retrieving rows too. The fewer rows you retrieve, the more efficient the statement will be. Because of that, you typically include a WHERE clause on your SELECT statements with a search condition that filters the rows in the base table so only the rows you need are retrieved. In the topics that follow, you'll learn a variety of ways to code this clause.

## How to use the comparison operators

Figure 3-10 shows how to use the *comparison operators* in the search condition of a WHERE clause to compare two expressions. If the result of the comparison is true, the row being tested is included in the query results.

The examples in this figure show how to use the comparison operators. The first WHERE clause, for example, uses the equal operator (=) to retrieve only those rows whose vendor_state column has a value of 'IA'. Here, the state code is a string literal so it must be enclosed in single or double quotes. In contrast, the second WHERE clause uses the greater than (>) operator to retrieve only those rows that have a balance greater than zero. In this case, zero (0) is a numeric literal so it isn't enclosed in quotes.

The third WHERE clause shows another way to retrieve all the invoices with a balance due by rearranging the comparison expression. Like the second clause, it uses the greater than operator. Instead of comparing the balance due to a value of zero, however, it compares the invoice total to the total of the payments and credits that have been applied to the invoice.

The fourth WHERE clause shows how you can use comparison operators other than equal with string data. In this example, the less than operator (<) is used to compare the value of the vendor_name column to a literal string that contains the letter M. That causes the query to return all vendors with names that begin with the letters A through L.

You can also use the comparison operators with date literals, as shown by the fifth and sixth WHERE clauses. The fifth clause retrieves rows with invoice dates on or before July 31, 2022, and the sixth clause retrieves rows with invoice dates on or after July 1, 2022. Like literal values for strings, literal values for dates must be enclosed in single or double quotes. Also, literal values for dates must use this format: YYYY-MM-DD. This is the default date format used by MySQL.

The last two WHERE clauses show how you can test for a not-equal condition. In both cases, only rows with a credit total that isn't equal to zero are retrieved.

Whenever possible, you should compare expressions that have similar data types. If you compare expressions that have different data types, MySQL implicitly converts the data type for you. Generally, this implicit conversion is acceptable. However, implicit conversions can occasionally yield unexpected results. To prevent this, you can explicitly convert the data type by using the CAST or CONVERT functions, which you'll learn about in chapter 8.

## The syntax of the WHERE clause with comparison operators

```
WHERE expression_1 operator expression_2
```

## The comparison operators

| | |
|---|---|
| = | Equal |
| < | Less than |
| > | Greater than |
| <= | Less than or equal to |
| >= | Greater than or equal to |
| <> | Not equal |
| != | Not equal |

## Examples of WHERE clauses that retrieve...

### Vendors located in Iowa

```
WHERE vendor_state = 'IA'
```

### Invoices with a balance due (two variations)

```
WHERE invoice_total - payment_total - credit_total > 0
WHERE invoice_total > payment_total + credit_total
```

### Vendors with names from A to L

```
WHERE vendor_name < 'M'
```

### Invoices on or before a specified date

```
WHERE invoice_date <= '2022-07-31'
```

### Invoices on or after a specified date

```
WHERE invoice_date >= '2022-07-01'
```

### Invoices with credits that don't equal zero (two variations)

```
WHERE credit_total <> 0
WHERE credit_total != 0
```

## Description

- You can use a *comparison operator* to compare any two expressions. Since MySQL automatically converts the data for comparison, the expressions may be of unlike data types. However, the comparison may sometimes produce unexpected results.
- If the result of a comparison is a true value, the row being tested is included in the result set. If it's a false or null value, the row isn't included.
- To use a string literal or a date literal in a comparison, enclose it in quotes. To use a numeric literal, enter the number without quotes.
- Character comparisons performed on MySQL databases are not case-sensitive. So, for example, 'CA' and 'ca' are considered equivalent.
- If you compare a null value using one of these comparison operators, the result is always a null value.

Figure 3-10 How to use the comparison operators

## How to use the AND, OR, and NOT logical operators

Figure 3-11 shows how to use *logical operators* in a WHERE clause. You can use the AND and OR operators to combine two or more search conditions into a *compound condition*. And you can use the NOT operator to negate a search condition. The examples in this figure show how these operators work.

The first two examples show the AND and OR operators. When you use the AND operator, both conditions must be true. So, in the first example, only those vendors in the state of New Jersey and the city of Springfield are retrieved from the Vendors table. When you use the OR operator, though, only one of the conditions must be true. So, in the second example, all the vendors in the state of New Jersey and all the vendors in the city of Pittsburg (no matter what state) are retrieved.

The third example shows how to use the NOT operator to negate a condition. Here, vendors that are not in the state of California are returned. The fourth example shows a compound condition that uses two NOT operators. This condition is difficult to read. To make it easier to read, you can rewrite this condition to remove the NOT operators as shown in the fifth example.

The last two examples in this figure show how the order of precedence for the logical operators and the use of parentheses affect the result of a search condition. By default, the NOT operator is evaluated first, followed by AND, and then by OR. However, you can use parentheses to override the order of precedence or to clarify a logical expression, just as you can with arithmetic expressions.

In the next to last example, for instance, no parentheses are used, so the two conditions connected by the AND operator are evaluated first. In the last example, though, parentheses are used so the two conditions connected by the OR operator are evaluated first. If you take a minute to review the results in this figure, you should quickly see how these two conditions differ.

## The syntax of the WHERE clause with logical operators

```
WHERE [NOT] search_condition_1 {AND|OR} [NOT] search_condition_2 ...
```

## Examples of WHERE clauses that use logical operators

### The AND operator

```
WHERE vendor_state = 'NJ' AND vendor_city = 'Springfield'
```

### The OR operator

```
WHERE vendor_state = 'NJ' OR vendor_city = 'Pittsburg'
```

### The NOT operator

```
WHERE NOT vendor_state = 'CA'
```

### The NOT operator in a complex search condition

```
WHERE NOT (invoice_total >= 5000 OR NOT invoice_date <= '2022-08-01')
```

### The same condition rephrased to eliminate the NOT operator

```
WHERE invoice_total < 5000 AND invoice_date <= '2022-08-01'
```

## A compound condition without parentheses

```
WHERE invoice_date > '2022-07-03' OR invoice_total > 500
  AND invoice_total - payment_total - credit_total > 0
```

| invoice_number | invoice_date | invoice_total | balance_due |
|---|---|---|---|
| 203339-13 | 2022-07-05 | 17.50 | 0.00 |
| 111-92R-10093 | 2022-07-06 | 39.77 | 0.00 |
| 963253258 | 2022-07-06 | 111.00 | 0.00 |
| 963253271 | 2022-07-07 | 158.00 | 0.00 |
| 963253230 | 2022-07-07 | 739.20 | 0.00 |

(33 rows)

## The same compound condition with parentheses

```
WHERE (invoice_date > '2022-07-03' OR invoice_total > 500)
  AND invoice_total - payment_total - credit_total > 0
```

| invoice_number | invoice_date | invoice_total | balance_due |
|---|---|---|---|
| 39104 | 2022-07-10 | 85.31 | 85.31 |
| 963253264 | 2022-07-18 | 52.25 | 52.25 |
| 31361833 | 2022-07-21 | 579.42 | 579.42 |
| 263253268 | 2022-07-21 | 59.97 | 59.97 |
| 263253270 | 2022-07-22 | 67.92 | 67.92 |

(11 rows)

## Description

- The AND and OR *logical operators* create *compound conditions* that consist of two or more conditions. The AND operator specifies that the search must satisfy both conditions. The OR operator specifies that the search must satisfy at least one condition.
- You can use the NOT operator to negate a condition. Because this can make the search condition unclear, you should rephrase the condition if possible so it doesn't use NOT.
- When MySQL evaluates a compound condition, it evaluates the operators in this order: (1) NOT, (2) AND, and (3) OR. You can use parentheses to override this order.

Figure 3-11 How to use the AND, OR, and NOT logical operators

## How to use the IN operator

Figure 3-12 shows how to code a WHERE clause that uses the IN operator. When you use this operator, the value of the test expression is compared with the list of expressions in the IN phrase. If the test expression is equal to one of the expressions in the list, the row is included in the query results. This is shown by the first example in this figure, which returns all rows whose terms_id column is equal to 1, 3, or 4.

You can also use the NOT operator with the IN phrase to test for a value that's not in a list of expressions. This is shown by the second example. Here, only those vendors that aren't in California, Nevada, or Oregon are retrieved.

At the top of this figure, the syntax of the IN phrase shows that you can code a *subquery* in place of a list of expressions. As you'll learn in chapter 7, subqueries are a powerful feature. For now, though, you should know that a subquery is simply a SELECT statement within another statement.

In the third example, for instance, a subquery is used to return a list of vendor_id values for vendors who have invoices dated July 18, 2022. Then, the WHERE clause retrieves a row only if the vendor_id is in that list. Note that for this to work, the subquery must return a single column, in this case, vendor_id.

## The syntax of the WHERE clause with an IN phrase

```
WHERE test_expression [NOT] IN
      ({subquery|expression_1 [, expression_2]...})
```

## Examples of the IN phrase

### An IN phrase with a list of numeric literals

```
WHERE terms_id IN (1, 3, 4)
```

### An IN phrase preceded by NOT

```
WHERE vendor_state NOT IN ('CA', 'NV', 'OR')
```

### An IN phrase with a subquery

```
WHERE vendor_id IN
    (SELECT vendor_id
     FROM invoices
     WHERE invoice_date = '2022-07-18')
```

## Description

- You can use the IN phrase to test whether an expression is equal to a value in a list of expressions. Each of the expressions in the list is automatically converted to the same type of data as the test expression.
- The list of expressions can be coded in any order without affecting the order of the rows in the result set.
- You can use the NOT operator to test for an expression that's not in the list of expressions.
- You can also compare the test expression to the items in a list returned by a *subquery*.

Figure 3-12 How to use the IN operator

## How to use the BETWEEN operator

Figure 3-13 shows how to use the BETWEEN operator in a WHERE clause. When you use this operator, the value of a test expression is compared to the range of values specified in the BETWEEN phrase. If the value falls within this range, the row is included in the query results.

The first example in this figure shows a simple WHERE clause that uses the BETWEEN operator. It retrieves invoices with invoice dates between June 1, 2022 and June 30, 2022. Note that the range is inclusive, so invoices with invoice dates of June 1 and June 30 are included in the results.

The second example shows how to use the NOT operator to select rows that aren't within a given range. In this case, vendors with zip codes that aren't between 93600 and 93799 are included in the results.

The third example shows how you can use a calculated value in the test expression. Here, the payment_total and credit_total columns are subtracted from the invoice_total column to give the balance due. Then, this value is compared to the range specified in the BETWEEN phrase.

The last example shows how you can use calculated values in the BETWEEN phrase. Here, the first value is the credit_total column and the second value is the credit_total column plus 500. So the results include all those invoices where the amount paid is between the credit amount and $500 more than the credit amount.

## The syntax of the WHERE clause with a BETWEEN phrase

```
WHERE test_expression [NOT] BETWEEN begin_expression AND end_expression
```

## Examples of the BETWEEN phrase

### A BETWEEN phrase with literal values

```
WHERE invoice_date BETWEEN '2022-06-01' AND '2022-06-30'
```

### A BETWEEN phrase preceded by NOT

```
WHERE vendor_zip_code NOT BETWEEN 93600 AND 93799
```

### A BETWEEN phrase with a test expression coded as a calculated value

```
WHERE invoice_total - payment_total - credit_total BETWEEN 200 AND 500
```

### A BETWEEN phrase with the upper limit coded as a calculated value

```
WHERE payment_total BETWEEN credit_total AND credit_total + 500
```

## Description

- You can use the BETWEEN phrase to test whether an expression falls within a range of values. The lower limit must be coded as the first expression, and the upper limit must be coded as the second expression. Otherwise, MySQL returns an empty result set.
- The two expressions used in the BETWEEN phrase for the range of values are inclusive. That is, the result set includes values that are equal to the upper or lower limit.
- You can use the NOT operator to test for an expression that's not within the given range.

Figure 3-13 How to use the BETWEEN operator

## How to use the LIKE and REGEXP operators

To retrieve rows that match a specific *string pattern*, or *mask*, you can use the LIKE or REGEXP operators as shown in figure 3-14. The LIKE operator is an older operator that lets you search for simple string patterns. When you use this operator, the mask can contain one or both of the *wildcard* symbols shown in the first table in this figure.

In contrast to the LIKE operator, the REGEXP operator allows you to create complex string patterns known as *regular expressions*. To do that, you can use the special characters and constructs shown in the second table in this figure. Although creating regular expressions can be tricky at first, they allow you to search for virtually any string pattern.

In the first example in this figure, the LIKE phrase specifies that all vendors in cities that start with the letters SAN should be included in the query results. Here, the percent sign (%) indicates that any character or characters can follow these three letters. So San Diego and Santa Ana are both included in the results.

The second example selects all vendors whose vendor name starts with the letters COMPU, followed by any one character, the letters ER, and any characters after that. The vendor names Compuserve and Computerworld both match that pattern.

In the third example, the REGEXP phrase searches for the letters SA within the vendor_city column. Since the letters can be in any position within the string, both Pasadena and Santa Ana are included in the results.

The next two examples demonstrate how to use REGEXP to match a pattern to the beginning or end of the string being tested. In the fourth example, the mask ^SA matches the letters SA at the beginning of vendor_city, as in Santa Ana and Sacramento. In contrast, the mask NA$ matches the letters NA at the end of vendor_city, as shown in the fifth example.

The sixth example uses the pipe ( | ) character to search for either of two string patterns: RS or SN. In this case, the first pattern would match Traverse City and the second would match Fresno, so both are included in the result set.

The last four examples use brackets to specify multiple values. In the seventh example, the vendor_state column is searched for values that contain the letter N followed by either C or V. That excludes NJ and NY. In contrast, the eighth example searches for states that contain the letter N followed by any letter from A to J. This excludes NV and NY.

The ninth example searches the values in the vendor_contact_last_name column for a name that can be spelled two different ways: Damien or Damion. To do that, the mask specifies the two possible characters in the fifth position, E and O, within brackets. In the final example, the REGEXP phrase searches for a vendor_city that ends with any letter, a vowel, and then the letter N.

Both the LIKE and REGEXP operators provide powerful functionality for finding information in a database. However, searches that use these operators sometimes run slowly since they can't use a table's indexes. As a result, you should only use these operators when necessary.

### The syntax of the WHERE clause with a LIKE phrase

```
WHERE match_expression [NOT] LIKE pattern
```

### The syntax of the WHERE clause with a REGEXP phrase

```
WHERE match_expression [NOT] REGEXP pattern
```

### LIKE wildcards

| Symbol | Description |
|---|---|
| `%` | Matches any string of zero or more characters. |
| `_` | Matches any single character. |

### REGEXP special characters and constructs

| Character/Construct | Description |
|---|---|
| `^` | Matches the pattern to the beginning of the value being tested. |
| `$` | Matches the pattern to the end of the value being tested. |
| `.` | Matches any single character. |
| `[charlist]` | Matches any single character listed within the brackets. |
| `[char1-char2]` | Matches any single character within the given range. |
| `\|` | Separates two string patterns and matches either one. |

### WHERE clauses that use the LIKE and REGEXP operators

| Example | Results that match the mask |
|---|---|
| `WHERE vendor_city LIKE 'SAN%'` | "San Diego", "Santa Ana" |
| `WHERE vendor_name LIKE 'COMPU_ER%'` | "Compuserve", "Computerworld" |
| `WHERE vendor_city REGEXP 'SA'` | "Pasadena", "Santa Ana" |
| `WHERE vendor_city REGEXP '^SA'` | "Santa Ana", "Sacramento" |
| `WHERE vendor_city REGEXP 'NA$'` | "Gardena", "Pasadena", "Santa Ana" |
| `WHERE vendor_city REGEXP 'RS\|SN'` | "Traverse City", "Fresno" |
| `WHERE vendor_state REGEXP 'N[CV]'` | "NC" and "NV" but not "NJ" or "NY" |
| `WHERE vendor_state REGEXP 'N[A-J]'` | "NC" and "NJ" but not "NV" or "NY" |
| `WHERE vendor_contact_last_name REGEXP 'DAMI[EO]N'` | "Damien" and "Damion" |
| `WHERE vendor_city REGEXP '[A-Z][AEIOU]N$'` | "Boston", "Mclean", "Oberlin" |

### Description

- You use the LIKE and REGEXP operators to retrieve rows that match a *string pattern*, called a *mask*. The mask determines which values in the column satisfy the condition.
- The mask for a LIKE phrase can contain special symbols, called *wildcards*. The mask for a REGEXP phrase can contain special characters and constructs. Masks aren't case-sensitive.
- If you use the NOT keyword, only those rows with values that don't match the string pattern are included in the result set.
- Most LIKE and REGEXP phrases significantly degrade performance compared to other types of searches, so use them only when necessary.

Figure 3-14 How to use the LIKE and REGEXP operators

For the sake of brevity, this chapter only presents the most common symbols that are used in regular expressions. However, MySQL supports most of the symbols that are standard for creating regular expressions. For more information about creating regular expressions, please consult the online MySQL Reference Manual. If you're familiar with using regular expressions in other programming languages such as PHP, you'll find that they work similarly in MySQL.

## How to use the IS NULL clause

In chapter 1, you learned that a column can contain a *null value*. A null value is typically used to indicate that a value is not known. A null value is not the same as an empty string ( '' ). An empty string is typically used to indicate that the value is known, and it doesn't exist.

If you're working with a database that allows null values, you need to know how to test for them in search conditions. To do that, you use the IS NULL clause as shown in figure 3-15.

This figure uses a table named Null_Sample from the EX database to show how to search for null values. This table contains two columns: invoice_id and invoice_total. The values in this table are displayed in the first example.

The second example shows what happens when you retrieve all the rows with invoice_total equal to zero. In this case, the row that has a null value isn't included in the result set. As the third example shows, this row isn't included in the result set when invoice_total isn't equal to zero either. Instead, you have to use the IS NULL clause to retrieve rows with null values, as shown by the fourth example.

You can also use the NOT operator with the IS NULL clause, as shown by the last example. When you use this operator, all of the rows that don't contain null values are included in the query results.

## The syntax of the WHERE clause with the IS NULL clause

```
WHERE expression IS [NOT] NULL
```

## The contents of the Null_Sample table

```
SELECT * FROM null_sample
```

| invoice_id | invoice_total |
|---|---|
| 1 | 125.00 |
| 2 | 0.00 |
| 3 | NULL |
| 4 | 2199.99 |
| 5 | 0.00 |

## A SELECT statement that retrieves rows with zero values

```
SELECT * FROM null_sample
WHERE invoice_total = 0
```

| invoice_id | invoice_total |
|---|---|
| 2 | 0.00 |
| 5 | 0.00 |

## A SELECT statement that retrieves rows with non-zero values

```
SELECT * FROM null_sample
WHERE invoice_total <> 0
```

| invoice_id | invoice_total |
|---|---|
| 1 | 125.00 |
| 4 | 2199.99 |

## A SELECT statement that retrieves rows with null values

```
SELECT * FROM null_sample
WHERE invoice_total IS NULL
```

| invoice_id | invoice_total |
|---|---|
| 3 | NULL |

## A SELECT statement that retrieves rows without null values

```
SELECT *
FROM null_sample
WHERE invoice_total IS NOT NULL
```

| invoice_id | invoice_total |
|---|---|
| 1 | 125.00 |
| 2 | 0.00 |
| 4 | 2199.99 |
| 5 | 0.00 |

## Description

- A *null value* represents a value that's unknown, unavailable, or not applicable. It isn't the same as a zero or an empty string ('').

Figure 3-15 How to use the IS NULL clause

# How to code the ORDER BY clause

The ORDER BY clause specifies the sort order for the rows in a result set. In most cases, you'll use column names from the base table to specify the sort order as you saw in some of the examples earlier in this chapter. However, you can also use other techniques to sort the rows in a result set, as described in the figures that follow.

## How to sort by a column name

Figure 3-16 presents the expanded syntax of the ORDER BY clause. This syntax shows that you can sort by one or more expressions in either ascending or descending sequence. The three examples in this figure show how to code this clause for expressions that involve column names.

The first two examples show how to sort the rows in a result set by a single column. In the first example, the rows in the Vendors table are sorted in ascending sequence by the vendor_name column. Since ascending is the default sequence, the ASC keyword can be omitted. In the second example, the rows are sorted by the vendor_name column in descending sequence.

To sort by more than one column, you simply list the names in the ORDER BY clause separated by commas as shown in the third example. This can be referred to as a *nested sort* because one sort is nested within another. Here, the rows in the Vendors table are first sorted by the vendor_state column in ascending sequence. Then, within each state, the rows are sorted by the vendor_city column in ascending sequence. Finally, within each city, the rows are sorted by the vendor_name column in ascending sequence.

### The expanded syntax of the ORDER BY clause

```
ORDER BY expression [ASC|DESC][, expression [ASC|DESC]]...
```

### An ORDER BY clause that sorts by one column in ascending sequence

```
SELECT vendor_name,
  CONCAT(vendor_city, ', ', vendor_state, ' ', vendor_zip_code) AS address
FROM vendors
ORDER BY vendor_name
```

| vendor_name | address |
|---|---|
| Abbey Office Furnishings | Fresno, CA 93722 |
| American Booksellers Assoc | Tarrytown, NY 10591 |
| American Express | Los Angeles, CA 90096 |
| ASC Signs | Fresno, CA 93703 |

### An ORDER BY clause that sorts by one column in descending sequence

```
SELECT vendor_name,
  CONCAT(vendor_city, ', ', vendor_state, ' ', vendor_zip_code) AS address
FROM vendors
ORDER BY vendor_name DESC
```

| vendor_name | address |
|---|---|
| Zylka Design | Fresno, CA 93711 |
| Zip Print & Copy Center | Fresno, CA 93777 |
| Zee Medical Service Co | Washington, IA 52353 |
| Yesmed, Inc | Fresno, CA 93718 |

### An ORDER BY clause that sorts by three columns

```
SELECT vendor_name,
  CONCAT(vendor_city, ', ', vendor_state, ' ', vendor_zip_code) AS address
FROM vendors
ORDER BY vendor_state, vendor_city, vendor_name
```

| vendor_name | address |
|---|---|
| AT&T | Phoenix, AZ 85062 |
| Computer Library | Phoenix, AZ 85023 |
| Wells Fargo Bank | Phoenix, AZ 85038 |
| Aztek Label | Anaheim, CA 92807 |

### Description

- The ORDER BY clause specifies how you want the rows in the result set sorted. You can sort by one or more columns, and you can sort each column in either ascending (ASC) or descending (DESC) sequence. ASC is the default.
- By default, in an ascending sort, special characters appear first in the sort sequence, followed by numbers, then letters. This sort order is determined by the character set used by the server, which you can change when you start the server.
- Null values appear first in the sort sequence, even if you're using DESC.
- You can sort by any column in the base table regardless of whether it's included in the SELECT clause.

Figure 3-16 How to sort by a column name

## How to sort by an alias, expression, or column number

Figure 3-17 presents three more techniques that you can use to specify sort columns. First, you can use a column alias that's defined in the SELECT clause. The first SELECT statement in this figure, for example, sorts by a column named Address, which is an alias for the concatenation of the vendor_city, vendor_state, and vendor_zip_code columns. Notice that within the Address column, the result set is also sorted by the vendor_name column.

You can also use an arithmetic or string expression in the ORDER BY clause, as shown by the second example in this figure. Here, the expression consists of the vendor_contact_last_name column concatenated with the vendor_contact_first_name column. Notice that neither of these columns is included in the SELECT clause. Although MySQL allows this coding technique, many other SQL dialects don't.

The last example in this figure shows how you can use column numbers to specify a sort order. To use this technique, you code the number that corresponds to the column of the result set, where 1 is the first column, 2 is the second column, and so on. In this example, the ORDER BY clause sorts the result set by the second column, which contains the concatenated address, then by the first column, which contains the vendor name. As a result, this statement returns the same result set that's returned by the first statement.

However, the statement that uses column numbers is more difficult to read because you have to look at the SELECT clause to see what columns the numbers refer to. In addition, if you add or remove columns from the SELECT clause, you may also have to change the ORDER BY clause to reflect the new column positions. As a result, you should avoid using this technique in most situations.

### An ORDER BY clause that uses an alias

```
SELECT vendor_name,
  CONCAT(vendor_city, ', ', vendor_state, ' ', vendor_zip_code) AS address
FROM vendors
ORDER BY address, vendor_name
```

| vendor_name | address |
|---|---|
| Aztek Label | Anaheim, CA 92807 |
| Blue Shield of California | Anaheim, CA 92850 |
| Malloy Lithographing Inc | Ann Arbor, MI 48106 |
| Data Reproductions Corp | Auburn Hills, MI 48326 |

### An ORDER BY clause that uses an expression

```
SELECT vendor_name,
  CONCAT(vendor_city, ', ', vendor_state, ' ', vendor_zip_code) AS address
FROM vendors
ORDER BY CONCAT(vendor_contact_last_name, vendor_contact_first_name)
```

| vendor_name | address |
|---|---|
| Dristas Groom & McCormick | Fresno, CA 93720 |
| Internal Revenue Service | Fresno, CA 93888 |
| US Postal Service | Madison, WI 53707 |
| Yale Industrial Trucks-Fresno | Fresno, CA 93706 |

### An ORDER BY clause that uses column positions

```
SELECT vendor_name,
  CONCAT(vendor_city, ', ', vendor_state, ' ', vendor_zip_code) AS address
FROM vendors
ORDER BY 2, 1
```

| vendor_name | address |
|---|---|
| Aztek Label | Anaheim, CA 92807 |
| Blue Shield of California | Anaheim, CA 92850 |
| Malloy Lithographing Inc | Ann Arbor, MI 48106 |
| Data Reproductions Corp | Auburn Hills, MI 48326 |

### Description

- The ORDER BY clause can include a column alias that's specified in the SELECT clause if the column alias does not include spaces.
- The ORDER BY clause can include any valid expression. The expression can refer to any column in the base table, even if it isn't included in the result set.
- The ORDER BY clause can use numbers to specify the columns to use for sorting. In that case, 1 represents the first column in the result set, 2 represents the second column, and so on.

Figure 3-17 How to sort by an alias, expression, or column number

# How to code the LIMIT clause

The LIMIT clause specifies the maximum number of rows that are returned in the result set. For most queries, you want to see the entire result set so you won't use this clause. However, there may be times when you want to retrieve just a subset of a larger result set.

Figure 3-18 presents the expanded syntax of the LIMIT clause. This clause can take one or two arguments as shown by the three examples in this figure.

## How to limit the number of rows

In its simplest form, you code the LIMIT clause with a single numeric argument. Then, the number of rows in the result set is, at most, the number you specify. But if the result set is smaller than the number you specify, the LIMIT clause has no effect.

In the first example, the SELECT statement includes the LIMIT 5 clause, so the entire result set is five rows. Without the LIMIT clause, this statement would return 114 rows. Because the result set is sorted by invoice_total in descending sequence, this result set represents the five largest invoices.

## How to return a range of rows

If you code the optional offset argument of the LIMIT clause, it represents an *offset*, or starting point for the result set. This offset starts from a value of 0, which refers to the first row in the result set. In the second example, then, the offset is 2 so the result set starts with the third invoice. Then, since the row count is 3, the result set contains just 3 rows.

Similarly, the third example has an offset of 100, so the result set starts with row 101. Note that the row count for the LIMIT clause in this example is 1000. Since the table contains only 114 rows, though, the result set contains just the last 14 rows in the table.

## The expanded syntax of the LIMIT clause

```
LIMIT [offset,] row_count
```

## A SELECT statement with a LIMIT clause that starts with the first row

```
SELECT vendor_id, invoice_total
FROM invoices
ORDER BY invoice_total DESC
LIMIT 5
```

| vendor_id | invoice_total |
|---|---|
| 110 | 37966.19 |
| 110 | 26881.40 |
| 110 | 23517.58 |
| 72 | 21842.00 |
| 110 | 20551.18 |

## A SELECT statement with a LIMIT clause that starts with the third row

```
SELECT invoice_id, vendor_id, invoice_total
FROM invoices
ORDER BY invoice_id
LIMIT 2, 3
```

| invoice_id | vendor_id | invoice_total |
|---|---|---|
| 3 | 123 | 138.75 |
| 4 | 123 | 144.70 |
| 5 | 123 | 15.50 |

## A SELECT statement with a LIMIT clause that starts with the 101st row

```
SELECT invoice_id, vendor_id, invoice_total
FROM invoices
ORDER BY invoice_id
LIMIT 100, 1000
```

| invoice_id | vendor_id | invoice_total |
|---|---|---|
| 101 | 123 | 30.75 |
| 102 | 110 | 20551.18 |
| 103 | 122 | 2051.59 |
| 104 | 123 | 44.44 |

```
(14 rows)
```

## Description

- You can use the LIMIT clause to limit the number of rows returned by the SELECT statement. This clause takes one or two integer arguments.
- If you code a single argument, it specifies the maximum row count, beginning with the first row. If you code both arguments, the *offset* specifies the first row to return, where the offset of the first row is 0.
- If you want to retrieve all of the rows from a certain offset to the end of the result set, code -1 for the row count.
- Typically, you'll use an ORDER BY clause whenever you use the LIMIT clause.

Figure 3-18 How to code the LIMIT clause

# Perspective

The goal of this chapter has been to teach you the basic skills for coding SELECT statements. As a result, you'll use these skills in almost every SELECT statement you code.

As you'll see in the next chapter and in chapters 6 and 7, though, there's a lot more to coding SELECT statements than what's presented here. In these chapters, then, you'll learn additional skills for coding SELECT statements. When you complete these chapters, you'll know everything you need to know about retrieving data from a MySQL database.

## Terms

keyword
base table
search condition
filter
Boolean expression
expression
column alias
arithmetic expression
arithmetic operator
order of precedence
literal value
string
function
argument
parameter
concatenate
comparison operator
logical operator
compound condition
subquery
string pattern
mask
wildcard
regular expression
null value
nested sort
offset

## Exercises

### Run some of the examples in this chapter

In these exercises, you'll use MySQL Workbench to run some of the scripts for the examples in this chapter. This assumes that you already know how to use MySQL Workbench, as described in chapter 2.

1. Start MySQL Workbench.
2. Open the script named 3-02.sql that you should find in this directory: murach/mysql/book_scripts/ch03. When it opens, you should see all of the queries for figure 3-2. Note that each of these queries has a semicolon at the end of it.
3. Move the insertion point into the first query and press Ctrl+Enter or click on the Execute Current Statement button to run the query. This shows you the data that's in the Invoices table that you'll be working with in this chapter.
4. Move the insertion point into the second query and run it.

5. Open the script named 3-05.sql in the ch03 directory. Then, run the second query. When you do, you'll see that the result set is in sequence by the invoice_id column.
6. Delete the ORDER BY clause from the SELECT statement and run the query again. Scroll through the result set to see that the rows are no longer in a particular sequence. When you're done, close the script without saving the changes.
7. Open and run the queries for any of the other examples in this chapter that you're interested in reviewing.

## Enter and run your own SELECT statements

In these exercises, you'll enter and run your own SELECT statements. To do that, you can open the script for an example that is similar to the statement you need to write, copy the statement into a new SQL tab, and modify the statement. That can save you both time and syntax errors.

8. Write a SELECT statement that returns three columns from the Vendors table: vendor_name, vendor_contact_last_name, and vendor_contact_first_name. Then, run this statement to make sure it works correctly.

   Add an ORDER BY clause to this statement that sorts the result set by last name and then first name, both in ascending sequence. Then, run this statement again to make sure it works correctly. This is a good way to build and test a statement, one clause at a time.
9. Write a SELECT statement that returns one column from the Vendors table named full_name that joins the vendor_contact_last_name and vendor_contact_first_name columns.

   Format this column with the last name, a comma, a space, and the first name like this:

   ```
   Doe, John
   ```

   Sort the result set by last name and then first name in ascending sequence.

   Return only the contacts whose last name begins with the letter A, B, C, or E. This should retrieve 41 rows.
10. Write a SELECT statement that returns these column names and data from the Invoices table:

| | |
|---|---|
| Due Date | The invoice_due_date column |
| Invoice Total | The invoice_total column |
| 10% | 10% of the value of invoice_total |
| Plus 10% | The value of invoice_total plus 10% |

   Return only the rows with an invoice total that's greater than or equal to 500 and less than or equal to 1000. This should retrieve 12 rows.

   Sort the result set in descending sequence by invoice_due_date.

11. Write a SELECT statement that returns these columns from the Invoices table:

| | |
|---|---|
| invoice_number | The invoice_number column |
| invoice_total | The invoice_total column |
| payment_credit_total | Sum of the payment_total and credit_total columns |
| balance_due | The invoice_total column minus the payment_total and credit_total columns |

Return only invoices that have a balance due that's greater than $50.

Sort the result set by balance due in descending sequence.

Use the LIMIT clause so the result set contains only the rows with the 5 largest balances.

**Work with nulls and test expressions**

12. Write a SELECT statement that returns these columns from the Invoices table:

| | |
|---|---|
| invoice_number | The invoice_number column |
| invoice_date | The invoice_date column |
| balance_due | The invoice_total column minus the payment_total and credit_total columns |
| payment_date | The payment_date column |

Return only the rows where the payment_date column contains a null value. This should retrieve 11 rows.

13. Write a SELECT statement without a FROM clause that uses the CURRENT_DATE function to return the current date in its default format.

Use the DATE_FORMAT function to format the current date in this format:

```
mm-dd-yyyy
```

This displays the month, day, and four-digit year of the current date.

Give this column an alias of current_date. To do that, you must enclose the alias in quotes since that name is already used by the CURRENT_DATE function.

14. Write a SELECT statement without a FROM clause that creates a row with these columns:

| | |
|---|---|
| starting_principal | Starting principal of $50,000 |
| interest | 6.5% of the principal |
| principal_plus_interest | The principal plus the interest |

To calculate the third column, add the expressions you used for the first two columns.

# 4

# How to retrieve data from two or more tables

In the last chapter, you learned how to create result sets that contain data from a single table. Now, this chapter shows you how to create result sets that contain data from two or more tables. To do that, you can use an inner join, an outer join, or a union.

# How to work with inner joins

A *join* lets you combine columns from two or more tables into a single result set. To start, this chapter shows how to code the most common type of join, an *inner join*.

## How to code an inner join

Figure 4-1 shows how to use the *explicit syntax* to code an inner join. This syntax is also called the *SQL-92 syntax* because it was introduced by the SQL-92 standards. It's generally considered a best practice to use this syntax.

To join data from two tables, you code the names of the two tables in the FROM clause along with the JOIN keyword and an ON phrase that specifies the *join condition*. The join condition indicates how the two tables should be compared. In most cases, they're compared based on the relationship between the primary key of the first table and a foreign key of the second table.

In this figure, for example, the SELECT statement joins data from the Vendors and Invoices tables based on the vendor_id column in each table. Since the join condition uses the equal operator, the value of the vendor_id column in a row in the Vendors table must match the vendor_id in a row in the Invoices table for that row to be included in the result set. In other words, only vendors with one or more invoices are included.

Although you code most inner joins using the equal operator, you can compare two tables based on other conditions too. For example, you can use the greater than or less than operators for an inner join condition.

In this figure, the Vendors table is joined with the Invoices table using a column that has the same name in both tables: vendor_id. As a result, the columns must be qualified so MySQL can tell which table they come from. To code a *qualified column name*, you can enter the table name and a period in front of the column name.

In this figure, the SELECT statement only uses qualified column names in the join condition. However, you must qualify a column name anywhere it appears in the statement if the same name occurs in both tables. If you don't, MySQL returns an error indicating that the column name is ambiguous.

## The explicit syntax for an inner join

```
SELECT select_list
FROM table_1
    [INNER] JOIN table_2
        ON join_condition_1
   [[INNER] JOIN table_3
        ON join_condition_2]...
```

## An inner join of the Vendors and Invoices tables

```
SELECT invoice_number, vendor_name
FROM vendors INNER JOIN invoices
    ON vendors.vendor_id = invoices.vendor_id
ORDER BY invoice_number
```

| invoice_number | vendor_name |
|---|---|
| 0-2058 | Malloy Lithographing Inc |
| 0-2060 | Malloy Lithographing Inc |
| 0-2436 | Malloy Lithographing Inc |
| 1-200-5164 | Federal Express Corporation |
| 1-202-2978 | Federal Express Corporation |
| 10843 | Yesmed, Inc |

(114 rows)

## Description

- A *join* combines columns from two or more tables into a result set based on the *join conditions* you specify. For an *inner join*, only those rows that satisfy the join condition are included in the result set.
- A join condition names a column in each of the two tables involved in the join and indicates how the two columns should be compared. In most cases, you use the equal operator to retrieve rows with matching columns. However, you can also use any of the other comparison operators in a join condition.
- Tables are typically joined on the relationship between the primary key in one table and a foreign key in the other table. However, you can also join tables based on relationships not defined in the database. These are called *ad hoc relationships*.
- If the two columns in a join condition have the same name, you must qualify them with the table name so MySQL can distinguish between them. To code a *qualified column name*, type the table name, followed by a period, followed by the column name.

## Note

- The INNER keyword is optional and is seldom used.

Figure 4-1 How to code an inner join

## How to use table aliases

When you name a table to be joined in the FROM clause, you can refer to the table by an alias as shown in figure 4-2. A *table alias* is an alternative table name that's typically just a letter or two. This makes it easier to qualify the column names in the rest of the statement, and it makes the query easier to code and read, especially when the table names are long.

The first example in this figure joins data from the Vendors and Invoices tables. Here, both tables have been assigned aliases that consist of a single letter.

The second example only assigns an alias to the second table, not the first. Here, the alias shortens the name of the Invoice_Line_Items table to just Line_Items. As a result, the shorter name can be used to refer to the invoice_id column of the table in the join condition. Although you can use this technique when you code a query, most programmers use abbreviations of the table names as shown in the first example and throughout the rest of this chapter.

After you assign a table alias, you must use the alias in place of the original table name throughout the query. Otherwise, MySQL returns an error message instead of a result set.

### The syntax for an inner join that uses table aliases

```
SELECT select_list
FROM table_1 a1
    [INNER] JOIN table_2 a2
        ON a1.column_name operator a2.column_name
   [[INNER] JOIN table_3 a3
        ON a2.column_name operator a3.column_name]...
```

### Aliases for all tables

```
SELECT invoice_number, vendor_name, invoice_due_date,
    invoice_total - payment_total - credit_total AS balance_due
FROM vendors v JOIN invoices i
    ON v.vendor_id = i.vendor_id
WHERE invoice_total - payment_total - credit_total > 0
ORDER BY invoice_due_date DESC
```

| invoice_number | vendor_name | invoice_due_date | balance_due |
|---|---|---|---|
| 547480102 | Blue Cross | 2022-08-31 | 224.00 |
| 0-2436 | Malloy Lithographing Inc | 2022-08-30 | 10976.06 |
| 9982771 | Ford Motor Credit Company | 2022-08-23 | 503.20 |
| P-0608 | Malloy Lithographing Inc | 2022-08-22 | 19351.18 |
| 263253270 | Federal Express Corporation | 2022-08-21 | 67.92 |

(11 rows)

### An alias for only one table

```
SELECT invoice_number, line_item_amount, line_item_description
FROM invoices JOIN invoice_line_items line_items
    ON invoices.invoice_id = line_items.invoice_id
WHERE account_number = 540
ORDER BY invoice_date
```

| invoice_number | line_item_amount | line_item_description |
|---|---|---|
| 177271-001 | 478.00 | Publishers Marketing |
| 972110 | 207.78 | Prospect list |
| 133560 | 175.00 | Card deck advertising |
| 97/522 | 765.13 | Catalog design |
| 587056 | 2184.50 | PC card deck |

(6 rows)

### Description

- A *table alias* is an alternative table name assigned in the FROM clause. You can use an alias, which is typically just a letter or two, to make a SQL statement easier to code and read.
- If you assign an alias to a table, you must use that alias to refer to the table throughout your query. You can't use the original table name.
- You can use an alias for one table in a join without using an alias for another table.

Figure 4-2 How to use table aliases

## How to join to a table in another database

If you used the procedure described in appendix A (Windows) or appendix B (macOS) of this book to create the databases for this book, all of the tables are organized into three databases, which are also known as *schemas*. First, all tables pertaining to accounts payable such as the Vendors and Invoices tables are stored in the database, or schema, named AP. Then, all tables pertaining to order management are stored in a database named OM. Finally, all tables that are used by the smaller examples presented in this book are stored in a database named EX.

When you use MySQL Workbench to run a query against a database, you don't need to qualify a table name with its database name. For example, when you run a query against the AP database, you don't need to qualify the Vendors table with the name of the database.

However, you may occasionally need to join to a table that's in another database. To do that, you must qualify the table name in the other database by prefixing the table name with the database name. For example, let's say you need to join the Vendors table in the AP database with the Customers table in the OM database. To do that, you need to qualify the Customers table with the name of the OM database as shown in figure 4-3.

## The syntax of a table name that's qualified with a database name

```
database_name.table_name
```

## Join to a table in another database

```
SELECT vendor_name, customer_last_name, customer_first_name,
    vendor_state AS state, vendor_city AS city
FROM vendors v
    JOIN om.customers c
    ON v.vendor_zip_code = c.customer_zip
ORDER BY state, city
```

| vendor_name | customer_last_name | customer_first_name | state | city |
|---|---|---|---|---|
| Wells Fargo Bank | Marissa | Kyle | AZ | Phoenix |
| Aztek Label | Irvin | Ania | CA | Anaheim |
| Zylka Design | Holbrooke | Rashad | CA | Fresno |
| Lou Gentile's Flower Basket | Damien | Deborah | CA | Fresno |
| Costco | Neftaly | Thalia | CA | Fresno |
| Costco | Holbrooke | Rashad | CA | Fresno |
| Shields Design | Damien | Deborah | CA | Fresno |
| Wakefield Co | Holbrooke | Rashad | CA | Fresno |
| Wakefield Co | Neftaly | Thalia | CA | Fresno |
| Gary McKeighan Insurance | Neftaly | Thalia | CA | Fresno |
| Gary McKeighan Insurance | Holbrooke | Rashad | CA | Fresno |
| Digital Dreamworks | Neftaly | Thalia | CA | Fresno |

(37 rows)

## Description

- A MySQL server can store tables in multiple databases. These databases are sometimes referred to as *schemas*.
- When you run a SELECT statement against one database, you can join to a table in another database if you have appropriate privileges. To do that, you must prefix the table name in the other database with the name of that database.

## How to use compound join conditions

Although a join condition typically consists of a single comparison, you can include two or more comparisons in a join condition using the AND and OR operators. Figure 4-4 shows how this works.

The query in this figure uses the AND operator to return the first and last names of all customers in the Customers table whose first and last names also exist in the Employees table. Since Thomas Hardy is the only name that exists in both tables, this is the only row that's returned in the result set for this query.

### The Customers table

| customer_id | customer_last_name | customer_first_name | customer_address | customer_city | customer_state |
|---|---|---|---|---|---|
| 1 | Anders | Maria | 345 Winchell Pl | Anderson | IN |
| 2 | Trujillo | Ana | 1298 E Smathers St | Benton | AR |
| 3 | Moreno | Antonio | 6925 N Parkland Ave | Puyallup | WA |
| 4 | Hardy | Thomas | 83 d'Urberville Ln | Casterbridge | GA |
| 5 | Berglund | Christina | 22717 E 73rd Ave | Dubuque | IA |
| 6 | Moos | Hanna | 1778 N Bovine Ave | Peoria | IL |
| 7 | Citeaux | Fred | 1234 Main St | Normal | IL |

(24 rows)

### The Employees table

| employee_id | last_name | first_name | department_number | manager_id |
|---|---|---|---|---|
| 1 | Smith | Cindy | 2 | NULL |
| 2 | Jones | Elmer | 4 | 1 |
| 3 | Simonian | Ralph | 2 | 2 |
| 4 | Hernandez | Olivia | 1 | 9 |
| 5 | Aaronsen | Robert | 2 | 4 |
| 6 | Watson | Denise | 6 | 8 |
| 7 | Hardy | Thomas | 5 | 2 |

(9 rows)

### An inner join with two conditions

```
SELECT customer_first_name, customer_last_name
FROM customers c JOIN employees e
    ON c.customer_first_name = e.first_name
   AND c.customer_last_name = e.last_name
```

| customer_first_name | customer_last_name |
|---|---|
| Thomas | Hardy |

(1 row)

### Description

- A join condition can include two or more conditions connected by AND or OR operators.

## How to use a self-join

A *self-join* joins a table to itself. Although self-joins are rare, they are sometimes useful for retrieving data that can't be retrieved any other way. For example, figure 4-5 presents a self-join that returns rows from the Vendors table where the vendor is in a city and state that has at least one other vendor. In other words, it does not return a vendor if that vendor is the only vendor in that city and state.

Since this example uses the same table twice, it must use aliases to distinguish one occurrence of the table from the other. In addition, this query must qualify each column name with a table alias since every column occurs in both tables.

Then, the join condition uses three comparisons. The first two match the vendor_city and vendor_state columns in the two tables. As a result, the query returns rows for vendors that are in the same city and state as another vendor. However, since a vendor resides in the same city and state as itself, a third comparison is included to exclude rows that match a vendor with itself. To do that, this condition uses the not-equal operator to compare the vendor_name columns in the two tables.

In addition, this statement includes the DISTINCT keyword. That way, a vendor appears only once in the result set. Otherwise, a vendor would appear once for every other row with a matching city and state. For example, if a vendor is in a city and state that has nine other vendors in that city and state, this query would return nine rows for that vendor.

This example also shows how you can use columns other than key columns in a join condition. Keep in mind, however, that this is an unusual situation and you're not likely to code joins like this often.

### A self-join that returns vendors from cities in common with other vendors

```
SELECT DISTINCT v1.vendor_name, v1.vendor_city,
    v1.vendor_state
FROM vendors v1 JOIN vendors v2
    ON v1.vendor_city = v2.vendor_city AND
       v1.vendor_state = v2.vendor_state AND
       v1.vendor_name <> v2.vendor_name
ORDER BY v1.vendor_state, v1.vendor_city
```

| vendor_name | vendor_city | vendor_state |
|---|---|---|
| Computer Library | Phoenix | AZ |
| AT&T | Phoenix | AZ |
| Wells Fargo Bank | Phoenix | AZ |
| Aztek Label | Anaheim | CA |
| Blue Shield of California | Anaheim | CA |
| Abbey Office Furnishings | Fresno | CA |
| California Business Machines | Fresno | CA |
| Postmaster | Fresno | CA |

(84 rows)

## Description

- A *self-join* is a join that joins a table with itself.
- When you code a self-join, you must use aliases for the tables, and you must qualify each column name with the alias.

Figure 4-5 How to use a self-join

## How to join more than two tables

So far, this chapter has only showed how to join data from two tables. However, it's common for programmers to need to join data from more than two tables. For example, it's not unheard of to need to join 10 or more tables. Fortunately, once you code the join condition correctly, you can often reuse it.

The SELECT statement in figure 4-6 joins data from four tables: Vendors, Invoices, Invoice_Line_Items, and General_Ledger_Accounts. Each of the joins is based on the relationship between the primary key of one table and a foreign key of the other table. For example, the account_number column is the primary key of the General_Ledger_Accounts table and a foreign key of the Invoice_Line_Items table.

This SELECT statement also shows how table aliases make a statement easier to code and read. Here, the one-letter and two-letter aliases that are used for the tables allow you to code the ON clauses more concisely.

## A statement that joins four tables

```
SELECT vendor_name, invoice_number, invoice_date,
    line_item_amount, account_description
FROM vendors v
    JOIN invoices i
        ON v.vendor_id = i.vendor_id
    JOIN invoice_line_items li
        ON i.invoice_id = li.invoice_id
    JOIN general_ledger_accounts gl
        ON li.account_number = gl.account_number
WHERE invoice_total - payment_total - credit_total > 0
ORDER BY vendor_name, line_item_amount DESC
```

| vendor_name | invoice_number | invoice_date | line_item_amount | account_description |
|---|---|---|---|---|
| Blue Cross | 547480102 | 2022-08-01 | 224.00 | Group Insurance |
| Cardinal Business Media, Inc. | 134116 | 2022-07-28 | 90.36 | Direct Mail Advertising |
| Data Reproductions Corp | 39104 | 2022-07-10 | 85.31 | Book Printing Costs |
| Federal Express Corporation | 263253270 | 2022-07-22 | 67.92 | Freight |
| Federal Express Corporation | 263253268 | 2022-07-21 | 59.97 | Freight |
| Federal Express Corporation | 963253264 | 2022-07-18 | 52.25 | Freight |
| Federal Express Corporation | 263253273 | 2022-07-22 | 30.75 | Freight |
| Ford Motor Credit Company | 9982771 | 2022-07-24 | 503.20 | Travel and Accomodations |
| Ingram | 31361833 | 2022-07-21 | 579.42 | Books, Dues, and Subscriptions |

(11 rows)

## Description

- You can think of a multi-table join as a series of two-table joins proceeding from left to right.

## How to use the implicit inner join syntax

Although it's generally considered a best practice to use the explicit inner join syntax described earlier in this chapter, MySQL also provides the *implicit inner join syntax* shown in figure 4-7. This syntax was widely used prior to the introduction of the explicit syntax. You should be familiar with the older implicit syntax mainly because you may need to maintain existing SQL statements that use it.

When you use the implicit syntax for an inner join, you code the tables in the FROM clause separated by commas. Then, you code the join conditions in the WHERE clause.

The first SELECT statement joins data from the Vendors and Invoices tables. Like the SELECT statement shown in figure 4-1, this statement joins these tables on an equal comparison between the vendor_id columns in the two tables. In this case, though, the comparison is coded as the search condition of the WHERE clause. However, both of these statements return the same result set.

The second SELECT statement uses the implicit syntax to join data from four tables. This is the same join you saw in figure 4-6. In this example, the three join conditions are combined in the WHERE clause using the AND operator. In addition, an AND operator is used to combine the join conditions with the search condition.

Because the explicit syntax for joins lets you separate join conditions from search conditions, statements that use the explicit syntax are typically easier to read than those that use the implicit syntax. In addition, the explicit syntax helps you avoid a common coding mistake with the implicit syntax: omitting the join condition. As you'll learn later in this chapter, an implicit join without a join condition results in a cross join, which can return a large number of rows. For these reasons, we recommend that you use the explicit syntax in all your new SQL code.

## The implicit syntax for an inner join

```
SELECT select_list
FROM table_1, table_2 [, table_3]...
WHERE table_1.column_name operator table_2.column_name
    [AND table_2.column_name operator table_3.column_name]...
```

## Join the Vendors and Invoices tables

```
SELECT invoice_number, vendor_name
FROM vendors v, invoices i
WHERE v.vendor_id = i.vendor_id
ORDER BY invoice_number
```

| invoice_number | vendor_name |
|---|---|
| 0-2058 | Malloy Lithographing Inc |
| 0-2060 | Malloy Lithographing Inc |
| 0-2436 | Malloy Lithographing Inc |
| 1-200-5164 | Federal Express Corporation |
| 1-202-2978 | Federal Express Corporation |

```
(114 rows)
```

## Join four tables

```
SELECT vendor_name, invoice_number, invoice_date,
    line_item_amount, account_description
FROM  vendors v, invoices i, invoice_line_items li,
    general_ledger_accounts gl
WHERE v.vendor_id = i.vendor_id
  AND i.invoice_id = li.invoice_id
  AND li.account_number = gl.account_number
  AND invoice_total - payment_total - credit_total > 0
ORDER BY vendor_name, line_item_amount DESC
```

| vendor_name | invoice_number | invoice_date | line_item_amount | account_description |
|---|---|---|---|---|
| Blue Cross | 547480102 | 2022-08-01 | 224.00 | Group Insurance |
| Cardinal Business Media, Inc. | 134116 | 2022-07-28 | 90.36 | Direct Mail Advertising |
| Data Reproductions Corp | 39104 | 2022-07-10 | 85.31 | Book Printing Costs |
| Federal Express Corporation | 263253270 | 2022-07-22 | 67.92 | Freight |
| Federal Express Corporation | 263253268 | 2022-07-21 | 59.97 | Freight |
| Federal Express Corporation | 963253264 | 2022-07-18 | 52.25 | Freight |
| Federal Express Corporation | 263253273 | 2022-07-22 | 30.75 | Freight |
| Ford Motor Credit Company | 9982771 | 2022-07-24 | 503.20 | Travel and Accomodations |

```
(11 rows)
```

## Description

- Instead of coding a join condition in the FROM clause, you can code it in the WHERE clause along with any search conditions. In that case, you list the tables in the FROM clause separated by commas.
- This syntax for coding joins is referred to as the *implicit syntax*. It was used prior to the SQL-92 standards, which introduced the explicit syntax.

Figure 4-7 How to use the implicit inner join syntax

# How to work with outer joins

Although inner joins are the most common type of join, MySQL also supports *outer joins*. Unlike an inner join, an outer join returns all of the rows from one of the tables involved in the join, regardless of whether the join condition is true.

## How to code an outer join

Figure 4-8 presents the explicit syntax for coding an outer join. Because this syntax is similar to the explicit syntax for inner joins, you shouldn't have any trouble understanding how it works. The main difference is that you include the LEFT or RIGHT keyword to specify the type of outer join you want to perform. You can also include the OUTER keyword, but it's optional and is usually omitted.

When you use a *left outer join*, the result set includes all the rows from the first, or left, table. Similarly, when you use a *right outer join*, the result set includes all the rows from the second, or right, table.

The example in this figure illustrates a left outer join. Here, the Vendors table is joined with the Invoices table. In addition, the result set includes vendor rows even if no matching invoices are found. In that case, null values are returned for the columns in the Invoices table.

## The explicit syntax for an outer join

```
SELECT select_list
FROM table_1
    {LEFT|RIGHT} [OUTER] JOIN table_2
        ON join_condition_1
   [{LEFT|RIGHT} [OUTER] JOIN table_3
        ON join_condition_2]...
```

## What outer joins do

| Joins of this type | Retrieve unmatched rows from |
|---|---|
| Left outer join | The first (left) table |
| Right outer join | The second (right) table |

## A left outer join

```
SELECT vendor_name, invoice_number, invoice_total
FROM vendors LEFT JOIN invoices
    ON vendors.vendor_id = invoices.vendor_id
ORDER BY vendor_name
```

| vendor_name | invoice_number | invoice_total |
|---|---|---|
| Abbey Office Furnishings | 203339-13 | 17.50 |
| American Booksellers Assoc | NULL | NULL |
| American Express | NULL | NULL |
| ASC Signs | NULL | NULL |
| Ascom Hasler Mailing Systems | NULL | NULL |

(202 rows)

## Description

- An *outer join* retrieves all rows that satisfy the join condition, plus unmatched rows in the left or right table.
- In most cases, you use the equal operator to retrieve rows with matching columns. However, you can also use any of the other comparison operators.
- When a row with unmatched columns is retrieved, any columns from the other table that are included in the result set are given null values.

## Note

- The OUTER keyword is optional and typically omitted.

## Outer join examples

To give you a better understanding of how outer joins work, figure 4-9 shows four more examples. To start, part 1 of this figure shows the Departments table, the Employees table, and the Projects table from the EX database. These tables are used by the examples shown in parts 2 and 3 of this figure. In addition, they're used in other examples later in this chapter.

The first example performs a left outer join on the Departments and Employees tables. Here, the join condition joins the tables based on the values in their department_number columns. Then, the result set produced by this statement shows that department number 3 (Operations) is included in the result set even though none of the employees in the Employees table work in that department. As a result, MySQL assigns a null value to the last_name column from that table.

The second example uses a right outer join to join the Departments and Employees table. In this case, all of the rows from the Employees table are included in the result set. However, two of the employees, Locario and Watson, are assigned to a department that doesn't exist in the Departments table. If the department_number column in the Employees table had been defined as a foreign key to the Departments table, this would not have been allowed by MySQL. In this case, though, a foreign key wasn't defined, so null values are returned for the department_name column in these two rows.

When coding outer joins, it's a common practice to avoid using right joins. To do that, you can substitute a left outer join for a right outer join by reversing the order of the tables in the FROM clause and using the LEFT keyword instead of RIGHT. This often makes it easier to read statements that join more than two tables.

The third example shows that you can use outer joins to work with more than two tables. To do that, you use skills similar to those that you use to work with inner joins with more than two tables. In this example, the statement uses left outer joins to join all three tables: Departments, Employees, and Projects. Because of this, the result set uses a null value to show that none of the employees are assigned to the Operations department. In addition, the result set uses null values to show that two employees, Hardy and Jones, aren't assigned to a project.

The fourth example shows that you can combine inner joins and outer joins in the same query. Here, the query works like the third example, but it uses an inner join for the first join instead of a left outer join. Because of this, the result set doesn't include a row for the Operations department. However, it still displays the rows for the two employees, Hardy and Jones, who aren't assigned to a project.

## The Departments table

| department_number | department_name |
|---|---|
| 1 | Accounting |
| 2 | Payroll |
| 3 | Operations |
| 4 | Personnel |
| 5 | Maintenance |

## The Employees table

| employee_id | last_name | first_name | department_number | manager_id |
|---|---|---|---|---|
| 1 | Smith | Cindy | 2 | NULL |
| 2 | Jones | Elmer | 4 | 1 |
| 3 | Simonian | Ralph | 2 | 2 |
| 4 | Hernandez | Olivia | 1 | 9 |
| 5 | Aaronsen | Robert | 2 | 4 |
| 6 | Watson | Denise | 6 | 8 |
| 7 | Hardy | Thomas | 5 | 2 |
| 8 | O'Leary | Rhea | 4 | 9 |
| 9 | Locario | Paulo | 6 | 1 |

## The Projects table

| project_number | employee_id |
|---|---|
| P1011 | 8 |
| P1011 | 4 |
| P1012 | 3 |
| P1012 | 1 |
| P1012 | 5 |
| P1013 | 6 |
| P1013 | 9 |
| P1014 | 10 |

## Description

- The examples in this figure use the Departments, Employees, and Projects tables from the EX database.

Figure 4-9 Outer join examples (part 1 of 3)

## A left outer join

```
SELECT department_name, d.department_number, last_name
FROM departments d
    LEFT JOIN employees e
    ON d.department_number = e.department_number
ORDER BY department_name
```

| department_name | department_number | last_name |
|---|---|---|
| Accounting | 1 | Hernandez |
| Maintenance | 5 | Hardy |
| Operations | 3 | NULL |
| Payroll | 2 | Smith |
| Payroll | 2 | Simonian |
| Payroll | 2 | Aaronsen |
| Personnel | 4 | Jones |
| Personnel | 4 | O'Leary |

(8 rows)

## A right outer join

```
SELECT department_name, e.department_number, last_name
FROM departments d
    RIGHT JOIN employees e
    ON d.department_number = e.department_number
ORDER BY department_name
```

| department_name | department_number | last_name |
|---|---|---|
| NULL | 6 | Watson |
| NULL | 6 | Locario |
| Accounting | 1 | Hernandez |
| Maintenance | 5 | Hardy |
| Payroll | 2 | Smith |
| Payroll | 2 | Simonian |
| Payroll | 2 | Aaronsen |
| Personnel | 4 | Jones |
| Personnel | 4 | O'Leary |

(9 rows)

## Description

- A left outer join returns unmatched rows from the first (left) table.
- A right outer join returns unmatched rows from the second (right) table.

Figure 4-9 Outer join examples (part 2 of 3)

### Join three tables using left outer joins

```
SELECT department_name, last_name, project_number
FROM departments d
    LEFT JOIN employees e
        ON d.department_number = e.department_number
    LEFT JOIN projects p
        ON e.employee_id = p.employee_id
ORDER BY department_name, last_name
```

| department_name | last_name | project_number |
|---|---|---|
| Accounting | Hernandez | P1011 |
| Maintenance | Hardy | NULL |
| Operations | NULL | NULL |
| Payroll | Aaronsen | P1012 |
| Payroll | Simonian | P1012 |
| Payroll | Smith | P1012 |
| Personnel | Jones | NULL |
| Personnel | O'Leary | P1011 |

(8 rows)

### Combine an outer and an inner join

```
SELECT department_name, last_name, project_number
FROM departments d
    JOIN employees e
        ON d.department_number = e.department_number
    LEFT JOIN projects p
        ON e.employee_id = p.employee_id
ORDER BY department_name, last_name
```

| department_name | last_name | project_number |
|---|---|---|
| Accounting | Hernandez | P1011 |
| Maintenance | Hardy | NULL |
| Payroll | Aaronsen | P1012 |
| Payroll | Simonian | P1012 |
| Payroll | Smith | P1012 |
| Personnel | Jones | NULL |
| Personnel | O'Leary | P1011 |

(7 rows)

### Description

- You can use outer joins to join multiple tables.
- You can combine inner and outer joins within a single SELECT statement.

Figure 4-9 Outer join examples (part 3 of 3)

# Other skills for working with joins

Now that you know how to work with inner and outer joins, you're ready to learn how to join tables with the USING and NATURAL keywords. In addition, you're ready to learn about another type of join, called a cross join.

## How to join tables with the USING keyword

When you use the equal operator to join two tables on a common column, the join can be referred to as an *equijoin* (or an *equi-join*). When you code an equijoin, it's common for the columns that are being compared to have the same name. For joins like these, you can simplify the query with the USING keyword. To do that, you code a USING clause instead of an ON clause to specify the join as shown in figure 4-10.

The first example in this figure shows how to join the Vendors and Invoices tables on the vendor_id column with a USING clause. This returns the same results as the query shown in figure 4-1 that uses the ON clause. However, the USING clause only works because the vendor_id column exists in both the Vendors and Invoices tables.

The second example shows how to join the Departments, Employees, and Projects tables with the USING keyword. Here, the first USING clause uses an inner join to join the Departments table to the Employees table on the department_number column. Then, the second USING clause uses a left join to join the Employees table to the Projects table on the employee_id column. This shows that you can use a USING clause for both inner and outer joins, and this query returns the same result as the last query shown in figure 4-9.

In some cases, such as when a table has a composite primary key, you may want to join tables by multiple columns. To do that with a USING clause, you can code multiple column names within the parentheses, separating the column names with commas. This yields the same result as coding two equijoins connected with the AND operator.

Since the USING clause is more concise than the ON clause, it can make your code easier to read and maintain. As a result, it often makes sense to use the USING clause when you're developing new statements. However, if you can't get the USING clause to work correctly because of the way your database is structured, you can always use the ON clause instead.

## The syntax for a join that uses the USING keyword

```
SELECT select_list
FROM table_1
    [{LEFT|RIGHT} [OUTER]] JOIN table_2
        USING (join_column_1[, join_column_2]...)
   [[{LEFT|RIGHT} [OUTER]] JOIN table_3
        USING (join_column_1[, join_column_2]...)]...
```

## Use the USING keyword to join two tables

```
SELECT invoice_number, vendor_name
FROM vendors
    JOIN invoices USING (vendor_id)
ORDER BY invoice_number
```

| invoice_number | vendor_name |
|---|---|
| 0-2058 | Malloy Lithographing Inc |
| 0-2060 | Malloy Lithographing Inc |
| 0-2436 | Malloy Lithographing Inc |
| 1-200-5164 | Federal Express Corporation |
| 1-202-2978 | Federal Express Corporation |
| 10843 | Yesmed, Inc |

(114 rows)

## Use the USING keyword to join three tables

```
SELECT department_name, last_name, project_number
FROM departments
    JOIN employees USING (department_number)
    LEFT JOIN projects USING (employee_id)
ORDER BY department_name
```

| department_name | last_name | project_number |
|---|---|---|
| Accounting | Hernandez | P1011 |
| Maintenance | Hardy | NULL |
| Payroll | Simonian | P1012 |
| Payroll | Smith | P1012 |
| Payroll | Aaronsen | P1012 |
| Personnel | O'Leary | P1011 |
| Personnel | Jones | NULL |

(7 rows)

## Description

- You can use the USING keyword to simplify the syntax for joining tables.
- The join can be an inner join or an outer join.
- The tables must be joined by a column that has the same name in both tables.
- To include multiple columns, separate them with commas.
- The join must be an *equijoin*, which means that the equal operator is used to compare the two columns.

Figure 4-10 How to join tables with the USING keyword

## How to join tables with the NATURAL keyword

Figure 4-11 shows how to use the NATURAL keyword to code a *natural join*. When you code a natural join, you don't specify the column that's used to join the two tables. Instead, the database automatically joins the two tables based on all columns in the two tables that have the same name. As a result, this type of join only works correctly if the database is designed in a certain way.

For instance, if you use a natural join to join the Vendors and Invoices tables as shown in the first example, the join works correctly because these tables only have one column in common: the vendor_id column. As a result, the database joins these two tables on the vendor_id column. However, if these tables had another column in common, this query would attempt to join these tables on both columns and might yield unexpected results.

In addition, you may get unexpected results if you use natural joins for complex queries. In that case, you can use the USING or ON clause to explicitly specify the join since these clauses give you more control over the join. If necessary, you can mix a natural join with the USING or ON clause within a single SELECT statement. In this figure, for example, the second SELECT statement uses a natural join for the first join and a USING clause for the second join. The result is the same as the result for the second statement in figure 4-10.

Finally, since natural joins don't explicitly specify the join column, they may not work correctly if the structure of the database changes later. So although natural joins are easy to code, you'll usually want to avoid using them for production code.

## The syntax for a join that uses the NATURAL keyword

```
SELECT select_list
FROM table_1
     NATURAL JOIN table_2
    [NATURAL JOIN table_3]...
```

## Use the NATURAL keyword to join tables

```
SELECT invoice_number, vendor_name
FROM vendors
    NATURAL JOIN invoices
ORDER BY invoice_number
```

| invoice_number | vendor_name |
|---|---|
| 0-2058 | Malloy Lithographing Inc |
| 0-2060 | Malloy Lithographing Inc |
| 0-2436 | Malloy Lithographing Inc |
| 1-200-5164 | Federal Express Corporation |
| 1-202-2978 | Federal Express Corporation |
| 10843 | Yesmed, Inc |

(114 rows)

## Use the NATURAL keyword in a statement that joins three tables

```
SELECT department_name AS dept_name, last_name, project_number
FROM departments
    NATURAL JOIN employees
    LEFT JOIN projects USING (employee_id)
ORDER BY department_name
```

| dept_name | last_name | project_number |
|---|---|---|
| Accounting | Hernandez | P1011 |
| Maintenance | Hardy | NULL |
| Payroll | Simonian | P1012 |
| Payroll | Smith | P1012 |
| Payroll | Aaronsen | P1012 |
| Personnel | O'Leary | P1011 |
| Personnel | Jones | NULL |

(7 rows)

## Description

- You can use the NATURAL keyword to create a *natural join* that joins two tables based on all columns in the two tables that have the same name.
- Although the code for a natural join is shorter than the code for joins that use the ON or USING clause, a natural join only works correctly for certain types of database structures. In addition, a natural join often yields unexpected results for complex queries. As a result, it's more common to use the ON or USING clause to join tables.

Figure 4-11 How to join tables with the NATURAL keyword

## How to use cross joins

A *cross join* produces a result set that includes each row from the first table joined with each row from the second table. The result set is known as the *Cartesian product* of the tables. Figure 4-12 shows how to code a cross join using either the explicit or implicit syntax.

To use the explicit syntax, you include the CROSS JOIN keywords between the two tables in the FROM clause. Because of the way a cross join works, you don't code an ON clause that includes a join condition. The same is true when you use the implicit syntax. In that case, you simply list the tables in the FROM clause and omit the join condition from the WHERE clause.

The two SELECT statements in this figure illustrate how cross joins work. Both of these statements combine data from the Departments and Employees tables. For both statements, the result is a table that includes 45 rows. That's each of the five rows in the Departments table combined with each of the nine rows in the Employees table. Although this result set is relatively small, you can imagine how large it would be if the tables included hundreds or thousands of rows.

As you study these examples, you should realize that cross joins have few practical uses in a relational database. As a result, you'll rarely, if ever, need to use one. In fact, you're most likely to code a cross join by accident if you use the implicit join syntax and forget to code the join condition in the WHERE clause. That's one of the reasons why it's generally considered a good practice to use the explicit join syntax.

## How to code a cross join using the explicit syntax

### The explicit syntax for a cross join

```
SELECT select_list
FROM table_1 CROSS JOIN table_2
```

### A cross join that uses the explicit syntax

```
SELECT departments.department_number, department_name, employee_id,
    last_name
FROM departments CROSS JOIN employees
ORDER BY departments.department_number
```

| department_number | department_name | employee_id | last_name |
|---|---|---|---|
| 1 | Accounting | 2 | Jones |
| 1 | Accounting | 7 | Hardy |
| 1 | Accounting | 4 | Hernandez |
| 1 | Accounting | 1 | Smith |
| 1 | Accounting | 9 | Locario |

(45 rows)

## How to code a cross join using the implicit syntax

### The implicit syntax for a cross join

```
SELECT select_list
FROM table_1, table_2
```

### A cross join that uses the implicit syntax

```
SELECT departments.department_number, department_name, employee_id,
    last_name
FROM departments, employees
ORDER BY departments.department_number
```

| department_number | department_name | employee_id | last_name |
|---|---|---|---|
| 1 | Accounting | 2 | Jones |
| 1 | Accounting | 7 | Hardy |
| 1 | Accounting | 4 | Hernandez |
| 1 | Accounting | 1 | Smith |
| 1 | Accounting | 9 | Locario |

(45 rows)

## Description

- A *cross join* joins each row from the first table with each row from the second table. The result set returned by a cross join is known as a *Cartesian product*.

Figure 4-12 How to use cross joins

# How to work with unions

Like a join, a *union* combines data from two or more tables. Instead of combining columns from base tables, however, a union combines rows from two or more result sets.

## How to code a union

Figure 4-13 shows how to code a union. To start, you use the UNION keyword to connect two or more SELECT statements. For this to work, the result of each SELECT statement must have the same number of columns, and the data types of the corresponding columns in each table must be compatible.

In this figure, I have indented all of the SELECT statements that are connected by the UNION operator to make it easier to see how this statement works. However, in a production environment, it's common to see the SELECT statements and the UNION operator coded at the same level of indentation.

If you want to sort the result of a union operation, you can code an ORDER BY clause after the last SELECT statement. In an ORDER BY clause, you must use the column names that are specified in the first SELECT statement. That's because the column names in the first SELECT statement are the ones that are used in the final result set.

By default, a union operation removes duplicate rows from the result set. If that's not what you want, you can include the ALL keyword. In most cases, though, you'll omit this keyword.

## A union that combines result sets from different tables

The example in figure 4-13 shows how to use a union to combine data from two different tables. In this case, the Active_Invoices table contains invoices with outstanding balances, and the Paid_Invoices table contains invoices that have been paid in full. Both of these tables have the same structure as the Invoices table that's been used in this book so far.

This union operation combines the rows in both tables that have an invoice date on or after June 1, 2022. Here, the first SELECT statement includes a column named source that contains a literal value of "Active." Then, the second SELECT statement includes a column by the same name, but it contains a literal value of "Paid." This column is used to indicate which table each row in the result set came from.

Although this column is assigned the same name in both SELECT statements, you don't have to use the same name for corresponding columns. That's because the corresponding relationships are determined by the order in which the columns are coded in the SELECT clauses, not by their names. When you use column aliases, though, you'll typically assign the same name to corresponding columns so the statement is easier to understand.

## The syntax for a union operation

```
    SELECT_statement_1
UNION [ALL]
    SELECT_statement_2
[UNION [ALL]
    SELECT_statement_3]...
[ORDER BY order_by_list]
```

## A union that combines result sets from two different tables

```
    SELECT 'Active' AS source, invoice_number, invoice_date, invoice_total
    FROM active_invoices
    WHERE invoice_date >= '2022-06-01'
UNION
    SELECT 'Paid' AS source, invoice_number, invoice_date, invoice_total
    FROM paid_invoices
    WHERE invoice_date >= '2022-06-01'
ORDER BY invoice_total DESC
```

| source | invoice_number | invoice_date | invoice_total |
|---|---|---|---|
| Paid | 0-2058 | 2022-05-08 | 37966.19 |
| Paid | P-0259 | 2022-04-16 | 26881.40 |
| Paid | 0-2060 | 2022-05-08 | 23517.58 |
| Active | 40318 | 2022-07-18 | 21842.00 |
| Active | P-0608 | 2022-04-11 | 20551.18 |
| Active | 0-2436 | 2022-05-07 | 10976.06 |
| Paid | P02-3772 | 2022-06-03 | 7125.34 |
| Paid | 509786 | 2022-05-31 | 6940.25 |
| Paid | 10843 | 2022-06-04 | 4901.26 |

(22 rows)

## Description

- A *union* combines the result sets of two or more SELECT statements into one result set.
- Each result set must return the same number of columns, and the corresponding columns in each result set must have compatible data types.
- By default, a union eliminates duplicate rows. If you want to include duplicate rows, code the ALL keyword.
- The column names in the final result set are taken from the first SELECT clause. Column aliases assigned by the other SELECT clauses have no effect on the final result set.
- To sort the rows in the final result set, code an ORDER BY clause after the last SELECT statement. This clause must refer to the column names assigned in the first SELECT clause.

Figure 4-13 How to combine result sets from different tables

## A union that combines result sets from the same tables

The first example in figure 4-14 shows how to use unions to combine result sets created from a single table. In this example, rows from the Invoices table that have a balance due are combined with rows from the same table that are paid in full. As in the previous figure, a column named source is added at the beginning of each result set. That way, the final result set indicates whether each invoice is active or paid.

The second example shows how to use unions to combine result sets created from the same two tables after they have been joined. Here, each SELECT statement joins data from the Invoices and Vendors tables. The first SELECT statement retrieves invoices with totals greater than $10,000. Then, it calculates a payment of 33% of the invoice total. The two other SELECT statements are similar. The second one retrieves invoices with totals between $500 and $10,000 and calculates a 50% payment. And the third one retrieves invoices with totals less than $500 and sets the payment amount at 100% of the total. Although this isn't the most practical example, it helps illustrate the flexibility of union operations.

In both of these examples, the same column aliases are assigned in each SELECT statement. Although the aliases in the second and third SELECT statements are optional, they make the query easier to read. In particular, they make it easy to see that the three SELECT statements have the same number and types of columns.

## A union that combines result sets from a single table

```
    SELECT 'Active' AS source, invoice_number, invoice_date, invoice_total
    FROM invoices
    WHERE invoice_total - payment_total - credit_total > 0
UNION
    SELECT 'Paid' AS source, invoice_number, invoice_date, invoice_total
    FROM invoices
    WHERE invoice_total - payment_total - credit_total <= 0
ORDER BY invoice_total DESC
```

| source | invoice_number | invoice_date | invoice_total |
|---|---|---|---|
| Paid | 0-2058 | 2022-05-28 | 37966.19 |
| Paid | P-0259 | 2022-07-19 | 26881.40 |
| Paid | 0-2060 | 2022-07-24 | 23517.58 |
| Paid | 40318 | 2022-06-01 | 21842.00 |
| Active | P-0608 | 2022-07-23 | 20551.18 |
| Active | 0-2436 | 2022-07-31 | 10976.06 |
| Paid | P02-3772 | 2022-05-21 | 7125.34 |
| Paid | 509786 | 2022-06-18 | 6940.25 |

(114 rows)

## A union that combines result sets from the same two tables

```
    SELECT invoice_number, vendor_name, '33% Payment' AS payment_type,
        invoice_total AS total, invoice_total * 0.333 AS payment
    FROM invoices JOIN vendors
        ON invoices.vendor_id = vendors.vendor_id
    WHERE invoice_total > 10000
UNION
    SELECT invoice_number, vendor_name, '50% Payment' AS payment_type,
        invoice_total AS total, invoice_total * 0.5 AS payment
    FROM invoices JOIN vendors
        ON invoices.vendor_id = vendors.vendor_id
    WHERE invoice_total BETWEEN 500 AND 10000
UNION
    SELECT invoice_number, vendor_name, 'Full amount' AS payment_type,
        invoice_total AS total, invoice_total AS payment
    FROM invoices JOIN vendors
        ON invoices.vendor_id = vendors.vendor_id
    WHERE invoice_total < 500
ORDER BY payment_type, vendor_name, invoice_number
```

| invoice_number | vendor_name | payment_type | total | payment |
|---|---|---|---|---|
| 40318 | Data Reproductions Corp | 33% Payment | 21842.00 | 7273.38600 |
| 0-2058 | Malloy Lithographing Inc | 33% Payment | 37966.19 | 12642.74127 |
| 0-2060 | Malloy Lithographing Inc | 33% Payment | 23517.58 | 7831.35414 |
| 0-2436 | Malloy Lithographing Inc | 33% Payment | 10976.06 | 3655.02798 |
| P-0259 | Malloy Lithographing Inc | 33% Payment | 26881.40 | 8951.50620 |
| P-0608 | Malloy Lithographing Inc | 33% Payment | 20551.18 | 6843.54294 |
| 509786 | Bertelsmann Industry Svcs. Inc | 50% Payment | 6940.25 | 3470.12500 |
| 587056 | Cahners Publishing Company | 50% Payment | 2184.50 | 1092.25000 |

(114 rows)

Figure 4-14 How to combine result sets from the same tables

## A union that simulates a full outer join

A *full outer join* returns unmatched rows from both the left and right tables. Although MySQL doesn't provide a keyword for coding a full outer join, you can simulate a full outer join by coding a union that combines the result sets for a left outer join and a right outer join as shown in figure 4-15.

The example in this figure uses the UNION keyword to combine the result sets for the left and right outer joins shown in figure 4-9. As a result, this example returns all the rows from the Departments and Employees tables even if the rows don't have matching columns in the other table.

To make it easier to identify the unmatched rows, this statement includes the department_number column from both tables. This shows that two rows in the Employees table don't have matching rows in the Departments table, and it shows that one row in the Departments table doesn't have a matching row in the Employees table. In other words, two employees haven't been assigned to a department, and one department doesn't have any employees.

### A union that simulates a full outer join

```
     SELECT department_name AS dept_name, d.department_number AS d_dept_no,
            e.department_number AS e_dept_no, last_name
     FROM departments d
         LEFT JOIN employees e
         ON d.department_number = e.department_number
UNION
     SELECT department_name AS dept_name, d.department_number AS d_dept_no,
            e.department_number AS e_dept_no, last_name
     FROM departments d
         RIGHT JOIN employees e
         ON d.department_number = e.department_number
ORDER BY dept_name
```

| dept_name | d_dept_no | e_dept_no | last_name |
|---|---|---|---|
| NULL | NULL | 6 | Watson |
| NULL | NULL | 6 | Locario |
| Accounting | 1 | 1 | Hernandez |
| Maintenance | 5 | 5 | Hardy |
| Operations | 3 | NULL | NULL |
| Payroll | 2 | 2 | Smith |
| Payroll | 2 | 2 | Simonian |
| Payroll | 2 | 2 | Aaronsen |
| Personnel | 4 | 4 | Jones |
| Personnel | 4 | 4 | O'Leary |

(10 rows)

## Description

- When you use a *full outer join*, the result set includes all the rows from both tables.
- MySQL doesn't provide a keyword for full outer joins, but you can simulate a full outer join by using the UNION keyword to combine the result sets from a left outer join and a right outer join.

Figure 4-15 How to simulate a full outer join

# Perspective

In this chapter, you learned a variety of techniques for combining data from two or more tables into a single result set. In particular, you learned how to use the explicit syntax to code inner joins. Of all the techniques presented in this chapter, this is the one you'll use most often. So you'll want to be sure you understand it thoroughly before you go on.

## Terms

| | |
|---|---|
| join | implicit syntax |
| join condition | outer join |
| inner join | left outer join |
| ad hoc relationship | right outer join |
| qualified column name | equijoin |
| explicit syntax | natural join |
| SQL-92 syntax | cross join |
| table alias | Cartesian product |
| schema | union |
| self-join | full outer join |

## Exercises

1. Write a SELECT statement that returns all columns from the Vendors table inner-joined with all columns from the Invoices table. This should return 114 rows. *Hint: You can use an asterisk (*) to select the columns from both tables.*

2. Write a SELECT statement that returns these four columns:

| | |
|---|---|
| vendor_name | The vendor_name column from the Vendors table |
| invoice_number | The invoice_number column from the Invoices table |
| invoice_date | The invoice_date column from the Invoices table |
| balance_due | The invoice_total column minus the payment_total and credit_total columns from the Invoices table |

   Use these aliases for the tables: v for Vendors and i for Invoices.

   Return one row for each invoice with a non-zero balance. This should return 11 rows.

   Sort the result set by vendor_name in ascending order.

3. Write a SELECT statement that returns these three columns:

| | |
|---|---|
| vendor_name | The vendor_name column from the Vendors table |
| default_account | The default_account_number column from the Vendors table |
| description | The account_description column from the General_Ledger_Accounts table |

   Return one row for each vendor. This should return 122 rows.

   Sort the result set by account_description and then by vendor_name.

4. Write a SELECT statement that returns these five columns:

| | |
|---|---|
| vendor_name | The vendor_name column from the Vendors table |
| invoice_date | The invoice_date column from the Invoices table |
| invoice_number | The invoice_number column from the Invoices table |
| li_sequence | The invoice_sequence column from the Invoice_Line_Items table |
| li_amount | The line_item_amount column from the Invoice_Line_Items table |

   Use aliases for the tables. This should return 118 rows.

   Sort the final result set by vendor_name, invoice_date, invoice_number, and invoice_sequence.

5. Write a SELECT statement that returns three columns:

| | |
|---|---|
| vendor_id | The vendor_id column from the Vendors table |
| vendor_name | The vendor_name column from the Vendors table |
| contact_name | A concatenation of the vendor_contact_first_name and vendor_contact_last_name columns with a space between |

   Return one row for each vendor whose contact has the same last name as another vendor's contact. This should return 2 rows. *Hint: Use a self-join to check that the vendor_id columns aren't equal but the vendor_contact_last_name columns are equal.*

   Sort the result set by vendor_contact_last_name.

6. Write a SELECT statement that returns these three columns:

| | |
|---|---|
| account_number | The account_number column from the General_Ledger_Accounts table |
| account_description | The account_description column from the General_Ledger_Accounts table |
| invoice_id | The invoice_id column from the Invoice_Line_Items table |

   Return one row for each account number that has never been used. This should return 54 rows. *Hint: Use an outer join and only return rows where the invoice_id column contains a null value.*

   Remove the invoice_id column from the SELECT clause.

   Sort the final result set by the account_number column.

7. Use the UNION operator to generate a result set consisting of two columns from the Vendors table: vendor_name and vendor_state. If the vendor is in California, the vendor_state value should be "CA"; otherwise, the vendor_state value should be "Outside CA." Sort the final result set by vendor_name.

# 5

# How to insert, update, and delete data

In the last two chapters, you learned how to code the SELECT statement to retrieve and summarize data. Now, you'll learn how to code the INSERT, UPDATE, and DELETE statements to modify the data in a table. When you're done with this chapter, you'll know how to code the four statements that are used every day by professional application developers.

As you read this chapter, keep in mind that by default, MySQL automatically commits changes to the database immediately after each INSERT, UPDATE, or DELETE statement is executed. Usually, that's what you want. If it isn't, you can refer to chapter 14 to learn how to turn off auto-commit mode.

# How to create test tables

Before you begin experimenting with INSERT, UPDATE, and DELETE statements, you need to make sure that your experimentation won't affect "live" data that's used by other people at your business or school.

## How to create the tables for this book

If you're only working with the tables for this book, you can use the procedure shown in appendix A (Windows) or B (macOS) to create the tables for this book. Then, you can experiment all you want without worrying about how much you change these tables. If you ever want to restore these tables to their original state, you can use the procedure shown in the appendix to do that.

## How to create a copy of a table

If you're working with tables that are running on a server that's available from your business or school, it's usually a good idea to create a copy of some or all of a table before you do any testing. To do that, you can use the CREATE TABLE AS statement with a SELECT statement as shown in figure 5-1. When you use this technique, the result set that's defined by the SELECT statement is copied into a new table. Then, you can experiment all you want with the test table and delete it when you're done.

When you use this technique to create tables, MySQL only copies the column definitions and data. In other words, MySQL doesn't retain other parts of the column definitions such as primary keys, foreign keys, and indexes. As a result, when you experiment with copied tables, you may get different results than you would get with the original tables. Still, this is usually preferable to experimenting with live data.

The examples in this figure show how to use the CREATE TABLE AS statement. Here, the first example copies all of the columns from all of the rows in the Invoices table into a new table named Invoices_Copy. The second example copies all of the columns in the Invoices table into a new table named Old_Invoices, but only for rows where the balance due is zero. And the third example creates a table that contains summary data from the Invoices table.

When you're done experimenting with test tables, you can use the DROP TABLE statement that's shown in this figure to delete any tables you don't need anymore. In this figure, for instance, the fourth example shows how to drop the Old_Invoices table.

## The syntax of the CREATE TABLE AS statement

```
CREATE TABLE table_name AS select_statement
```

## Create a complete copy of the Invoices table

```
CREATE TABLE invoices_copy AS
SELECT *
FROM invoices
```

## Create a partial copy of the Invoices table

```
CREATE TABLE old_invoices AS
SELECT *
FROM invoices
WHERE invoice_total - payment_total - credit_total = 0
```

## Create a table with summary rows from the Invoices table

```
CREATE TABLE vendor_balances AS
SELECT vendor_id, SUM(invoice_total) AS sum_of_invoices
FROM invoices
WHERE (invoice_total - payment_total - credit_total) <> 0
GROUP BY vendor_id
```

## Delete a table

```
DROP TABLE old_invoices
```

## Description

- You can use the CREATE TABLE AS statement to create a new table based on the result set defined by a SELECT statement.
- Each column name in the SELECT clause must be unique. If you use a calculated value in the select list, you must name the column.
- You can code the other clauses of the SELECT statement just as you would for any other SELECT statement, including grouping, aggregates, joins, and subqueries.
- If you code the CREATE TABLE AS statement as shown above, the table you name must not exist. If it does, you must delete the table by using the DROP TABLE statement before you execute the CREATE TABLE AS statement.
- When you use the CREATE TABLE AS statement to create a table, only the column definitions and data are copied. Definitions of primary keys, foreign keys, indexes, and so on are not included in the new table.

Figure 5-1 How to create a table from a SELECT statement

# How to insert new rows

To add rows to a table, you use the INSERT statement. In most cases, you use this statement to add a single row to a table. However, you can also use it to add multiple rows to a table.

## How to insert a single row

Figure 5-2 starts by showing how to code INSERT statements that insert a single row. Because the examples in this figure insert rows into the Invoices table, this figure reviews the column definitions for this table. This shows the sequence of the columns in the table and which columns have default values or allow null values. It also shows that invoice_id is an auto increment column.

When you code an INSERT statement, you name the table in the INSERT clause, followed by an optional list of columns. Then, you list the values to be inserted in the VALUES clause.

The first two examples in this figure illustrate how this works. The first example doesn't include a column list. Because of that, the VALUES clause must include a value for every column in the table, and those values must be listed in the same sequence that the columns appear in the table. That way, MySQL knows which value to assign to which column. Notice that this statement uses the NULL keyword to assign a null value to the payment_date column. You'll learn more about using this keyword in the next figure.

The second INSERT statement includes a column list. However, this list doesn't include four columns. It doesn't include the invoice_id column since MySQL automatically increments this column if a value isn't specified. It doesn't include the payment_total and credit_total columns since these columns provide a default value of 0. And it doesn't include the payment_date column since this column allows a null value. In addition, the columns aren't listed in the same sequence as the columns in the table. When you include a list of columns, you can code the columns in any sequence you like. Then, you just need to be sure you code the values in the VALUES clause in the same sequence.

When you specify the values for the columns to be inserted, you must be sure that those values are compatible with the data types of the columns. For example, you must enclose literal values for dates and strings within quotes. However, the quotes are optional when you code literal values for numbers. Either way, if any of the values aren't compatible with the corresponding column data types, MySQL returns an error and the row isn't inserted.

## How to insert multiple rows

The third example in figure 5-2 shows how to insert multiple rows. When you do that, you follow the same rules as you do for inserting a single row. Then, you separate each list of values with a comma. This technique is often useful when you need to create a script that inserts data into a database.

## The syntax of the INSERT statement

```
INSERT [INTO] table_name [(column_list)]
VALUES (expression_1[, expression_2]...)[,
       (expression_1[, expression_2]...)]...
```

## The column definitions for the Invoices table

```
invoice_id          INT             NOT NULL     AUTO_INCREMENT,
vendor_id           INT             NOT NULL,
invoice_number      VARCHAR(50)     NOT NULL,
invoice_date        DATE            NOT NULL,
invoice_total       DECIMAL(9,2)    NOT NULL,
payment_total       DECIMAL(9,2)    NOT NULL     DEFAULT 0,
credit_total        DECIMAL(9,2)    NOT NULL     DEFAULT 0,
terms_id            INT             NOT NULL,
invoice_due_date    DATE            NOT NULL,
payment_date        DATE
```

## Insert a single row without using a column list

```
INSERT INTO invoices VALUES
(115, 97, '456789', '2022-08-01', 8344.50, 0, 0, 1, '2022-08-31', NULL)

(1 row affected)
```

## Insert a single row using a column list

```
INSERT INTO invoices
    (vendor_id, invoice_number, invoice_total, terms_id, invoice_date,
     invoice_due_date)
VALUES
    (97, '456789', 8344.50, 1, '2022-08-01', '2022-08-31')

(1 row affected)
```

## Insert multiple rows

```
INSERT INTO invoices VALUES
(116, 97, '456701', '2022-08-02', 270.50, 0, 0, 1, '2022-09-01', NULL),
(117, 97, '456791', '2022-08-03', 4390.00, 0, 0, 1, '2022-09-02', NULL),
(118, 97, '456792', '2022-08-03', 565.60, 0, 0, 1, '2022-09-02', NULL)

(3 rows affected)
```

## Description

- You use the INSERT statement to add one or more rows to a table.
- In the INSERT clause, you specify the name of the table that you want to add a row to, along with an optional column list. The INTO keyword is also optional.
- In the VALUES clause, you specify the values to be inserted. If you don't include a column list in the INSERT clause, you must specify the column values in the same order as in the table, and you must code a value for each column. If you include a column list, you must specify the column values in the same order as in the column list, and you can omit columns that have default values, accept null values, or are automatically generated.
- To insert a null value into a column, you can use the NULL keyword. To insert a default value or to have MySQL generate a value for an auto increment column, you can use the DEFAULT keyword.

Figure 5-2 How to insert rows

## How to insert default values and null values

If a column allows null values, you can use the INSERT statement to insert a null value into that column. Similarly, if a column is defined with a default value, you can use the INSERT statement to insert that value. Finally, if a column is defined as an auto increment column, you can have MySQL generate a value for the column. The technique you use depends on whether the INSERT statement includes a column list, as shown by the examples in figure 5-3.

All of these INSERT statements use a table named Color_Sample from the EX database. This table contains the three columns shown at the top of this figure. The first column, color_id, is defined so MySQL automatically generates its value whenever necessary. The second column, color_number, is defined with a default value of 0. And the third column, color_name, is defined so it allows null values.

The first two statements show how to assign an automatically incremented value, a default value, or a null value using a column list. To do that, you omit the column from the list. In the first statement, for example, the column list names only the color_number column. As a result, MySQL automatically assigns a value of 1 to the color_id column (assuming the table doesn't contain any rows) and a null value to the color_name column. Similarly, in the second statement, the column list names only the color_name column. As a result, MySQL assigns a value of 2 to the color_id column and a value of 0 to the color_number column.

The next three statements show how to assign an automatically incremented, default, or null value to a column without including a column list. To do that, you can use the DEFAULT and NULL keywords. For example, the third statement specifies a value for the color_name column, but uses the DEFAULT keyword for the color_id and color_number columns. As a result, MySQL assigns an automatically incremented value of 3 to the color_id column and a default value of 0 to the color_number column. The fourth statement uses the NULL keyword to assign a null value to the color_name column. Finally, the fifth statement shows what happens if you use the DEFAULT keyword for the first two columns and the NULL keyword for the third column.

### The column definitions for the Color_Sample table

```
color_id        INT            NOT NULL    AUTO_INCREMENT,
color_number    INT            NOT NULL    DEFAULT 0,
color_name      VARCHAR(50)
```

### Five INSERT statements for the Color_Sample table

```
INSERT INTO color_sample (color_number)
VALUES (606)

INSERT INTO color_sample (color_name)
VALUES ('Yellow')

INSERT INTO color_sample
VALUES (DEFAULT, DEFAULT, 'Orange')

INSERT INTO color_sample
VALUES (DEFAULT, 808, NULL)

INSERT INTO color_sample
VALUES (DEFAULT, DEFAULT, NULL)
```

### The Color_Sample table after the rows have been inserted

| color_id | color_number | color_name |
|---|---|---|
| 1 | 606 | NULL |
| 2 | 0 | Yellow |
| 3 | 0 | Orange |
| 4 | 808 | NULL |
| 5 | 0 | NULL |

### Description

- If a column is defined so it allows null values, you can use the NULL keyword in the list of values to insert a null value into that column.
- If a column is defined with a default value, you can use the DEFAULT keyword in the list of values to insert the default value for that column.
- If a column is defined as an auto increment column, you can use the DEFAULT keyword in the list of values to have MySQL generate the value for the column.
- If you include a column list, you can omit columns with default values and null values. Then, the default value or null value is assigned automatically. You can also omit an auto increment column. Then, MySQL generates the value for the column.

Figure 5-3 How to insert default values and null values

## How to use a subquery in an INSERT statement

A *subquery* is just a SELECT statement that's coded within another SQL statement. Since you already know how to code SELECT statements, you shouldn't have much trouble coding subqueries as described in this chapter. Then, in chapter 7, you'll learn more about coding subqueries.

Figure 5-4 shows how to code a subquery in an INSERT statement. Here, both examples use a SELECT statement instead of a VALUES clause. As a result, the subquery specifies the values for the new rows by selecting these values from another table.

Both examples retrieve rows from the Invoices table and insert them into a table named Invoice_Archive. This table is defined with the same columns as the Invoices table. However, the invoice_id column isn't defined as an auto increment column, and the payment_total and credit_total columns aren't defined with default values. As a result, you must include values for these columns.

The first example shows how you can use a subquery in an INSERT statement without a column list. In this example, the SELECT clause of the subquery uses an asterisk to retrieve all the columns in the Invoices table. Then, after MySQL applies the search condition in the WHERE clause, all the rows in the result set are inserted into the Invoice_Archive table.

The second example shows how you can use a subquery in an INSERT statement with a column list. Just as when you use the VALUES clause, you can list the columns in any sequence. However, the columns must be listed in the same sequence in the SELECT clause of the subquery. In addition, you can omit auto increment columns, columns that are defined with default values, and columns that allow null values.

When you code a subquery in an INSERT statement, you don't code parentheses around the SELECT statement. That's because the SELECT statement is coded instead of the VALUES clause. However, when you code a subquery in the WHERE clause of an UPDATE or INSERT statement, you do code parentheses around the SELECT statement.

Before you execute an INSERT statement that uses a subquery, you should make sure that the rows and columns retrieved by the subquery are the ones you want to insert. To do that, you can execute the SELECT statement by itself. Then, when you're sure it retrieves the correct data, you can add the INSERT clause to insert the rows into another table.

### The syntax for using a subquery to insert one or more rows

```
INSERT [INTO] table_name [(column_list)] select_statement
```

### Insert paid invoices into the Invoice_Archive table

```
INSERT INTO invoice_archive
SELECT *
FROM invoices
WHERE invoice_total - payment_total - credit_total = 0

(103 rows affected)
```

### The same statement with a column list

```
INSERT INTO invoice_archive
    (invoice_id, vendor_id, invoice_number, invoice_total, credit_total,
    payment_total, terms_id, invoice_date, invoice_due_date)
SELECT
    invoice_id, vendor_id, invoice_number, invoice_total, credit_total,
    payment_total, terms_id, invoice_date, invoice_due_date
FROM invoices
WHERE invoice_total - payment_total - credit_total = 0

(103 rows affected)
```

### Description

- A *subquery* is a SELECT statement that's coded within another SQL statement.
- To insert rows selected from one or more tables into another table, you can code a subquery in place of the VALUES clause. Then, MySQL inserts the rows returned by the subquery into the target table. For this to work, the target table must already exist.
- The rules for working with a column list are the same as they are for any INSERT statement.

Figure 5-4 How to use a subquery in an INSERT statement

# How to update existing rows

To modify the data in one or more rows of a table, you use the UPDATE statement. Although most of the UPDATE statements you code will perform simple updates, you can also code more complex UPDATE statements that include subqueries if necessary.

## How to update rows

Figure 5-5 presents the syntax of the UPDATE statement. Most UPDATE statements include all three of the clauses shown here. The UPDATE clause names the table to be updated. The SET clause names the columns to be updated and the values to be assigned to those columns. And the WHERE clause specifies the condition a row must meet to be updated.

When you use MySQL Workbench, you should realize that it will execute an UPDATE statement only if the condition on the WHERE clause refers to a primary or foreign key. That's because, by default, Workbench runs in "safe update" mode. If that's not what you want, you can turn safe update mode off as described in this figure. For example, because the WHERE clauses in the first and third UPDATE statements in this figure refer to the invoice_number column, which isn't a key column, you have to turn safe update mode off to execute them.

The first UPDATE statement modifies the values of two columns in the Invoices table: payment_date and payment_total. Since the WHERE clause in this statement identifies a single row, MySQL only updates the columns in that row. In this example, the values for the columns are coded as a literal values. You should realize, though, that you can assign any valid expression to a column as long as it evaluates to a value that's compatible with the data type of the column. You can also use the NULL keyword to assign a null value to a column that allows nulls, and you can use the DEFAULT keyword to assign the default value to a column that's defined with a default value.

The second UPDATE statement modifies a single column in the Invoices table, terms_id. This time, however, the WHERE clause specifies that all the rows for vendor 95 should be updated. Since this vendor has six rows in the Invoices table, MySQL updates all six rows.

The third UPDATE statement shows how you can use an expression to assign a value to a column. In this case, the expression increases the value of the credit_total column by 100. Like the first UPDATE statement, this statement updates a single row.

Before you execute an UPDATE statement, you may want to make sure that you've selected the correct rows. To do that, you can code a SELECT statement with the same search condition. Then, if the SELECT statement returns the correct rows, you can copy its WHERE clause into your UPDATE statement.

## The syntax of the UPDATE statement

```
UPDATE table_name
SET column_name_1 = expression_1[, column_name_2 = expression_2]...
[WHERE search_condition]
```

## Update two columns for a single row

```
UPDATE invoices
SET payment_date = '2022-09-21',
    payment_total = 19351.18
WHERE invoice_number = '97/522'

(1 row affected)
```

## Update one column for multiple rows

```
UPDATE invoices
SET terms_id = 1
WHERE vendor_id = 95

(6 rows affected)
```

## Update one column for one row

```
UPDATE invoices
SET credit_total = credit_total + 100
WHERE invoice_number = '97/522'

(1 row affected)
```

## Description

- You use the UPDATE statement to modify one or more rows in a table.
- In the SET clause, you name each column and its new value. You can specify the value for a column as a literal or an expression.
- In the WHERE clause, you can specify the conditions that must be met for a row to be updated.
- You can use the DEFAULT and NULL keywords to specify default and null values.
- By default, MySQL Workbench runs in safe update mode. That prevents you from updating rows if the WHERE clause is omitted or doesn't refer to a primary key or foreign key column.
- To get around the restrictions of safe update mode, you can turn this mode off. To do that, select Edit→Preferences, select the SQL Editor node, uncheck the box next to "Safe Updates", and restart MySQL Workbench.

## Warning

- If you turn off safe update mode and omit the WHERE clause in an UPDATE statement, all rows in the table will be updated.

Figure 5-5 How to update rows

## How to use a subquery in an UPDATE statement

When you code the search condition on the WHERE clause of an UPDATE statement, you can include a subquery to identify the rows to be updated. Figure 5-6 presents two statements that illustrate how you do that.

In the first statement, a subquery is used in the WHERE clause to identify the invoices to be updated. This subquery returns the vendor_id value for the vendor in the Vendors table with the name "Pacific Bell." Then, all the invoices with that vendor_id value are updated.

The second UPDATE statement also uses a subquery in the WHERE clause. This subquery returns a list of the vendor_id values for all vendors in California, Arizona, and Nevada. Then, the IN operator is used to update all the invoices with vendor_id values in that list. Although this subquery returns 80 vendors, many of these vendors don't have invoices. As a result, the UPDATE statement only affects 40 invoices.

To execute the second UPDATE statement from MySQL Workbench, you have to turn safe update mode off. That's because the WHERE clause in this statement uses the IN operator.

### Update all invoices for a vendor

```
UPDATE invoices
SET terms_id = 1
WHERE vendor_id =
   (SELECT vendor_id
    FROM vendors
    WHERE vendor_name = 'Pacific Bell')

(6 rows affected)
```

### Update the terms for all invoices for vendors in three states

```
UPDATE invoices
SET terms_id = 1
WHERE vendor_id IN
   (SELECT vendor_id
    FROM vendors
    WHERE vendor_state IN ('CA', 'AZ', 'NV'))

(40 rows affected)
```

### Description

- You can code a subquery in the WHERE clause of an UPDATE statement to provide one or more values used in the search condition.

Figure 5-6 How to use a subquery in an UPDATE statement

# How to delete existing rows

To delete one or more rows from a table, you use the DELETE statement. If necessary, you can use subqueries in a DELETE statement to help identify the rows to be deleted.

## How to delete rows

Figure 5-7 presents the syntax of the DELETE statement along with four examples that show how it works. To start, the DELETE clause specifies the name of the table and must include the FROM keyword.

The WHERE clause specifies a search condition that identifies the rows to be deleted. Although this clause is optional, you'll almost always include it. If you don't, you could inadvertently delete all of the rows in the table. Fortunately, MySQL Workbench runs in safe update mode by default, which prevents a DELETE statement from executing if it doesn't include a WHERE clause that refers to a primary key or foreign key column.

If you want to make sure that you've selected the correct rows before you delete them, you can code a SELECT statement that retrieves those rows. Then, once you're sure the SELECT statement is retrieving the correct rows, you can convert the SELECT statement to a DELETE statement.

The first DELETE statement in this figure deletes a single row from the General_Ledger_Accounts table. To do that, it specifies the account_number value of the row to be deleted in the WHERE clause. The second DELETE statement deletes a single row from the Invoice_Line_Items table. To do that, it specifies the invoice_id value and the invoice_sequence value of the row to be deleted in the WHERE clause. Finally, the third DELETE statement deletes four rows from the Invoice_Line_Items table. To do that, it specifies 12 as the invoice_id value of the row to be deleted. Since the invoice for this ID has four line items, this deletes all four line items.

If you try to delete a row that has one or more related rows in another table, MySQL typically returns an error message and doesn't delete the row. For example, MySQL returns an error message if you attempt to delete a row from the Vendors table that has related rows in the Invoices table. Usually, that's what you want.

## How to use a subquery in a DELETE statement

If you want to delete a row from the Vendors table that has related rows in the Invoices table, you need to start by deleting the rows in the Invoice_Line_Items table for the vendor's invoices. To do that, you can use a subquery as shown in the fourth example in figure 5-7. Here, the subquery selects all the invoice IDs for the vendor from the Invoices table. Then, the DELETE statement deletes all the invoice line items with those IDs.

## The syntax of the DELETE statement

```
DELETE FROM table_name
[WHERE search_condition]
```

## Delete one row

```
DELETE FROM general_ledger_accounts
WHERE account_number = 306

(1 row affected)
```

## Delete one row using a compound condition

```
DELETE FROM invoice_line_items
WHERE invoice_id = 78 AND invoice_sequence = 2

(1 row affected)
```

## Delete multiple rows

```
DELETE FROM invoice_line_items
WHERE invoice_id = 12

(4 rows affected)
```

## Use a subquery in a DELETE statement

```
DELETE FROM invoice_line_items
WHERE invoice_id IN
    (SELECT invoice_id
     FROM invoices
     WHERE vendor_id = 115)

(4 rows affected)
```

## Description

- You can use the DELETE statement to delete one or more rows from the table you name in the DELETE clause.
- You specify the conditions that must be met for a row to be deleted in the WHERE clause.
- You can use a subquery within the WHERE clause.
- A foreign key constraint may prevent you from deleting a row. In that case, you can only delete the row if you delete all child rows for that row first.
- By default, MySQL Workbench runs in safe update mode. That prevents you from deleting rows if the WHERE clause is omitted or doesn't refer to a primary key or foreign key column. For information on turning safe update mode off, see figure 5-5.

## Warning

- If you turn safe update mode off and omit the WHERE clause from a DELETE statement, all the rows in the table will be deleted.

Figure 5-7 How to delete rows

# Perspective

In this chapter, you learned how to use the INSERT, UPDATE, and DELETE statements to modify the data in a database. In chapters 10 and 11, you'll learn more about how table definitions can affect the way these statements work. And in chapter 14, you'll learn more about executing groups of INSERT, UPDATE, and DELETE statements as a single transaction.

## Term

subquery

## Exercises

To test whether a table has been modified correctly as you do these exercises, you can write and run an appropriate SELECT statement. Or, when you're using MySQL Workbench, you can right-click on a table name in the Navigator window and select Select Rows - Limit 1000 to display the data for the table in a Result tab. To refresh the data in this tab after modifying the table data, click the Refresh button in the toolbar at the top of the tab.

1. Write an INSERT statement that adds this row to the Terms table:

   | | |
   |---|---|
   | terms_id: | 6 |
   | terms_description: | Net due 120 days |
   | terms_due_days: | 120 |

   Use MySQL Workbench to review the column definitions for the Terms table, and include a column list with the required columns in the INSERT statement.
2. Write an UPDATE statement that modifies the row you just added to the Terms table. This statement should change the terms_description column to "Net due 125 days", and it should change the terms_due_days column to 125.
3. Write a DELETE statement that deletes the row you added to the Terms table in exercise 1.
4. Write an INSERT statement that adds this row to the Invoices table:

   | | |
   |---|---|
   | invoice_id: | The next automatically generated ID |
   | vendor_id: | 32 |
   | invoice_number: | AX-014-027 |
   | invoice_date: | 8/1/2022 |
   | invoice_total: | $434.58 |
   | payment_total: | $0.00 |
   | credit_total: | $0.00 |
   | terms_id: | 2 |
   | invoice_due_date: | 8/31/2022 |
   | payment_date: | null |

   Write this statement without using a column list.

5. Write an INSERT statement that adds these rows to the Invoice_Line_Items table:

| | | |
|---|---|---|
| invoice_sequence: | 1 | 2 |
| account_number: | 160 | 527 |
| line_item_amount: | $180.23 | $254.35 |
| line_item_description: | Hard drive | Exchange Server update |

   Set the invoice_id column of these two rows to the invoice ID that was generated by MySQL for the invoice you added in exercise 4.

6. Write an UPDATE statement that modifies the invoice you added in exercise 4. This statement should change the credit_total column so it's 10% of the invoice_total column, and it should change the payment_total column so the sum of the payment_total and credit_total columns are equal to the invoice_total column.

7. Write an UPDATE statement that modifies the Vendors table. Change the default_account_number column to 403 for the vendor with an ID of 44.

8. Write an UPDATE statement that modifies the Invoices table. Change the terms_id column to 2 for each invoice that's for a vendor with a default_terms_id of 2.

9. Write a DELETE statement that deletes the row that you added to the Invoices table in exercise 4. When you execute this statement, it will produce an error since the invoice has related rows in the Invoice_Line_Items table. To fix that, precede the DELETE statement with another DELETE statement that deletes the line items for this invoice. (Remember that to code two or more statements in a script, you must end each statement with a semicolon.)

# Section 2

## More SQL skills as you need them

In section 1, you learned a professional subset of SQL skills that you can use to work with data in an existing database. Now, in this section, you can add to those skills by learning new skills whenever you need them. To make that possible, each chapter in this section has been designed as an independent module. As a result, you can read these chapters in whatever sequence you prefer.

In chapter 6, you'll learn how to summarize the data that you retrieve. In chapter 7, you'll learn more about coding subqueries. In chapter 8, you'll learn more about the types of data that MySQL supports. And in chapter 9, you'll learn how to use MySQL functions in your SQL statements.

# 6

# How to code summary queries

In this chapter, you'll learn how to code queries that summarize data. For example, you can use summary queries to report sales totals by vendor or state. Similarly, you can use summary queries to get a count of the number of invoices that were processed each day of the month. But first, you'll learn how to use a special type of function called an aggregate function. Aggregate functions allow you to do jobs like calculate averages, summarize totals, or find the highest value for a given column, and you'll use them in summary queries.

# How to work with aggregate functions

In chapter 3, you learned how to use *scalar functions*, which operate on a single value and return a single value. In this chapter, you'll learn how to use *aggregate functions*, which operate on a series of values and return a single summary value. Because aggregate functions typically operate on the values in columns, they are sometimes referred to as *column functions*. A query that contains one or more aggregate functions is typically referred to as a *summary query*.

## How to code aggregate functions

Figure 6-1 presents the syntax of the most common aggregate functions. Most of these functions operate on an expression. Typically, the expression is just a column name. For example, you could get the average of all values in the invoice_total column like this:

```
AVG(invoice_total)
```

However, an expression can also be more complex. In this figure, for example, the expression that's coded for the SUM function calculates the balance due of an invoice using the invoice_total, payment_total, and credit_total columns. The result is a single value that represents the total amount due for all the selected invoices. In this case, the WHERE clause selects only those invoices with a balance due.

When you use these functions, you can also code the ALL or DISTINCT keyword. The ALL keyword is the default, which means that all values except null values are included in the calculation. In other words, null values are excluded from these functions.

If you don't want duplicate values included, you can code the DISTINCT keyword. In most cases, you'll use DISTINCT only with the COUNT function as shown in the next figure. You won't use it with MIN or MAX because it has no effect on those functions. And it doesn't usually make sense to use it with the AVG and SUM functions.

Unlike the other aggregate functions, you can't use the ALL or DISTINCT keywords or an expression with COUNT(*). Instead, you code this function exactly as shown in the syntax. The value returned by this function is the number of rows in the base table that satisfy the search condition of the query, including rows with null values. In this figure, for example, the COUNT(*) function in the query indicates that the Invoices table contains 11 invoices with a balance due.

## The syntax of some common aggregate functions

| Function syntax | Result |
|---|---|
| `AVG([ALL|DISTINCT] expression)` | The average of the non-null values in the expression. |
| `SUM([ALL|DISTINCT] expression)` | The total of the non-null values in the expression. |
| `MIN([ALL|DISTINCT] expression)` | The lowest non-null value in the expression. |
| `MAX([ALL|DISTINCT] expression)` | The highest non-null value in the expression. |
| `COUNT([ALL|DISTINCT] expression)` | The number of non-null values in the expression. |
| `COUNT(*)` | The number of rows selected by the query. |

## A summary query that counts unpaid invoices and calculates the total due

```
SELECT COUNT(*) AS number_of_invoices,
    SUM(invoice_total - payment_total - credit_total) AS total_due
FROM invoices
WHERE invoice_total - payment_total - credit_total > 0
```

| number_of_invoices | total_due |
|---|---|
| 11 | 32020.42 |

## Description

- *Aggregate functions*, also called *column functions*, perform a calculation on the values in a set of selected rows.
- A *summary query* is a SELECT statement that includes one or more aggregate functions.
- The expression you specify for the AVG and SUM functions must result in a numeric value. The expression for the MIN, MAX, and COUNT functions can result in a numeric, date, or string value.
- By default, all values are included in the calculation regardless of whether they're duplicated. If you want to omit duplicate values, code the DISTINCT keyword. This keyword is typically used with the COUNT function.
- All of the aggregate functions except for COUNT(*) ignore null values.

Figure 6-1 How to code aggregate functions

## Queries that use aggregate functions

This figure presents four more queries that use aggregate functions. The first two queries use the COUNT(*) function to count the number of rows in the Invoices table that satisfy the search condition. In both cases, only those invoices with invoice dates after 1/1/2022 are included in the count. In addition, the first query uses the AVG function to calculate the average amount of those invoices and the SUM function to calculate the total amount of those invoices. In contrast, the second query uses the MIN and MAX functions to get the minimum and maximum invoice amounts.

Although the MIN, MAX, and COUNT functions are typically used on columns that contain numeric data, they can also be used on columns that contain character or date data. In the third query, for example, they're used on the vendor_name column in the Vendors table. Here, the MIN function returns the name of the vendor that's lowest in the sort sequence, the MAX function returns the name of the vendor that's highest in the sort sequence, and the COUNT function returns the total number of vendors. Note that since the vendor_name column can't contain null values, the COUNT(*) function would have returned the same result.

The fourth query shows how using the DISTINCT keyword can affect the result of a COUNT function. Here, the first COUNT function uses the DISTINCT keyword to count the number of vendors that have invoices after 1/1/2022 in the Invoices table. To do that, it looks for distinct values in the vendor_id column. In contrast, since the second COUNT function doesn't include the DISTINCT keyword, it counts every invoice that's after 1/1/2022. Although you could use the COUNT(*) function instead, this example uses COUNT(vendor_id) to clearly show the difference between coding and not coding the DISTINCT keyword.

With two exceptions, a SELECT clause that contains an aggregate function can contain only aggregate functions. The first exception is if the column specification results in a literal value. This is shown by the first column in the first two queries in figure 6-2. The second exception is if the query includes a GROUP BY clause. Then, the SELECT clause can include any columns specified in the GROUP BY clause as shown in the next two figures.

## A summary query that uses the COUNT(*), AVG, and SUM functions

```
SELECT 'After 1/1/2022' AS selection_date,
    COUNT(*) AS number_of_invoices,
    ROUND(AVG(invoice_total), 2) AS avg_invoice_amt,
    SUM(invoice_total) AS total_invoice_amt
FROM invoices
WHERE invoice_date > '2022-01-01'
```

| selection_date | number_of_invoices | avg_invoice_amt | total_invoice_amt |
|---|---|---|---|
| After 1/1/2022 | 114 | 1879.74 | 214290.51 |

## A summary query that uses the MIN and MAX functions

```
SELECT 'After 1/1/2022' AS selection_date,
    COUNT(*) AS number_of_invoices,
    MAX(invoice_total) AS highest_invoice_total,
    MIN(invoice_total) AS lowest_invoice_total
FROM invoices
WHERE invoice_date > '2022-01-01'
```

| selection_date | number_of_invoices | highest_invoice_total | lowest_invoice_total |
|---|---|---|---|
| After 1/1/2022 | 114 | 37966.19 | 6.00 |

## A summary query that works on non-numeric columns

```
SELECT MIN(vendor_name) AS first_vendor,
    MAX(vendor_name) AS last_vendor,
    COUNT(vendor_name) AS number_of_vendors
FROM vendors
```

| first_vendor | last_vendor | number_of_vendors |
|---|---|---|
| Abbey Office Furnishings | Zylka Design | 122 |

## A summary query that uses the DISTINCT keyword

```
SELECT COUNT(DISTINCT vendor_id) AS number_of_vendors,
    COUNT(vendor_id) AS number_of_invoices,
    ROUND(AVG(invoice_total), 2) AS avg_invoice_amt,
    SUM(invoice_total) AS total_invoice_amt
FROM invoices
WHERE invoice_date > '2022-01-01'
```

| number_of_vendors | number_of_invoices | avg_invoice_amt | total_invoice_amt |
|---|---|---|---|
| 34 | 114 | 1879.74 | 214290.51 |

## Description

- To count all of the selected rows, you typically use the COUNT(*) function. Alternately, you can use the COUNT function with the name of any column that can't contain null values.
- To count only the rows with unique values in a specified column, you can code the COUNT function with the DISTINCT keyword followed by the name of the column.

Figure 6-2 Queries that use aggregate functions

# How to group and summarize data

Now that you understand how aggregate functions work, you're ready to learn how to group data and use aggregate functions to summarize the data in each group. To do that, you can use two clauses of the SELECT statement: GROUP BY and HAVING.

## How to code the GROUP BY and HAVING clauses

Figure 6-3 shows the syntax of the SELECT statement with the GROUP BY and HAVING clauses. The GROUP BY clause determines how the selected rows are grouped, and the HAVING clause determines which groups are included in the final results. These clauses are coded after the WHERE clause but before the ORDER BY clause. That makes sense because the WHERE clause is applied before the rows are grouped, and the ORDER BY clause is applied after the rows are grouped.

In the GROUP BY clause, you list one or more columns or expressions separated by commas. Then, the rows in the result set are grouped by those columns or expressions in ascending sequence. That means that a single row is returned for each unique set of values in the GROUP BY columns. In this figure, for instance, the first example groups the results by a single column. In the next figure, you can see examples that group by multiple columns.

This example calculates the average invoice amount for each vendor who has invoices in the Invoices table. To do that, it uses a GROUP BY clause to group the invoices by vendor_id. As a result, the AVG function calculates the average of the invoice_total column for each group rather than for the entire result set.

The example in this figure also includes a HAVING clause. The search condition in this clause specifies that only those vendors with invoices that average over $2,000 should be included. Note that this condition must be applied after the rows are grouped and the average for each group has been calculated.

In addition to the AVG function, the SELECT clause includes the vendor_id column. That's usually what you want since it shows which average goes with which group. However, if you don't want to include the columns used in the GROUP BY clause in the SELECT clause, you don't have to.

In most cases, the SELECT clause for a statement that includes a GROUP BY clause will only include the columns that are used for grouping, along with the aggregate functions. However, you can also include expressions that result in a constant value as well as columns that are functionally dependent on a column that's used for grouping.

For a column to be *functionally dependent* on a grouping column, MySQL must be able to unambiguously determine its value based on the grouping column. This means if the grouping column is the primary key for the table, you can include any other column in the SELECT clause because MySQL can always determine the value for those columns. However, if another column or combination of columns also contains unique, non-null values, then you

## The syntax of a SELECT statement with GROUP BY and HAVING clauses

```
SELECT select_list
FROM table_source
[WHERE search_condition]
[GROUP BY group_by_list]
[HAVING search_condition]
[ORDER BY order_by_list]
```

## A summary query that calculates the average invoice amount by vendor

```
SELECT vendor_id, ROUND(AVG(invoice_total), 2) AS average_invoice_amount
FROM invoices
GROUP BY vendor_id
HAVING AVG(invoice_total) > 2000
ORDER BY average_invoice_amount DESC
```

| vendor_id | average_invoice_amount |
|---|---|
| 110 | 23978.48 |
| 72 | 10963.66 |
| 104 | 7125.34 |
| 99 | 6940.25 |
| 119 | 4901.26 |
| 122 | 2575.33 |
| 86 | 2433.00 |
| 100 | 2184.50 |

(8 rows)

## A summary query that includes a functionally dependent column

```
SELECT vendor_name, vendor_state,
       ROUND(AVG(invoice_total), 2) AS average_invoice_amount
FROM vendors JOIN invoices ON vendors.vendor_id = invoices.vendor_id
GROUP BY vendor_name
HAVING AVG(invoice_total) > 2000
ORDER BY average_invoice_amount DESC
```

## Description

- The GROUP BY clause groups the rows of a result set based on one or more columns or expressions. To include two or more columns or expressions, separate them by commas.
- If you include aggregate functions in the SELECT clause, the aggregate is calculated for each group specified by the GROUP BY clause.
- If you include two or more columns or expressions in the GROUP BY clause, the results are grouped by the first column, then by the second column if there are any ties, and so on.
- The HAVING clause specifies a search condition for including a group in the results. MySQL applies this condition after it groups the rows that satisfy the search condition in the WHERE clause.
- When a SELECT statement includes a GROUP BY clause, the SELECT clause can include the columns used for grouping, aggregate functions, and expressions that result in a constant value.
- The SELECT clause can also include columns that are *functionally dependent* on a column used for grouping. To be functionally dependent, MySQL must be able to unambiguously determine the column's value based on the grouping column.

Figure 6-3 How to code the GROUP BY and HAVING clauses can group by those columns and include other columns from the table in the SELECT statement as well.

The second example illustrates how this works. This example gets the vendor name, vendor state, and the average invoice total for each vendor. To do that, it joins the Vendors and Invoices table and groups the rows by vendor_name. Although the vendor_state column isn't included in the GROUP BY clause, it can be included in the SELECT clause because MySQL can determine the value of the vendor_state column based on the vendor_name column. This is because the vendor_name column contains only unique, non-null values.

## Queries that use the GROUP BY and HAVING clauses

Figure 6-4 presents three more queries that group data. The first query in this figure groups the rows in the Invoices table by vendor_id and returns a count of the number of invoices for each vendor.

The second query shows how you can group by more than one column. Here, a join is used to combine the vendor_state and vendor_city columns from the Vendors table with a count and average of the invoices in the Invoices table. Because the rows are grouped by both state and city, a row is returned for each state and city combination.

The third query is identical to the second query except that it includes a HAVING clause. This clause uses the COUNT function to limit the state and city groups that are included in the result set to those that have two or more invoices. In other words, it excludes groups that have only one invoice.

With MySQL 8.0.12 and earlier, the GROUP BY clause sorted the columns in ascending sequence by default. Then, to change that sequence, you could code the DESC keyword after the column name in the GROUP BY clause. You could also code the ASC keyword to make it clear that the rows were sorted in ascending sequence. And, you could improve the performance of a query by coding an ORDER BY NULL clause so the result set wasn't sorted at all.

With MySQL 8.0.13 and later, the columns in a GROUP BY clause are not automatically sorted. In addition, you can no longer specify the ASC or DESC keywords on this clause. Instead, you must code an ORDER BY clause to sort the rows in a result set. Otherwise, MySQL doesn't guarantee the sort sequence.

### A summary query that counts the number of invoices by vendor

```
SELECT vendor_id, COUNT(*) AS invoice_qty
FROM invoices
GROUP BY vendor_id
```

| vendor_id | invoice_qty |
|---|---|
| 34 | 2 |
| 37 | 3 |
| 48 | 1 |
| 72 | 2 |
| 80 | 2 |

(34 rows)

### A summary query that calculates the number of invoices and the average invoice amount for the vendors in each state and city

```
SELECT vendor_state, vendor_city, COUNT(*) AS invoice_qty,
    ROUND(AVG(invoice_total), 2) AS invoice_avg
FROM invoices JOIN vendors
    ON invoices.vendor_id = vendors.vendor_id
GROUP BY vendor_state, vendor_city
ORDER BY vendor_state, vendor_city
```

| vendor_state | vendor_city | invoice_qty | invoice_avg |
|---|---|---|---|
| AZ | Phoenix | 1 | 662.00 |
| CA | Fresno | 19 | 1208.75 |
| CA | Los Angeles | 1 | 503.20 |
| CA | Oxnard | 3 | 188.00 |
| CA | Pasadena | 5 | 196.12 |

(20 rows)

### A summary query that limits the groups to those with two or more invoices

```
SELECT vendor_state, vendor_city, COUNT(*) AS invoice_qty,
    ROUND(AVG(invoice_total), 2) AS invoice_avg
FROM invoices JOIN vendors
    ON invoices.vendor_id = vendors.vendor_id
GROUP BY vendor_state, vendor_city
HAVING COUNT(*) >= 2
ORDER BY vendor_state, vendor_city
```

| vendor_state | vendor_city | invoice_qty | invoice_avg |
|---|---|---|---|
| CA | Fresno | 19 | 1208.75 |
| CA | Oxnard | 3 | 188.00 |
| CA | Pasadena | 5 | 196.12 |
| CA | Sacramento | 7 | 253.00 |
| CA | San Francisco | 3 | 1211.04 |

(12 rows)

### Description

- With MySQL 8.0.12 and earlier, the GROUP BY clause sorted the columns in ascending sequence by default, and you could code the ASC and DESC keywords on the clause.
- With MySQL 8.0.13 and later, the columns in a GROUP BY clause are not sorted by default. Instead, you must use the ORDER BY clause to specify a sort sequence.

Figure 6-4 Queries that use the GROUP BY and HAVING clauses

## How the HAVING clause compares to the WHERE clause

As you've seen, you can limit the groups included in a result set by coding a search condition in the HAVING clause. In addition, you can apply a search condition to each row before it's included in a group. To do that, you code the search condition in the WHERE clause just as you would for any SELECT statement. Figure 6-5 presents two examples that illustrate how this works.

The first example groups the invoices in the Invoices table by vendor name and calculates a count and average invoice amount for each group. Then, the HAVING clause limits the groups in the result set to those that have an average invoice total greater than $500.

In contrast, the second example includes a WHERE clause that limits the invoices included in the groups to those that have an invoice total greater than $500. In other words, the search condition in this example is applied to every row. In the previous example, it was applied to each group of rows. As a result, these examples show that there are eight invoices for Zylka Design in the Invoices table, but only seven of them are over $500.

Beyond this, there are two differences in the expressions that you can include in the WHERE and HAVING clauses. First, the HAVING clause can include aggregate functions as shown in the first example, but the WHERE clause can't. That's because the search condition in a WHERE clause is applied before the rows are grouped. Second, although the WHERE clause can refer to any column in the base tables, the HAVING clause can only refer to columns included in the SELECT clause. That's because it filters the summarized result set that's defined by the SELECT, FROM, WHERE, and GROUP BY clauses. In other words, it doesn't filter the base tables.

## A summary query with a search condition in the HAVING clause

```
SELECT vendor_name,
    COUNT(*) AS invoice_qty,
    ROUND(AVG(invoice_total), 2) AS invoice_avg
FROM vendors JOIN invoices
    ON vendors.vendor_id = invoices.vendor_id
GROUP BY vendor_name
HAVING AVG(invoice_total) > 500
ORDER BY invoice_qty DESC
```

| vendor_name | invoice_qty | invoice_avg |
|---|---|---|
| United Parcel Service | 9 | 2575.33 |
| Zylka Design | 8 | 867.53 |
| Malloy Lithographing Inc | 5 | 23978.48 |
| IBM | 2 | 600.06 |

(19 rows)

## A summary query with a search condition in the WHERE clause

```
SELECT vendor_name,
    COUNT(*) AS invoice_qty,
    ROUND(AVG(invoice_total), 2) AS invoice_avg
FROM vendors JOIN invoices
    ON vendors.vendor_id = invoices.vendor_id
WHERE invoice_total > 500
GROUP BY vendor_name
ORDER BY invoice_qty DESC
```

| vendor_name | invoice_qty | invoice_avg |
|---|---|---|
| United Parcel Service | 9 | 2575.33 |
| Zylka Design | 7 | 946.67 |
| Malloy Lithographing Inc | 5 | 23978.48 |
| Ingram | 2 | 1077.21 |

(20 rows)

## Description

- When you include a WHERE clause in a SELECT statement that uses grouping and aggregates, MySQL applies the search condition before it groups the rows and calculates the aggregates.
- When you include a HAVING clause in a SELECT statement that uses grouping and aggregates, MySQL applies the search condition after it groups the rows and calculates the aggregates.
- A WHERE clause can refer to any column in the base tables.
- A HAVING clause can only refer to a column included in the SELECT clause.
- A WHERE clause can't contain aggregate functions.
- A HAVING clause can contain aggregate functions.

Figure 6-5 How the HAVING clause compares to the WHERE clause

## How to code compound search conditions

You can code compound search conditions in a HAVING clause just as you can in a WHERE clause. The first example in figure 6-6 shows how this works. This query groups invoices by invoice date and calculates a count of the invoices and the sum of the invoice totals for each date. In addition, the HAVING clause specifies three conditions. First, the invoice date must be between 5/1/2022 and 5/31/2022. Second, the invoice count for each date must be greater than 1. And third, the sum of the invoice totals for reach date must be greater than $100.

In the HAVING clause of this query, the second and third conditions include aggregate functions. As a result, they must be coded in the HAVING clause. The first condition, however, doesn't include an aggregate function, so it could be coded in either the HAVING or WHERE clause. The second example shows this condition coded in the WHERE clause. Either way, both queries return the same result set.

So, where should you code your search conditions? In general, I think queries are easier to read when they include all the search conditions in the HAVING clause. However, if you prefer to code non-aggregate search conditions in the WHERE clause, that's OK too.

### A summary query with a compound condition in the HAVING clause

```
SELECT
    invoice_date,
    COUNT(*) AS invoice_qty,
    SUM(invoice_total) AS invoice_sum
FROM invoices
GROUP BY invoice_date
HAVING invoice_date BETWEEN '2022-05-01' AND '2022-05-31'
    AND COUNT(*) > 1
    AND SUM(invoice_total) > 100
ORDER BY invoice_date DESC
```

### The same query coded with a WHERE clause

```
SELECT
    invoice_date,
    COUNT(*) AS invoice_qty,
    SUM(invoice_total) AS invoice_sum
FROM invoices
WHERE invoice_date BETWEEN '2022-05-01' AND '2022-05-31'
GROUP BY invoice_date
HAVING COUNT(*) > 1
    AND SUM(invoice_total) > 100
ORDER BY invoice_date DESC
```

### The result set returned by both queries

| invoice_date | invoice_qty | invoice_sum |
|---|---|---|
| 2022-05-31 | 2 | 453.75 |
| 2022-05-25 | 3 | 2201.15 |
| 2022-05-23 | 2 | 347.75 |
| 2022-05-21 | 2 | 8078.44 |
| 2022-05-13 | 3 | 1888.95 |
| 2022-05-11 | 2 | 5009.51 |
| 2022-05-03 | 2 | 866.87 |

(7 rows)

### Description

- You can use the AND and OR operators to code compound search conditions in a HAVING clause just as you can in a WHERE clause.
- If a search condition includes an aggregate function, it must be coded in the HAVING clause. Otherwise, it can be coded in either the HAVING or the WHERE clause.

Figure 6-6 How to code compound search conditions

## How to use the WITH ROLLUP operator

You can use the WITH ROLLUP operator to add one or more summary rows to a result set that uses grouping and aggregates. The two examples in figure 6-7 show how this works.

The first example shows how the WITH ROLLUP operator works when you group by a single column. This statement groups the invoices by vendor_id and calculates an invoice count and invoice total for each vendor group. In addition, since the GROUP BY clause includes the WITH ROLLUP operator, this query adds a summary row to the end of the result set. This row summarizes all of the aggregate columns in the result set. In this case, it summarizes the invoice_count and invoice_total columns. Since the vendor_id column can't be summarized, it's assigned a null value.

The second query in this figure shows how the WITH ROLLUP operator works when you group by two columns. This query groups vendors by state and city and counts the number of vendors in each group. Then, this query adds summary rows for each state, and it adds a final summary row at the end of the result set.

Before MySQL 8.0.13, you couldn't use the use an ORDER BY clause to sort a result set if the GROUP BY clause included the WITH ROLLUP operator. Instead, you had to sort the individual columns by coding the ASC or DESC keyword after the column name in the GROUP BY clause. With MySQL 8.0.13 and later, however, you can't code the ASC or DESC keyword on the GROUP BY clause. Instead, if you want to sort the result set, you can now use an ORDER BY clause. However, when you use WITH ROLLUP the result set is sorted by the columns in the GROUP BY clause in ascending sequence by default. So you'll only code an ORDER BY clause if you want to change this sequence.

### A summary query that includes a final summary row

```
SELECT vendor_id, COUNT(*) AS invoice_count,
    SUM(invoice_total) AS invoice_total
FROM invoices
GROUP BY vendor_id WITH ROLLUP
```

| vendor_id | invoice_count | invoice_total |
|---|---|---|
| 119 | 1 | 4901.26 |
| 121 | 8 | 6940.25 |
| 122 | 9 | 23177.96 |
| 123 | 47 | 4378.02 |
| NULL | 114 | 214290.51 |

(35 rows)

### A summary query that includes a summary row for each grouping level

```
SELECT vendor_state, vendor_city, COUNT(*) AS qty_vendors
FROM vendors
WHERE vendor_state IN ('IA', 'NJ')
GROUP BY vendor_state, vendor_city WITH ROLLUP
```

| vendor_state | vendor_city | qty_vendors |
|---|---|---|
| IA | Fairfield | 1 |
| IA | Washington | 1 |
| IA | NULL | 2 |
| NJ | East Brunswick | 2 |
| NJ | Fairfield | 1 |
| NJ | Washington | 1 |
| NJ | NULL | 4 |
| NULL | NULL | 6 |

### Description

- You can use the WITH ROLLUP operator in the GROUP BY clause to add summary rows to the final result set.
- The WITH ROLLUP operator adds a summary row for each group specified in the GROUP BY clause. It also adds a summary row to the end of the result set that summarizes the entire result set.
- If the GROUP BY clause specifies a single group, the WITH ROLLUP operator only adds the final summary row.
- With MySQL 8.0.12 and earlier, you couldn't use the ORDER BY clause with the WITH ROLLUP operator. Instead, to sort individual columns, you coded the ASC or DESC keyword after the column in the GROUP BY clause.
- With MySQL 8.0.13 and later, you can't code the ASC or DESC keyword on the GROUP BY clause. However, you can now include an ORDER BY clause to sort the result set when the GROUP BY clause includes WITH ROLLUP.
- With MySQL 8.0.12 and earlier, you couldn't use the DISTINCT keyword in any of the aggregate functions when you used the WITH ROLLUP operator. With MySQL 8.0.13 and later, you can use the DISTINCT keyword.

Figure 6-7 How to use the WITH ROLLUP operator

## How to use the GROUPING function

When you group by a column that can contain null values, the result of the grouping can be a null value. In addition, when you use the WITH ROLLUP operator to summarize a column that can contain null values, the summary row will contain a null value in that column. Because of that, it can be difficult to distinguish between null values due to grouping and null values due to summarizing.

The first query in figure 6-8 illustrates how this works. Here, the query includes the invoice date and payment date from the Invoices table, as well as the sum of the invoice totals and the sum of the invoice balances. The first five rows in the result set are for the same invoice date. Both the first and the last of those five rows contain a null value in the Payment Date column. The first row contains a null value because one or more of the invoices for that invoice date contains a null value. The last row contains a null value because it is a summary row for all of the invoices for that invoice date. Without studying this result set carefully, though, it's difficult to tell which null values are for summary rows and which aren't.

To help distinguish between these null values, you can use the GROUPING function that was introduced with MySQL 8.0. This function evaluates the expression you specify to determine if the expression results in a null value because it's in a summary row. If it does, the GROUPING function returns a value of 1. Otherwise, it returns a value of 0.

This is illustrated by the second query in this figure. This query is the same as the first query except that it uses IF and GROUPING functions for the invoice_date and payment_date columns in the SELECT clause. You'll learn about the IF function in chapter 9. For now, just realize that it evaluates the expression in the first argument and returns the second argument if the expression is true or the third argument if it's not.

In this case, the first argument of each IF function is a GROUPING function. These GROUPING functions test if the invoice_date or payment_date column contains a null value because it's in a summary row. If so, the IF function returns the literal value that's specified by the second argument. Otherwise, it returns the value of the column grouping that's specified by the third argument. If you compare the results of this query with the results of the first query, you'll see that it's now obvious which rows are summary rows because they contain literal values instead of null values. This is a common use for the GROUPING function.

### The basic syntax of the GROUPING function

```
GROUPING(expression)
```

### A summary query that uses WITH ROLLUP on a table with null values

```
SELECT invoice_date, payment_date,
       SUM(invoice_total) AS invoice_total,
       SUM(invoice_total - credit_total - payment_total) AS balance_due
FROM invoices
WHERE invoice_date BETWEEN '2022-07-24' AND '2022-07-31'
GROUP BY invoice_date, payment_date WITH ROLLUP
```

| invoice_date | payment_date | invoice_total | balance_due |
|---|---|---|---|
| 2022-07-24 | NULL | 503.20 | 503.20 |
| 2022-07-24 | 2022-08-19 | 3689.99 | 0.00 |
| 2022-07-24 | 2022-08-23 | 67.00 | 0.00 |
| 2022-07-24 | 2022-08-27 | 23517.58 | 0.00 |
| 2022-07-24 | NULL | 27777.77 | 503.20 |
| 2022-07-25 | 2022-08-22 | 1000.46 | 0.00 |
| 2022-07-25 | NULL | 1000.46 | 0.00 |
| 2022-07-28 | NULL | 90.36 | 90.36 |
| 2022-07-28 | NULL | 90.36 | 90.36 |
| 2022-07-30 | 2022-09-03 | 22.57 | 0.00 |
| 2022-07-30 | NULL | 22.57 | 0.00 |
| 2022-07-31 | NULL | 10976.06 | 10976.06 |
| 2022-07-31 | NULL | 10976.06 | 10976.06 |
| NULL | NULL | 39867.22 | 11569.62 |

### A query that substitutes literals for nulls in summary rows

```
SELECT IF(GROUPING(invoice_date) = 1, 'Grand totals', invoice_date)
           AS invoice_date,
       IF(GROUPING(payment_date) = 1, 'Invoice date totals', payment_date)
           AS payment_date,
       SUM(invoice_total) AS invoice_total,
       SUM(invoice_total - credit_total - payment_total) AS balance_due
FROM invoices
WHERE invoice_date BETWEEN '2022-07-24' AND '2022-07-31'
GROUP BY invoice_date, payment_date WITH ROLLUP
```

| invoice_date | payment_date | invoice_total | balance_due |
|---|---|---|---|
| 2022-07-24 | NULL | 503.20 | 503.20 |
| 2022-07-24 | 2022-08-19 | 3689.99 | 0.00 |
| 2022-07-24 | 2022-08-23 | 67.00 | 0.00 |
| 2022-07-24 | 2022-08-27 | 23517.58 | 0.00 |
| 2022-07-24 | Invoice date totals | 27777.77 | 503.20 |
| 2022-07-25 | 2022-08-22 | 1000.46 | 0.00 |
| 2022-07-25 | Invoice date totals | 1000.46 | 0.00 |
| 2022-07-28 | NULL | 90.36 | 90.36 |
| 2022-07-28 | Invoice date totals | 90.36 | 90.36 |
| 2022-07-30 | 2022-09-03 | 22.57 | 0.00 |
| 2022-07-30 | Invoice date totals | 22.57 | 0.00 |
| 2022-07-31 | NULL | 10976.06 | 10976.06 |
| 2022-07-31 | Invoice date totals | 10976.06 | 10976.06 |
| Grand totals | Invoice date totals | 39867.22 | 11569.62 |

### Description

- The GROUPING function returns 1 if the expression is null. Otherwise, it returns 0.

Figure 6-8 How to use the GROUPING function (part 1 of 2)

Part 2 of figure 6-8 shows another common use for the GROUPING function. The query in this example is identical to the second one in part 1 of this figure, except that it includes a HAVING clause. This clause uses the GROUPING function to filter the result set so only the summary rows are included. To do that, it checks if this function returns a value of 1 for the invoice_date or payment_date column.

### A query that displays only summary rows

```
SELECT IF(GROUPING(invoice_date) = 1, 'Grand totals', invoice_date)
           AS invoice_date,
       IF(GROUPING(payment_date) = 1, 'Invoice date totals', payment_date)
           AS payment_date,
       SUM(invoice_total) AS invoice_total,
       SUM(invoice_total - credit_total - payment_total) AS balance_due
FROM invoices
WHERE invoice_date BETWEEN '2022-07-24' AND '2022-07-31'
GROUP BY invoice_date, payment_date WITH ROLLUP
HAVING GROUPING(invoice_date) = 1 OR GROUPING(payment_date) = 1
```

| invoice_date | payment_date | invoice_total | balance_due |
|---|---|---|---|
| 2022-07-24 | Invoice date totals | 27777.77 | 503.20 |
| 2022-07-25 | Invoice date totals | 1000.46 | 0.00 |
| 2022-07-28 | Invoice date totals | 90.36 | 90.36 |
| 2022-07-30 | Invoice date totals | 22.57 | 0.00 |
| 2022-07-31 | Invoice date totals | 10976.06 | 10976.06 |
| Grand totals | Invoice date totals | 39867.22 | 11569.62 |

### Description

- The GROUPING function is commonly used to replace the nulls that are generated by WITH ROLLUP with literal values. To do that, you can use it with the IF function as shown in this figure.
- The IF function evaluates the expression in the first argument and returns the second argument if the expression is true and the third argument if the expression is false. See chapter 9 for more information on this function.
- If you want to display just the summary rows produced by the WITH ROLLUP operator, you can include one or more GROUPING functions in the HAVING clause.
- In addition to the SELECT and HAVING clauses, you can code the GROUPING function in the ORDER BY clause.

Figure 6-8 How to use the GROUPING function (part 2 of 2)

# How to code aggregate window functions

In the figures that follow, you'll learn how to use the *aggregate window functions* that were introduced with MySQL 8.0. You can use the window functions with any of the aggregate functions presented in this chapter.

## How the aggregate window functions work

Earlier in this chapter, you learned how to use some of the aggregate functions with the GROUP BY clause to group and summarize data. When you use GROUP BY, a single row is returned for each unique set of values in the grouped columns. If a result set is grouped by the vendor_id column, for example, only one row is returned for each vendor, and that vendor is summarized by the aggregate functions that are included in the SELECT clause. Aggregate window functions are similar except that the groups, or *partitions*, aren't collapsed to a single row. Instead, all of the rows in the result set are returned.

Figure 6-9 illustrates how this works. To start, you code an aggregate window function by including the OVER clause. This clause defines the window that's used by the aggregate function. A *window* consists of all of the rows that are needed to evaluate the function for the current row.

The first example in this figure shows a SELECT statement that includes two aggregate window functions. Both of these functions use the SUM function to calculate a total of the invoice_total column. However, the OVER clause for the first function is empty, which means that all of the rows in the result set are included in a single partition. Because of that, the total_invoices column contains the same value for each column, which is the total of all of the invoices in the result set. In this case, to calculate the total of all invoices, the SUM function for each row needs a window into all of the other rows in the result set.

By contrast, the second window function in this query uses the PARTITION BY clause to partition the result set by the vendor_id column. That way, the sum of the invoice totals is calculated for each vendor instead of for all vendors. You can see the result of this function in the vendor_total column. In this case, to calculate the total of all invoices for each vendor, the SUM function for each row needs a window into all the other rows for the same vendor. That means that if the first row for vendor 110 is the current row, it needs a window into the other four rows for that vendor.

If you want to sort the rows within each partition, you can code the ORDER BY clause on the OVER clause. This is illustrated by the second example in this figure. Here, the second aggregate window function indicates that the invoices for each vendor should be sorted by the invoice_total column. If you compare the sequence of the invoices for vendor 110 in this result set with the sequence in the first result set, you shouldn't have any trouble understanding how this works.

### The basic syntax of the OVER clause

```
OVER([PARTITION BY expression1 [, expression2]...
     [ORDER BY expression1 [ASC|DESC] [, expression2 [ASC|DESC]]...)
```

### A SELECT statement with two aggregate window functions

```
SELECT vendor_id, invoice_date, invoice_total,
       SUM(invoice_total) OVER() AS total_invoices,
       SUM(invoice_total) OVER(PARTITION BY vendor_id) AS vendor_total
FROM invoices
WHERE invoice_total > 5000
```

| vendor_id | invoice_date | invoice_total | total_invoices | vendor_total |
|---|---|---|---|---|
| 72 | 2022-06-01 | 21842.00 | 155800.00 | 21842.00 |
| 99 | 2022-06-18 | 6940.25 | 155800.00 | 6940.25 |
| 104 | 2022-05-21 | 7125.34 | 155800.00 | 7125.34 |
| 110 | 2022-05-28 | 37966.19 | 155800.00 | 119892.41 |
| 110 | 2022-07-19 | 26881.40 | 155800.00 | 119892.41 |
| 110 | 2022-07-23 | 20551.18 | 155800.00 | 119892.41 |
| 110 | 2022-07-24 | 23517.58 | 155800.00 | 119892.41 |
| 110 | 2022-07-31 | 10976.06 | 155800.00 | 119892.41 |

### A SELECT statement that includes a cumulative total

```
SELECT vendor_id, invoice_date, invoice_total,
       SUM(invoice_total) OVER() AS total_invoices,
       SUM(invoice_total) OVER(PARTITION BY vendor_id
           ORDER BY invoice_total) AS vendor_total
FROM invoices
WHERE invoice_total > 5000
```

| vendor_id | invoice_date | invoice_total | total_invoices | vendor_total |
|---|---|---|---|---|
| 72 | 2022-06-01 | 21842.00 | 155800.00 | 21842.00 |
| 99 | 2022-06-18 | 6940.25 | 155800.00 | 6940.25 |
| 104 | 2022-05-21 | 7125.34 | 155800.00 | 7125.34 |
| 110 | 2022-07-31 | 10976.06 | 155800.00 | 10976.06 |
| 110 | 2022-07-23 | 20551.18 | 155800.00 | 31527.24 |
| 110 | 2022-07-24 | 23517.58 | 155800.00 | 55044.82 |
| 110 | 2022-07-19 | 26881.40 | 155800.00 | 81926.22 |
| 110 | 2022-05-28 | 37966.19 | 155800.00 | 119892.41 |

### Description

- A *window* consists of all of the rows that are needed to calculate the aggregate value for the current row.
- The window functions can be used with all of the aggregate functions listed in figure 6-1. The groups, or *partitions*, in an *aggregate window function* are not collapsed to a single row.
- To treat an aggregate function as a window function, you include an OVER clause that indicates how to partition the rows in the result set.
- If you code an empty OVER clause, the entire result set is treated as a single partition.
- If you code an OVER clause with a PARTITION BY clause, the aggregate function is performed on each partition.
- If you code an ORDER BY clause on the OVER clause, the rows within each partition are sorted and the values from one row to the next are cumulative.

Figure 6-9 How the aggregate window functions work

Another difference between these two result sets are the values in the vendor_total column for vendor 110. That's because, when you code the ORDER BY clause, the *frame* includes all of the rows from the start of the partition through the current row.

For the SUM function, this means that the column contains a cumulative total for each vendor. To see how this works, you can compare the values in the vendor_total column with the values in the invoice_total column for vendor 110. Here, the values for the first row are the same. However, the second row in the vendor_total column contains the value of the first row plus the value of the second row in the invoice_total column. The third row in the vendor_total column contains the value of the second row plus the value of the third row in the invoice_total column. And so on.

## How to use frames

In addition to partitioning the rows in the result set for an aggregate function, you can create a frame that defines a subset of the current partition. Because a frame is relative to the current row, it can move within a partition as the current row changes. As you'll see, that makes it easy to calculate cumulative totals and moving averages.

Figure 6-10 shows the syntax for defining a frame. To start, you can code the ROWS or RANGE keyword. If you use ROWS, the frame is determined by the number of rows before and after the current row. If you use RANGE, the frame is determined by the value of the rows before and after the current row. In some cases, you can get the same result with either ROWS or RANGE. In other cases, though, you'll need to use one or the other to get the result you want. You'll see examples of that in a minute.

Following the ROWS or RANGE keyword, you can specify just the starting row for the frame or both the starting and ending rows. If you specify just the starting row, the ending row is the current row. To specify both a starting and ending row, you code a BETWEEN clause.

To indicate where a frame starts or ends, you can code any of the values in the table shown in this figure. To illustrate, the first example in this figure shows how to define a frame that includes the first row in the partition up to and including the current row. To do that, it uses the ROWS keyword followed by a BETWEEN clause that specifies the starting and ending rows. In this case, UNBOUNDED PRECEDING indicates that the frame starts at the first row in the partition, and CURRENT ROW indicates that the frame ends at the current row. Then, because the rows in the partitions are sorted, the column contains cumulative values.

Note that, because the frame ends at the current row, you could also define the frame like this:

```
ROWS UNBOUNDED PRECEDING
```

## The syntax for defining a frame

```
{ROWS | RANGE} {frame_start | BETWEEN frame_start AND frame_end}
```

## Possible values for frame_start and frame_end

| Value | Description |
|---|---|
| `CURRENT ROW` | The frame starts or ends with the current row. |
| `UNBOUNDED PRECEDING` | The frame starts or ends with the first row in the partition. |
| `UNBOUNDED FOLLOWING` | The frame starts or ends with the last row in the partition. |
| `expr PRECEDING` | With ROWS, the frame starts expr rows before the current row. With RANGE, the frame starts with the first row before the current row whose value is expr less than the value of the current row. |
| `expr FOLLOWING` | With ROWS, the frame starts expr rows after the current row. With RANGE, the frame starts with the last row after the current row whose value is expr greater than the value of the current row. |

## A SELECT statement that defines a frame

```
SELECT vendor_id, invoice_date, invoice_total,
       SUM(invoice_total) OVER() AS total_invoices,
       SUM(invoice_total) OVER(PARTITION BY vendor_id ORDER BY invoice_date
           ROWS BETWEEN UNBOUNDED PRECEDING AND CURRENT ROW)
           AS vendor_total
FROM invoices
WHERE invoice_date BETWEEN '2022-04-01' AND '2022-04-30'
```

| vendor_id | invoice_date | invoice_total | total_invoices | vendor_total |
|---|---|---|---|---|
| 89 | 2022-04-24 | 95.00 | 5828.18 | 95.00 |
| 95 | 2022-04-30 | 16.33 | 5828.18 | 16.33 |
| 96 | 2022-04-26 | 662.00 | 5828.18 | 662.00 |
| 121 | 2022-04-24 | 601.95 | 5828.18 | 601.95 |
| 122 | 2022-04-08 | 3813.33 | 5828.18 | 3813.33 |
| 123 | 2022-04-10 | 40.20 | 5828.18 | 40.20 |
| 123 | 2022-04-13 | 138.75 | 5828.18 | 178.95 |
| 123 | 2022-04-16 | 144.70 | 5828.18 | 323.65 |
| 123 | 2022-04-16 | 15.50 | 5828.18 | 339.15 |
| 123 | 2022-04-16 | 42.75 | 5828.18 | 381.90 |
| 123 | 2022-04-21 | 172.50 | 5828.18 | 554.40 |
| 123 | 2022-04-24 | 42.67 | 5828.18 | 597.07 |
| 123 | 2022-04-25 | 42.50 | 5828.18 | 639.57 |

## Description

- A *frame* can be defined as the number of rows before and after the current row (ROWS) or a range of values based on the value of the current row (RANGE).
- If you specify just the starting row for a frame, the ending row is the current row. To specify both a starting and ending row, you use the BETWEEN clause. When you use BETWEEN, the starting row for a frame must not come after the ending row.
- If an ORDER BY clause is included in the OVER clause and you use the ROWS keyword, values are accumulated up to and including the current row as shown above.

Figure 6-10 How to use frames (part 1 of 2)

In that case, the ending row defaults to the current row. You can also omit the frame definition entirely, since it's the default when you include ORDER BY on the OVER clause. You saw how that worked in the previous figure.

Part 2 of figure 6-10 presents two more queries that use frames. The first query is almost identical to the one in part 1 of this figure. The only difference is that it uses the RANGE keyword instead of the ROWS keyword. Because of that, the frame includes all of the rows within the partition, along with the current row and any of its peers. In this case, a *peer* is a row that has the same value as other rows in the sort column. In this example, for instance, the result set includes three invoices dated 2022-04-16 for vendor 123. If you look at the vendor_total column for these rows, you'll see that they all contain the same value. That's because the value of the invoice_total column for all three of these rows is included in the accumulation for the rows.

The second example in this figure illustrates a common use for frames. Here, a moving average is calculated for the invoice totals. A *moving average* is an average that's calculated on the current row plus a specified number of rows before and after the current row. It's particularly useful when working with data over a period of time to eliminate short-term fluctuations so long-term trends become more obvious.

In this example, a three-month average is calculated for the sum of invoice totals. To do that, the RANGE keyword is coded with a BETWEEN clause that indicates that the invoice total for the current month, one month before the current month, and one month after the current month should be used to calculate the average. The three-month average for month 5, for example, is calculated by adding the values in the invoice_total column for months 4, 5, and 6 and dividing by 3.

Note that when you calculate a moving average, there isn't a row before the first row to include in the average. Because of that, the average for that row includes just the invoice totals for the current row and the next row. Similarly, the average for the last row includes just the invoice totals for the current row and the previous row.

This query also uses the MONTH function in the SELECT clause, the ORDER BY clause for the OVER clause, and the GROUP BY clause. The MONTH function extracts the numeric month from a date. You'll learn about this function as well as other functions for working with dates in chapter 9.

### A SELECT statement that creates peer groups

```
SELECT vendor_id, invoice_date, invoice_total,
       SUM(invoice_total) OVER() AS total_invoices,
       SUM(invoice_total) OVER(PARTITION BY vendor_id ORDER BY invoice_date
           RANGE BETWEEN UNBOUNDED PRECEDING AND CURRENT ROW)
               AS vendor_total
FROM invoices
WHERE invoice_date BETWEEN '2022-04-01' AND '2022-04-30'
```

| vendor_id | invoice_date | invoice_total | total_invoices | vendor_total |
|---|---|---|---|---|
| 89 | 2022-04-24 | 95.00 | 5828.18 | 95.00 |
| 95 | 2022-04-30 | 16.33 | 5828.18 | 16.33 |
| 96 | 2022-04-26 | 662.00 | 5828.18 | 662.00 |
| 121 | 2022-04-24 | 601.95 | 5828.18 | 601.95 |
| 122 | 2022-04-08 | 3813.33 | 5828.18 | 3813.33 |
| 123 | 2022-04-10 | 40.20 | 5828.18 | 40.20 |
| 123 | 2022-04-13 | 138.75 | 5828.18 | 178.95 |
| 123 | 2022-04-16 | 144.70 | 5828.18 | 381.90 |
| 123 | 2022-04-16 | 15.50 | 5828.18 | 381.90 |
| 123 | 2022-04-16 | 42.75 | 5828.18 | 381.90 |
| 123 | 2022-04-21 | 172.50 | 5828.18 | 554.40 |
| 123 | 2022-04-24 | 42.67 | 5828.18 | 597.07 |
| 123 | 2022-04-25 | 42.50 | 5828.18 | 639.57 |

Peer group

### A SELECT statement that calculates moving averages

```
SELECT MONTH(invoice_date) AS month, SUM(invoice_total) AS total_invoices,
       ROUND(AVG(SUM(invoice_total)) OVER(ORDER BY MONTH(invoice_date)
           RANGE BETWEEN 1 PRECEDING AND 1 FOLLOWING), 2) AS 3_month_avg
FROM invoices
GROUP BY MONTH(invoice_date)
```

| month | total_invoices | 3_month_avg |
|---|---|---|
| 4 | 5828.18 | 32212.64 |
| 5 | 58597.10 | 39614.34 |
| 6 | 54417.73 | 69370.19 |
| 7 | 95095.75 | 49955.08 |
| 8 | 351.75 | 47723.75 |

### Description

- If an ORDER BY clause is included in the OVER clause and you use the RANGE keyword, values are accumulated up to and including the current row as well as its peer rows. A *peer* is a row that's in the same sort sequence as other rows in the partition as shown by the first example above.
- You can use a frame to calculate a moving average. A *moving average* is calculated by adding the value of the current row to the values of zero or more preceding and following rows.
- Because there are no preceding rows for the first row in a partition, the moving average for that row consists of the average of the value of the current row plus the values of the following rows. Similarly, the moving average for the last row consists of the average of the value of the current row plus the values of the previous rows.

## How to use named windows

In some cases, you'll need to code a SELECT statement with two or more aggregate functions that use the same window. Then, you may want to use a *named window* so you don't have to repeat the definition for the window for each function. Figure 6-11 shows how to define and use a named window.

The first example in this figure shows a SELECT statement that includes four aggregate functions. Each function includes an OVER clause that partitions the rows in the result set by the vendor_id column. To do that, the PARTITION BY clause is repeated on each OVER clause.

An easier way to do this is to name the window by coding a WINDOW clause as shown in the second example. Here, the window is named vendor_window, and it's defined with the PARTITION BY clause. Then, the four aggregate functions include just the window name on the OVER clause. In other words, they don't have to repeat the PARTITION BY clause. Note that when you code just a window name, you don't enclose it in parentheses.

If you review the code in this example, you might wonder why you would use a named window. After all, the code isn't any simpler since the window definition consists of only a PARTITION BY clause. The answer is that if you wanted to change the window definition, you would only need to do it in one place. Of course, window names provide even more of an advantage as your window definitions get more complex.

The third example in this figure shows how you can modify a window definition when you use it. To do that, you can add a PARTITION BY or ORDER BY clause or a frame definition. In this example, the named window partitions the rows in the result set by the vendor_id column just like the second example. Then, the SELECT clause includes two columns that sum the invoice totals for each vendor. Both columns use the named window, but they sort the totals in a different sequence. To do that, the window name is followed by an ORDER BY clause, and both the name and clause are enclosed in parentheses.

When you use named windows, you should know that you can't modify any of the clauses that are included in the window definition. For example, because the window in the third example includes a PARTITION BY clause, you can't include that clause on an OVER clause that uses the named window. Instead, you can only add to the window definition.

### The syntax for naming a window

```
WINDOW window_name AS ([partition_clause] [order_clause] [frame_clause])
```

### A SELECT statement with four functions that use the same window

```
SELECT vendor_id, invoice_date, invoice_total,
       SUM(invoice_total) OVER(PARTITION BY vendor_id) AS vendor_total,
       ROUND(AVG(invoice_total) OVER(PARTITION BY vendor_id), 2) AS vendor_avg,
       MAX(invoice_total) OVER(PARTITION BY vendor_id) AS vendor_max,
       MIN(invoice_total) OVER(PARTITION BY vendor_id) AS vendor_min
FROM invoices
WHERE invoice_total > 5000
```

### A SELECT statement with a named window

```
SELECT vendor_id, invoice_date, invoice_total,
       SUM(invoice_total) OVER vendor_window AS vendor_total,
       ROUND(AVG(invoice_total) OVER vendor_window, 2) AS vendor_avg,
       MAX(invoice_total) OVER vendor_window AS vendor_max,
       MIN(invoice_total) OVER vendor_window AS vendor_min
FROM invoices
WHERE invoice_total > 5000
WINDOW vendor_window AS (PARTITION BY vendor_id)
```

### The result set for both statements

| vendor_id | invoice_date | invoice_total | vendor_total | vendor_avg | vendor_max | vendor_min |
|---|---|---|---|---|---|---|
| 72 | 2022-06-01 | 21842.00 | 21842.00 | 21842.00 | 21842.00 | 21842.00 |
| 99 | 2022-06-18 | 6940.25 | 6940.25 | 6940.25 | 6940.25 | 6940.25 |
| 104 | 2022-05-21 | 7125.34 | 7125.34 | 7125.34 | 7125.34 | 7125.34 |
| 110 | 2022-05-28 | 37966.19 | 119892.41 | 23978.48 | 37966.19 | 10976.06 |
| 110 | 2022-07-19 | 26881.40 | 119892.41 | 23978.48 | 37966.19 | 10976.06 |
| 110 | 2022-07-23 | 20551.18 | 119892.41 | 23978.48 | 37966.19 | 10976.06 |
| 110 | 2022-07-24 | 23517.58 | 119892.41 | 23978.48 | 37966.19 | 10976.06 |
| 110 | 2022-07-31 | 10976.06 | 119892.41 | 23978.48 | 37966.19 | 10976.06 |

### A SELECT statement that adds to the specification for a named window

```
SELECT vendor_id, invoice_date, invoice_total,
       SUM(invoice_total) OVER (vendor_window ORDER BY invoice_date ASC)
           AS invoice_date_asc,
       SUM(invoice_total) OVER (vendor_window ORDER BY invoice_date DESC)
           AS invoice_date_desc
FROM invoices
WHERE invoice_total > 5000
WINDOW vendor_window AS (PARTITION BY vendor_id)
```

### Description

- To define a *named window*, you code a WINDOW clause. This clause should be coded after the HAVING clause and before the ORDER BY clause, if those clauses are included.
- To use a named window, you code it on the OVER clause. If you code just the window name, you don't include parentheses.
- If a WINDOW clause doesn't include a PARTITION BY or ORDER BY clause or a frame definition, you can add it to the window when you use it.

Figure 6-11 How to use named windows

# Perspective

In this chapter, you learned how to code queries that group and summarize data. In most cases, you'll be able to use the techniques presented here to get the summary information you need.

## Terms

scalar function
aggregate function
column function
summary query
functionally dependent column
aggregate window function
partition
window
frame
peer
moving average
named window

## Exercises

1. Write a SELECT statement that returns one row for each vendor in the Invoices table that contains these columns:

   The vendor_id column from the Invoices table

   The sum of the invoice_total columns in the Invoices table for that vendor

   This should return 34 rows.

2. Write a SELECT statement that returns one row for each vendor that contains these columns:

   The vendor_name column from the Vendors table

   The sum of the payment_total columns in the Invoices table for that vendor

   Sort the result set in descending sequence by the payment total sum for each vendor.

3. Write a SELECT statement that returns one row for each vendor that contains three columns:

   The vendor_name column from the Vendors table

   The count of the invoices in the Invoices table for each vendor

   The sum of the invoice_total columns in the Invoices table for each vendor

   Sort the result set so the vendor with the most invoices appears first.

4. Write a SELECT statement that returns one row for each general ledger account number that contains three columns:

   The account_description column from the General_Ledger_Accounts table

   The count of the items in the Invoice_Line_Items table that have the same account_number

The sum of the line_item_amount columns in the Invoice_Line_Items table that have the same account_number

Return only those rows where the count of line items is greater than 1. This should return 10 rows.

Group the result set by the account_description column.

Sort the result set in descending sequence by the sum of the line item amounts.

5. Modify the solution to exercise 4 so it returns only invoices dated in the second quarter of 2022 (April 1, 2022 to June 30, 2022). This should still return 10 rows but with some different line item counts for each vendor. *Hint: Join to the Invoices table to code a search condition based on invoice_date.*

6. Write a SELECT statement that answers this question: What is the total amount invoiced for each general ledger account number? Return these columns:

   The account_number column from the Invoice_Line_Items table

   The sum of the line_item_amount columns from the Invoice_Line_Items table

   Use the WITH ROLLUP operator to include a row that gives the grand total. This should return 22 rows.

7. Write a SELECT statement that answers this question: Which vendors are being paid from more than one account? Return these columns:

   The vendor_name column from the Vendors table

   The count of distinct general ledger accounts that apply to that vendor's invoices

   This should return 2 rows.

8. Write a SELECT statement that answers this question: What are the last payment date and total amount due for each vendor with each terms id? Return these columns:

   The terms_id column from the Invoices table

   The vendor_id column from the Invoices table

   The last payment date for each combination of terms id and vendor id in the Invoices table

   The sum of the balance due (invoice_total - payment_total - credit_total) for each combination of terms id and vendor id in the Invoices table

   Use the WITH ROLLUP operator to include rows that give a summary for each terms id as well as a row that gives the grand total. This should return 40 rows.

   Use the IF and GROUPING functions to replace the null values in the terms_id and vendor_id columns with literal values if they're for summary rows.

9. Write a SELECT statement that uses aggregate window functions to calculate the total due for all vendors and the total due for each vendor. Return these columns:

   The vendor id from the Invoices table

   The balance due (invoice_total - payment_total - credit_total) for each invoice in the Invoices table with a balance due greater than 0

   The total balance due for all vendors in the Invoices table

   The total balance due for each vendor in the Invoices table

   Modify the column that contains the balance due for each vendor so it contains a cumulative total by balance due. This should return 11 rows.

10. Modify the solution to exercise 9 so it includes a column that calculates the average balance due for each vendor in the Invoices table. This column should contain a cumulative average by balance due.

    Modify the SELECT statement so it uses a named window for the last two aggregate window functions.

11. Write a SELECT statement that uses an aggregate window function to calculate a moving average of the sum of invoice totals. Return these columns:

    The month of the invoice date from the Invoices table

    The sum of the invoice totals from the Invoices table

    The moving average of the invoice totals sorted by invoice month

    The result set should be grouped by invoice month and the frame for the moving average should include the current row plus three rows before the current row.

# 7

# How to code subqueries

Subqueries allow you to build queries that would be difficult or impossible to build otherwise. In chapter 5, you learned how to use them in INSERT, UPDATE, and DELETE statements. In this chapter, you'll learn how to use subqueries in SELECT statements.

# An introduction to subqueries

As you learned in chapter 5, a *subquery* is a SELECT statement that's coded within another SQL statement. Since you already know how to code SELECT statements, you already know how to code subqueries. Now you just need to learn where you can code them and when you should use them.

## Where to code subqueries

Figure 7-1 shows that a subquery can be coded, or *introduced*, in the WHERE, HAVING, FROM, or SELECT clause of a SELECT statement. In this figure, for example, the SELECT statement shows how you can use a subquery in a WHERE clause. This statement retrieves all the invoices from the Invoices table that have invoice totals greater than the average of all the invoices. To do that, the subquery calculates the average of all the invoices. Then, the search condition tests each invoice to see if its invoice total is greater than that average.

When a subquery returns a single value as it does in this example, you can use it anywhere you would normally use a single value. However, a subquery can also return a list of values (a result set that has one column). In that case, you can use the subquery in place of a list of values, such as the list for an IN operator. In addition, a subquery can return a table of values (a result set that has multiple columns). In that case, you can use the subquery in the FROM clause in place of a table. In this chapter, you'll learn about all of these different types of subqueries.

Finally, you can code a subquery within another subquery. In that case, the subqueries are said to be nested. Because *nested subqueries* can be difficult to read, you should use them only when necessary.

## Four ways to introduce a subquery in a SELECT statement

1. In a WHERE clause as a search condition
2. In a HAVING clause as a search condition
3. In the FROM clause as a table specification
4. In the SELECT clause as a column specification

## Use a subquery in the WHERE clause

```
SELECT invoice_number, invoice_date, invoice_total
FROM invoices
WHERE invoice_total >
    (SELECT AVG(invoice_total)
     FROM invoices)
ORDER BY invoice_total
```

## The value returned by the subquery

```
1879.741316
```

## The result set

| invoice_number | invoice_date | invoice_total |
|---|---|---|
| 989319-487 | 2022-06-20 | 1927.54 |
| 97/522 | 2022-06-28 | 1962.13 |
| 989319-417 | 2022-07-23 | 2051.59 |
| 989319-427 | 2022-06-16 | 2115.81 |
| 989319-477 | 2022-06-08 | 2184.11 |

(21 rows)

## Description

- A *subquery* is a SELECT statement that's coded within another SQL statement. For this to work, you must enclose the subquery in parentheses.
- A subquery can return a single value, a list of values (a result set that has a single column), or a table of values (a result set that has multiple columns).
- A subquery can be coded, or *introduced*, anywhere a single value, a list of values, or a table is allowed.
- The syntax for a subquery is the same as for a standard SELECT statement. However, a subquery can't include an ORDER BY clause.
- Subqueries can be *nested* within other subqueries.

Figure 7-1 Where to code subqueries

## When to use subqueries

In the last figure, you saw an example of a subquery that returns an aggregate value that's used in the search condition of a WHERE clause. This type of subquery provides for processing that can't be done any other way. However, most subqueries can be restated as joins, and most joins can be restated as subqueries as shown by the SELECT statements in figure 7-2.

Both SELECT statements in this figure return a result set that consists of selected rows and columns from the Invoices table. In this case, only the invoices for vendors in California are returned.

The first statement uses a join to combine the Vendors and Invoices tables so the vendor_state column can be tested for each invoice. In contrast, the second statement uses a subquery to return a result set that consists of the vendor_id column for each vendor in California. Then, that result set is used with the IN operator in the search condition so only invoices with a vendor_id in that result set are included in the final result set.

So if you have a choice, which technique should you use? In general, I recommend that you use the technique that results in the most readable code. For example, a join tends to be more intuitive than a subquery when it uses an existing relationship between two tables. That's the case with the Vendors and Invoices tables used in this figure. On the other hand, a subquery tends to be more intuitive when it uses an ad hoc relationship.

You should also realize that when you use a subquery in a WHERE clause, its results can't be included in the final result set. For instance, the second example in this figure can't be changed to include the vendor_name column from the Vendors table. That's because the Vendors table isn't named in the FROM clause of the main query. So if you need to include information from both tables in the result set, you need to use a join.

### A query that uses an inner join

```
SELECT invoice_number, invoice_date, invoice_total
FROM invoices JOIN vendors
    ON invoices.vendor_id = vendors.vendor_id
WHERE vendor_state = 'CA'
ORDER BY invoice_date
```

### The same query restated with a subquery

```
SELECT invoice_number, invoice_date, invoice_total
FROM invoices
WHERE vendor_id IN
    (SELECT vendor_id
     FROM vendors
     WHERE vendor_state = 'CA')
ORDER BY invoice_date
```

### The result set returned by both queries

| invoice_number | invoice_date | invoice_total |
|---|---|---|
| 125520-1 | 2022-04-24 | 95.00 |
| 97/488 | 2022-04-24 | 601.95 |
| 111-92R-10096 | 2022-04-30 | 16.33 |
| 25022117 | 2022-05-01 | 6.00 |
| P02-88D77S7 | 2022-05-03 | 856.92 |

(40 rows)

### Advantages of joins

- The SELECT clause of a join can include columns from both tables.
- A join tends to be more intuitive when it uses an existing relationship between the two tables, such as a primary key to foreign key relationship.

### Advantages of subqueries

- You can use a subquery to pass an aggregate value to the main query.
- A subquery tends to be more intuitive when it uses an ad hoc relationship between the two tables.
- Long, complex queries can sometimes be easier to code using subqueries.

### Description

- Like a join, a subquery can be used to code queries that work with two or more tables.
- Most subqueries can be restated as joins and most joins can be restated as subqueries.

Figure 7-2 When to use subqueries

# How to code subqueries in the WHERE clause

You can use a variety of techniques to work with a subquery in a WHERE clause. You'll learn about these techniques in the topics that follow.

## How to use the IN operator

In chapter 3, you learned how to use the IN operator to test whether an expression is contained in a list of values. One way to provide that list of values is to use a subquery as shown by figure 7-3.

The example in this figure retrieves the vendors from the Vendors table that don't have invoices in the Invoices table. To do that, it uses a subquery to return a list of IDs for each vendor that's in the Invoices table. Then, the main query returns the ID, name, and state for the vendors whose IDs aren't in that list.

When you use the IN operator with a subquery, the subquery must return a single column that provides the list of values. In this figure, the subquery also includes the DISTINCT keyword. That way, if more than one invoice exists for a vendor, the subquery only includes a single ID for the vendor. Although that can make the main query more efficient, this keyword is optional and has no effect on the final result set.

In the previous figure, you saw that a query that uses a subquery with the IN operator can be restated using an inner join. Similarly, a query that uses a subquery with the NOT IN operator can typically be restated using an outer join. In this figure, for instance, the first query can be restated as shown in the second query. In this case, though, the first query is more readable.

## The syntax of a WHERE clause that uses an IN phrase

```
WHERE test_expression [NOT] IN (subquery)
```

## Get vendors without invoices

```
SELECT vendor_id, vendor_name, vendor_state
FROM vendors
WHERE vendor_id NOT IN
    (SELECT DISTINCT vendor_id
     FROM invoices)
ORDER BY vendor_id
```

## The result of the subquery

| vendor_id |
|---|
| 34 |
| 37 |
| 48 |
| 72 |
| 80 |
| 81 |
| 82 |

(34 rows)

## The result set

| vendor_id | vendor_name | vendor_state |
|---|---|---|
| 33 | Nielson | OH |
| 35 | Cal State Termite | CA |
| 36 | Graylift | CA |
| 38 | Venture Communications Int'l | NY |
| 39 | Custom Printing Company | MO |
| 40 | Nat Assoc of College Stores | OH |

(88 rows)

## The query restated without a subquery

```
SELECT v.vendor_id, vendor_name, vendor_state
FROM vendors v LEFT JOIN invoices i
    ON v.vendor_id = i.vendor_id
WHERE i.vendor_id IS NULL
ORDER BY v.vendor_id
```

## Description

- The IN operator allows you to test if a value is in a list of values returned by a subquery.
- When you use the IN operator, the subquery must return a single column of values.
- A query that uses the NOT IN operator with a subquery can typically be restated using an outer join.

Figure 7-3 How to use the IN operator

## How to use the comparison operators

Figure 7-4 shows how you can use the comparison operators to compare an expression with the result of a subquery. In this example, the subquery returns the average balance due of the invoices in the Invoices table that have a balance due greater than zero. Then, it uses that value to retrieve all invoices with a balance due that's less than the average.

When you use a comparison operator as shown in this figure, the subquery must return a single value. In most cases, that means that it uses an aggregate function. However, you can also use comparison operators with subqueries that return a list of values. To do that, you use the SOME, ANY, or ALL keywords as shown in the next two figures.

## The syntax of a WHERE clause that uses a comparison operator

```
WHERE expression comparison_operator [SOME|ANY|ALL] (subquery)
```

## Get invoices with a balance due less than the average

```
SELECT invoice_number, invoice_date,
    invoice_total - payment_total - credit_total AS balance_due
FROM invoices
WHERE invoice_total - payment_total - credit_total > 0
  AND invoice_total - payment_total - credit_total <
    (
     SELECT AVG(invoice_total - payment_total - credit_total)
     FROM invoices
     WHERE invoice_total - payment_total - credit_total > 0
    )
ORDER BY invoice_total DESC
```

## The value returned by the subquery

```
2910.947273
```

## The result set

| invoice_number | invoice_date | balance_due |
|---|---|---|
| 31361833 | 2022-07-21 | 579.42 |
| 9982771 | 2022-07-24 | 503.20 |
| 547480102 | 2022-08-01 | 224.00 |
| 134116 | 2022-07-28 | 90.36 |
| 39104 | 2022-07-10 | 85.31 |

(9 rows)

## Description

- You can use a comparison operator in a WHERE clause to compare an expression with the results of a subquery.
- If you code a search condition without the ANY, SOME, and ALL keywords, the subquery must return a single value.
- If you include the ANY, SOME, or ALL keyword, the subquery can return a list of values.

Figure 7-4 How to use the comparison operators

## How to use the ALL keyword

Figure 7-5 shows how to use the ALL keyword to modify a comparison operator so the condition must be true for all the values returned by a subquery. The table at the top of this figure shows how this works. Here, the values in parentheses represent the values returned by the query.

If you use the greater than operator (>), the expression must be greater than the largest value returned by the subquery. Conversely, if you use the less than operator (<), the expression must be less than the smallest value returned by the subquery. If you use the equal operator (=), all of the values returned by the subquery must be the same and the expression must be equal to that value. And if you use the not equal operator (<>), the expression must not equal any of the values returned by the subquery. However, a not equal condition can be restated using the NOT IN operator, which is usually easier to read. As a result, it's a better practice to use the NOT IN operator for this type of condition.

The query in this figure shows how to use the greater than operator with the ALL keyword. Here, the subquery selects the invoice_total column for all the invoices with a vendor_id value of 34. This results in a list of two values. Then, the main query retrieves the rows from the Invoices table that have invoice totals greater than both of the values returned by the subquery. In other words, this query returns all the invoices that have totals greater than 1083.58, which is the largest invoice for vendor number 34.

When you use the ALL keyword, the comparison evaluates to true if the subquery doesn't return any rows. In contrast, the comparison evaluates to false if the subquery returns only null values.

In many cases, you can rewrite a condition that uses the ALL keyword so it's easier to read. For example, you could rewrite the query in this figure to use the MAX function like this:

```
WHERE invoice_total >
    (SELECT MAX(invoice_total)
     FROM invoices
     WHERE vendor_id = 34)
```

As a result, we recommend replacing the ALL keyword with an equivalent condition whenever it makes the query easier to read.

## How the ALL keyword works

| Condition | Equivalent expression | Description |
|---|---|---|
| `x > ALL (1, 2)` | `x > 2` | Evaluates to true if x is greater than the largest value returned by the subquery. |
| `x < ALL (1, 2)` | `x < 1` | Evaluates to true if x is less than the smallest value returned by the subquery. |
| `x = ALL (1, 2)` | `(x = 1) AND (x = 2)` | Evaluates to true if the subquery returns a single value that's equal to x or if the subquery returns multiple values that are the same and these values are all equal to x. |
| `x <> ALL (1, 2)` | `x NOT IN (1, 2)` | Evaluates to true if x is not one of the values returned by the subquery. |

## Get invoices greater than the largest invoice for vendor 34

```
SELECT vendor_name, invoice_number, invoice_total
FROM invoices i JOIN vendors v ON i.vendor_id = v.vendor_id
WHERE invoice_total > ALL
    (SELECT invoice_total
     FROM invoices
     WHERE vendor_id = 34)
ORDER BY vendor_name
```

## The result of the subquery

| invoice_total |
|---|
| 116.54 |
| 1083.58 |

## The result set

| vendor_name | invoice_number | invoice_total |
|---|---|---|
| Bertelsmann Industry Svcs. Inc | 509786 | 6940.25 |
| Cahners Publishing Company | 587056 | 2184.50 |
| Computerworld | 367447 | 2433.00 |
| Data Reproductions Corp | 40318 | 21842.00 |

(25 rows)

## Description

- You can use the ALL keyword to test if a condition is true for all of the values returned by a subquery.
- If no rows are returned by the subquery, a comparison that uses the ALL keyword is always true.
- If all of the rows returned by the subquery contain a null value, a comparison that uses the ALL keyword is always false.

## How to use the ANY and SOME keywords

Figure 7-6 shows how to use the ANY and SOME keywords to test whether a comparison is true for any of the values returned by a subquery. Since both of these keywords work the same way, you can use whichever one you prefer. Although this book uses the ANY keyword in its examples, you can substitute the SOME keyword for the ANY keyword to get the same results.

The example in this figure shows how you can use the ANY keyword with the less than operator. This statement is similar to the one you saw in the previous figure, except that it retrieves invoices with invoice totals that are less than at least one of the invoice totals for a given vendor. Like the statement in the previous figure, this condition can be rewritten using the MAX function, as follows:

```
WHERE invoice_total <
    (SELECT MAX(invoice_total)
     FROM invoices
     WHERE vendor_id = 115)
```

Since this statement is easier to read, we recommend using statements like this one instead of statements that use the ANY keyword whenever possible.

### How the ANY keyword works

| Condition | Equivalent expression | Description |
|---|---|---|
| `x > ANY (1, 2)` | `x > 1` | Evaluates to true if x is greater than the smallest value returned by the subquery. |
| `x < ANY (1, 2)` | `x < 2` | Evaluates to true if x is less than the largest value returned by the subquery. |
| `x = ANY (1, 2)` | `x IN (1, 2)` | Evaluates to true if x is equal to any of the values returned by the subquery. |
| `x <> ANY (1, 2)` | `(x <> 1) OR (x <> 2)` | Evaluates to true if x is not equal to at least one of the values returned by the subquery. |

### Get invoices smaller than the largest invoice for vendor 115

```
SELECT vendor_name, invoice_number, invoice_total
FROM vendors JOIN invoices ON vendors.vendor_id = invoices.vendor_id
WHERE invoice_total < ANY
    (SELECT invoice_total
     FROM invoices
     WHERE vendor_id = 115)
```

### The result of the subquery

| invoice_total |
|---|
| 6.00 |
| 6.00 |
| 25.67 |
| 6.00 |

### The result set

| vendor_name | invoice_number | invoice_total |
|---|---|---|
| Federal Express Corporation | 963253251 | 15.50 |
| Pacific Bell | 111-92R-10096 | 16.33 |
| Roadway Package System, Inc | 25022117 | 6.00 |
| Compuserve | 21-4748363 | 9.95 |
| Federal Express Corporation | 4-321-2596 | 10.00 |

```
(17 rows)
```

### Description

- You can use the ANY keyword to test if a condition is true for at least one of the values returned by a subquery.
- If the subquery doesn't return any values, or if it only returns null values, a comparison that uses the ANY keyword evaluates to false.
- The SOME keyword works the same as the ANY keyword.

Figure 7-6 How to use the ANY and SOME keywords

## How to code correlated subqueries

So far, all of the subqueries in this chapter have been uncorrelated subqueries. An *uncorrelated subquery* is executed only once for the entire query. However, you can also code a *correlated subquery* that's executed once for each row that's processed by the main query. This type of query is similar to using a loop to do repetitive processing in a procedural programming language like PHP or Java.

Figure 7-7 shows how correlated subqueries work. The example retrieves rows from the Invoices table for those invoices that have an invoice total that's greater than the average of all the invoices for the same vendor. To do that, the WHERE clause of the subquery refers to the vendor_id value of the main query. That way, only the invoices for the current vendor are included in the average.

Each time MySQL processes a row in the main query, it substitutes the value in the vendor_id column for the column reference in the subquery. Then, MySQL executes the subquery based on that value. For example, if the vendor_id value is 95, MySQL executes this subquery:

```
SELECT AVG(invoice_total)
FROM invoices
WHERE vendor_id = 95
```

After MySQL executes this subquery, it uses the returned value to determine whether to include the current invoice in the result set. For example, for vendor 95, the subquery returns a value of 28.501667. Then, MySQL compares that value with the invoice total of the current invoice. If the invoice total is greater than that value, MySQL includes the invoice in the result set. Otherwise, it doesn't. MySQL repeats this process until it has processed each of the invoices in the Invoices table.

In this figure, the WHERE clause of the subquery qualifies the vendor_id column from the main query with the alias that's assigned to the Invoices table in that query. This is necessary because this statement uses the same table in the sub and main queries. So, the use of a table alias avoids ambiguity. However, if a subquery uses a different table than the main query, a table alias isn't necessary.

Since correlated subqueries can be difficult to code, you may want to test a subquery separately before using it within another SELECT statement. To do that, however, you'll need to substitute a literal value for the variable that refers to a column in the outer query. That's what I did to get the average invoice total for vendor 95. Once you're sure that the subquery works on its own, you can replace the literal value with a reference to the outer query so you can use it within a SELECT statement.

### Get each invoice amount that's higher than the average for each vendor

```
SELECT vendor_id, invoice_number, invoice_total
FROM invoices i
WHERE invoice_total >
    (SELECT AVG(invoice_total)
     FROM invoices
     WHERE vendor_id = i.vendor_id)
ORDER BY vendor_id, invoice_total
```

### The value returned by the subquery for vendor 95

```
28.501667
```

### The result set

| vendor_id | invoice_number | invoice_total |
|---|---|---|
| 83 | 31359783 | 1575.00 |
| 95 | 111-92R-10095 | 32.70 |
| 95 | 111-92R-10093 | 39.77 |
| 95 | 111-92R-10092 | 46.21 |
| 110 | P-0259 | 26881.40 |

(36 rows)

### Description

- A *correlated subquery* is a subquery that is executed once for each row in the main query. In contrast, an *uncorrelated subquery* is executed only once. All of the subqueries in the previous figures are uncorrelated subqueries.
- A correlated subquery refers to a value that's provided by a column in the main query. For each different value that's returned by the main query for that column, the subquery returns a different result.
- To refer to a column in the main query, you can qualify the column with a table name or alias. If a correlated subquery uses the same table as the main query, you can use table aliases to remove ambiguity.

## How to use the EXISTS operator

Figure 7-8 shows how to use the EXISTS operator with a subquery. This operator tests whether the subquery returns a result set. In other words, it tests whether the result set exists. When you use this operator, the subquery doesn't actually return a result set to the outer query. Instead, it returns an indication of whether any rows satisfy the search condition of the subquery. Because of that, queries that use this operator execute quickly.

You typically use the EXISTS operator with a correlated subquery as shown in this figure. This query retrieves all the vendors in the Vendors table that don't have invoices in the Invoices table. Although this query returns the same vendors as the queries shown in figure 7-3, it executes more quickly than either of those queries.

In this example, the correlated subquery selects all invoices that have the same vendor_id value as the current vendor in the outer query. Because the subquery doesn't actually return a result set, it doesn't matter what columns are included in the SELECT clause. As a result, it's customary to just code an asterisk.

After the subquery is executed, the search condition in the WHERE clause of the main query uses the NOT EXISTS operator to test whether any invoices were found for the current vendor. If not, the vendor row is included in the result set.

## The syntax of a subquery that uses the EXISTS operator

```
WHERE [NOT] EXISTS (subquery)
```

## Get all vendors that don't have invoices

```
SELECT vendor_id, vendor_name, vendor_state
FROM vendors
WHERE NOT EXISTS
    (SELECT *
     FROM invoices
     WHERE vendor_id = vendors.vendor_id)
```

## The result set

| vendor_id | vendor_name | vendor_state |
|---|---|---|
| 33 | Nielson | OH |
| 35 | Cal State Termite | CA |
| 36 | Graylift | CA |
| 38 | Venture Communications Int'l | NY |
| 39 | Custom Printing Company | MO |
| 40 | Nat Assoc of College Stores | OH |

(88 rows)

## Description

- You can use the EXISTS operator to test if at least one row is returned by a subquery.
- You can use the NOT EXISTS operator to test if no rows are returned by a subquery.
- When you use these operators with a subquery, it doesn't matter what columns you specify in the SELECT clause. As a result, you typically just code an asterisk (*).

# How to code subqueries in other clauses

Now that you know how to code subqueries in the WHERE clause of a SELECT statement, you're ready to learn how to code them in the HAVING, FROM, and SELECT clauses.

## How to code subqueries in the HAVING clause

When you code a HAVING clause, you specify a search condition just as you do when you code a WHERE clause. That includes search conditions that contain subqueries. To learn how to code subqueries in a HAVING clause, then, you can refer back to figures 7-3 through 7-8.

## How to code subqueries in the SELECT clause

Figure 7-9 shows how to use subqueries in the SELECT clause. To do that, you code the subquery in place of a column specification. As a result, the subquery must return a single value for that column.

In most cases, you code correlated subqueries in the SELECT clause. In this figure, for example, the subquery calculates the maximum invoice date for each vendor in the Vendors table. To do that, the subquery refers to the vendor_id column from the Vendors table in the main query.

Subqueries coded in the SELECT clause are typically difficult to read. As a result, you shouldn't use them if you can find a more readable solution. In most cases, you can replace the subquery with a join. In this figure, for example, the first query can be restated as shown in the second query. This query joins the Vendors and Invoices tables, groups the rows by vendor_name, and uses the MAX function to calculate the maximum invoice date for each vendor. As a result, this query is easier to read.

### Get the most recent invoice date for each vendor

```
SELECT vendor_name,
    (SELECT MAX(invoice_date) FROM invoices
     WHERE vendor_id = vendors.vendor_id) AS latest_inv
FROM vendors
ORDER BY latest_inv DESC
```

### The result set

| vendor_name | latest_inv |
|---|---|
| Federal Express Corporation | 2022-08-02 |
| Blue Cross | 2022-08-01 |
| Malloy Lithographing Inc | 2022-07-31 |
| Cardinal Business Media, Inc. | 2022-07-28 |
| Zylka Design | 2022-07-25 |

(122 rows)

### The same query restated using a join

```
SELECT vendor_name, MAX(invoice_date) AS latest_inv
FROM vendors v
    LEFT JOIN invoices i ON v.vendor_id = i.vendor_id
GROUP BY vendor_name
ORDER BY latest_inv DESC
```

### Description

- When you code a subquery in the SELECT clause, the subquery must return a single value, and you typically use a correlated subquery.
- A query that includes a subquery in its SELECT clause can typically be restated using a join instead of the subquery. Because a join is usually faster and easier to read, subqueries are seldom coded in the SELECT clause.

Figure 7-9 How to code subqueries in the SELECT clause

## How to code subqueries in the FROM clause

Figure 7-10 shows how to code a subquery in the FROM clause. To do that, you code a subquery in place of a table specification. When you code a subquery in the FROM clause, it can return a result set that contains any number of rows and columns. This result set is sometimes referred to as an *inline view*.

Subqueries are typically used in the FROM clause to create inline views that provide summarized data to another summary query. In this figure, for example, the subquery returns a result set that contains the vendor state, the vendor name, and the sum of invoice totals for each vendor. To do that, it groups the vendors by state and name. Once the subquery returns this result set, the main query groups the result set by vendor state and gets the largest sum of invoice totals for a vendor in each state.

When you code a subquery in the FROM clause, you must assign a table alias to the subquery. This is required even if you don't use the table alias in the main query. In this figure, for example, the query assigns a table alias of *t* (for temporary table) to the subquery.

In addition, you should assign a column alias to all calculated columns in a subquery. In this figure, for example, the subquery assigns a column alias of sum_of_invoices to the result of the SUM function. That makes it easier to refer to these columns from other clauses in the subquery if you need to do that. It also makes it possible to refer to the column from the main query. In this example, for instance, the sum_of_invoices column is referred to by the SELECT clause.

### Get the largest sum of invoice totals for a vendor in each state

```
SELECT vendor_state, MAX(sum_of_invoices) AS max_sum_of_invoices
FROM
(
     SELECT vendor_state, vendor_name,
         SUM(invoice_total) AS sum_of_invoices
     FROM vendors v JOIN invoices i
         ON v.vendor_id = i.vendor_id
     GROUP BY vendor_state, vendor_name
) t
GROUP BY vendor_state
ORDER BY vendor_state
```

### The result of the subquery (an inline view)

| vendor_state | vendor_name | sum_of_invoices |
|---|---|---|
| NV | United Parcel Service | 23177.96 |
| TN | Federal Express Corporation | 4378.02 |
| CA | Evans Executone Inc | 95.00 |
| CA | Zylka Design | 6940.25 |
| AZ | Wells Fargo Bank | 662.00 |
| CA | Pacific Bell | 171.01 |
| CA | Roadway Package System, Inc | 43.67 |
| CA | Fresno County Tax Collector | 856.92 |

(34 rows)

### The result set

| vendor_state | max_sum_of_invoices |
|---|---|
| AZ | 662.00 |
| CA | 7125.34 |
| DC | 600.00 |

(10 rows)

### Description

- A subquery that's coded in the FROM clause returns a result set that can be referred to as an *inline view*.
- When you code a subquery in the FROM clause, you must assign an alias to it. Then, you can use that alias just as you would any other table name or alias.
- When you code a subquery in the FROM clause, you should use an alias for any columns in the subquery that perform calculations. Then, the inline view can use these aliases as the column names of the table, and the main query can refer to the columns by these names.

Figure 7-10 How to code subqueries in the FROM clause

# How to work with complex queries

So far, the examples you've seen of queries that use subqueries have been relatively simple. However, these types of queries can get complicated in a hurry, particularly if the subqueries are nested. Because of that, you'll want to be sure that you plan and test these queries carefully. In a moment, you'll learn how to do that. But first, this chapter presents an example of a complex query.

## A complex query that uses subqueries

Figure 7-11 presents a complex query that uses multiple subqueries. The first subquery is used in the FROM clause of the outer query to create a result set that contains the state, name, and total invoice amount for each vendor in the Vendors table. This is the same subquery that was described in figure 7-10.

The second subquery is also used in the FROM clause of the outer query to create a result set that's joined with the first result set. This result set contains the state and the sum of invoice totals for the vendor in each state that has the largest sum of invoice totals. To create this result set, a third subquery is nested within the FROM clause of the subquery. This subquery is identical to the first subquery.

After this statement creates the two result sets, it joins them based on the columns in each table that contain the state and the the sum of invoice totals. The final result set includes the state, name, and the sum of invoice totals for the vendor in each state with the largest sum of invoice totals. This result set is sorted by state.

At this point, you might be wondering if there is an easier solution to this problem. For example, you might think that you could solve the problem by joining the Vendors and Invoices tables, grouping by vendor state, and calculating the sum of invoices for each vendor. However, if you group by vendor state, you can't include the name of the vendor in the result set. And if you group by vendor state and vendor name, the result set includes all vendors, not just the top vendor from each state. As a result, the query presented here is a fairly straightforward way of solving the problem.

When you code a complex subquery, it's often helpful to include comments. You can use *comments* to describe the different parts of the query without changing how the query operates. To code a single-line comment, you start the line with two dashes (--).

In this figure, the query includes three comments. The first comment identifies the first subquery, the second comment identifies the second subquery, and the third comment identifies the third subquery. These comments make it easier to read the main query by making it easier to identify the three subqueries and determine what they do. For example, these comments clearly show that the subqueries that have aliases of t1 and t2 return the same result set.

## A complex query that uses three subqueries

```
SELECT t1.vendor_state, vendor_name, t1.sum_of_invoices
FROM
    (
        -- sum of invoice totals by vendor
        SELECT vendor_state, vendor_name,
            SUM(invoice_total) AS sum_of_invoices
        FROM vendors v JOIN invoices i
            ON v.vendor_id = i.vendor_id
        GROUP BY vendor_state, vendor_name
    ) t1
    JOIN
        (
            -- top sum of invoice totals by state
            SELECT vendor_state,
                   MAX(sum_of_invoices) AS sum_of_invoices
            FROM
            (
                 -- sum of invoice totals by vendor
                 SELECT vendor_state, vendor_name,
                     SUM(invoice_total) AS sum_of_invoices
                 FROM vendors v JOIN invoices i
                     ON v.vendor_id = i.vendor_id
                 GROUP BY vendor_state, vendor_name
            ) t2
            GROUP BY vendor_state
        ) t3
    ON t1.vendor_state = t3.vendor_state AND
       t1.sum_of_invoices = t3.sum_of_invoices
ORDER BY vendor_state
```

## The result set

| vendor_state | vendor_name | sum_of_invoices |
|---|---|---|
| AZ | Wells Fargo Bank | 662.00 |
| CA | Digital Dreamworks | 7125.34 |
| DC | Reiter's Scientific & Pro Books | 600.00 |
| MA | Dean Witter Reynolds | 1367.50 |

(10 rows)

## Description

- This query retrieves the vendor from each state that has the largest sum of invoice totals. To do that, it uses three subqueries.
- This query uses comments to clearly identify its three queries.
- The subqueries named t1 and t2 return the same result set. This result set includes the vendor state, name, and sum of invoice totals.
- The subquery named t3 returns a result set that includes the vendor state and the largest sum of invoices for any vendor in that state. To do that, this subquery uses a nested subquery named t2.
- The subqueries named t1 and t3 are joined on both the vendor_state and sum_of_invoices columns.

Figure 7-11 A complex query that uses subqueries

## A procedure for building complex queries

To build a complex query like the one in the previous figure, you can use a procedure like the one in figure 7-12. To start, you should state the question in plain language so you're clear about what you want the query to answer. In this case, the question is, "Which vendor in each state has the largest sum of invoice totals?"

Once you're clear about the problem, you can outline the query using *pseudocode*. Pseudocode is code that represents the intent of the query, but doesn't necessarily use SQL code. The pseudocode shown in this figure, for example, uses part SQL code and part English. This pseudocode identifies the three columns returned by the main query, two subqueries, and even the join condition for the two subqueries.

The next step in the procedure is to code and test the subqueries to be sure they work the way you want them to. For example, this figure shows the code for the first subquery along with its result set. This returns all of the data that you want, but it also includes extra rows that you don't want. To remove the extra rows from the first query, you can code the second subquery shown in this figure. This subquery uses the first subquery as a nested subquery. Although this removes the extra rows, it also removes the vendor_name column.

Once you're sure that both subqueries work the way you want them to, you can use them in the main query. For example, the pseudocode in this figure shows that you should join the result sets returned by the subqueries on the vendor_state and sum_of_invoices columns. In addition, the code in the previous figure shows how these two subqueries are used in the main query. This allows you to get all of the columns you want in the final result set without any of the extra rows that you don't want.

Writing complex queries can be difficult, but following a procedure like the one shown in this figure can make it a little easier. At first, you might not be able to use pseudocode to identify subqueries. In that case, it's OK to skip ahead to step 3 and begin experimenting with possible subqueries. This may give you some ideas for how to solve the problem. Once you get these subqueries working correctly, you can begin coding a main query, and you can cut and paste the subqueries into the main query.

### A procedure for building complex queries

1. State the problem to be solved by the query in plain language.
2. Use pseudocode to outline the query.
3. Code the subqueries and test them to be sure that they return the correct data.
4. Code and test the final query.

### The problem to be solved by the query in figure 7-11

Which vendor in each state has the largest sum of invoice totals?

### Pseudocode for the query

```
SELECT vendor_state, vendor_name, sum_of_invoices
FROM (subquery returning vendor_state, vendor_name, sum_of_invoices)
JOIN (subquery returning vendor_state, largest_sum_of_invoices)
    ON vendor_state AND sum_of_invoices
ORDER BY vendor_state
```

### The code for the first subquery

```
SELECT vendor_state, vendor_name, SUM(invoice_total) AS sum_of_invoices
FROM vendors v JOIN invoices i
    ON v.vendor_id = i.vendor_id
GROUP BY vendor_state, vendor_name
```

### The result set for the first subquery

| vendor_state | vendor_name | sum_of_invoices |
|---|---|---|
| NV | United Parcel Service | 23177.96 |
| TN | Federal Express Corporation | 4378.02 |
| CA | Evans Executone Inc | 95.00 |

(34 rows)

### The code for the second subquery

```
SELECT vendor_state, MAX(sum_of_invoices) AS sum_of_invoices
FROM
(
     SELECT vendor_state, vendor_name,
         SUM(invoice_total) AS sum_of_invoices
     FROM vendors v JOIN invoices i
         ON v.vendor_id = i.vendor_id
     GROUP BY vendor_state, vendor_name
) t
GROUP BY vendor_state
```

### The result set for the second subquery

| vendor_state | sum_of_invoices |
|---|---|
| NV | 23177.96 |
| TN | 4378.02 |
| CA | 7125.34 |

(10 rows)

Figure 7-12 A procedure for building complex queries

# How to work with common table expressions

A *common table expression (CTE)* allows you to code an expression that defines a named temporary result set. You can use CTEs to simplify complex queries that use subqueries. This can make your code easier to read and maintain. In addition, you can use a CTE to loop through nested structures.

## How to code a CTE

Figure 7-13 shows how to use a CTE to simplify the complex query presented in figure 7-11. To start, the statement for the query begins with the WITH keyword to indicate that you are about to define a CTE. Then, it specifies summary as the name for the first result set, followed by the AS keyword, followed by a SELECT statement enclosed in parentheses that defines the result set. In this figure, for example, this statement returns the same result set as the subqueries named t1 and t2 that were presented in figure 7-11.

After the first CTE is defined, this example continues by defining a second CTE named top_in_state. To start, a comma is coded to separate the two CTEs. Then, this query specifies top_in_state as the name for the second result set, followed by the AS keyword, followed by a SELECT statement enclosed in parentheses that defines the result set. This SELECT statement refers to the summary result set that was defined by the first CTE. When coding multiple CTEs like this, a CTE can refer to any CTEs in the same WITH clause that are coded before it, but it can't refer to CTEs coded after it. As a result, this statement wouldn't work if the two CTEs were coded in the reverse order.

Finally, the SELECT statement that's coded immediately after the two CTEs uses both of these CTEs just as if they were tables. To do that, this SELECT statement joins the two result sets, specifies the columns to retrieve, and specifies the sort order. To avoid ambiguous references, each column is qualified by the name for the CTE. If you compare figure 7-13 with figure 7-11, I think you'll agree that the code in figure 7-13 is easier to read. That's partly because the result sets defined by the subqueries aren't nested within the SELECT statement. In addition, I think you'll agree that the code in figure 7-13 is easier to maintain. That's because this query reduces code duplication by only coding the summary subquery in one place, not in two places.

When using the syntax shown here to define CTEs, you must supply distinct names for all columns defined by the SELECT statement, including calculated values. That way, it's possible for other statements to refer to the columns in the result set. Most of the time, that's all you need to know to be able to work with CTEs. For more information about working with CTEs, you can look up "WITH Syntax (Common Table Expressions)" in the documentation for MySQL.

## The syntax of a CTE

```
WITH [RECURSIVE] cte_name1 AS (subquery1)
[, cte_name2 AS (subquery2)]
[...]
sql_statement
```

## Two CTEs and a query that uses them

```
WITH summary AS
(
    SELECT vendor_state, vendor_name, SUM(invoice_total) AS sum_of_invoices
    FROM vendors v JOIN invoices i
        ON v.vendor_id = i.vendor_id
    GROUP BY vendor_state, vendor_name
),
top_in_state AS
(
    SELECT vendor_state, MAX(sum_of_invoices) AS sum_of_invoices
    FROM summary
    GROUP BY vendor_state
)
SELECT summary.vendor_state, summary.vendor_name,
       top_in_state.sum_of_invoices
FROM summary JOIN top_in_state
    ON summary.vendor_state = top_in_state.vendor_state AND
       summary.sum_of_invoices = top_in_state.sum_of_invoices
ORDER BY summary.vendor_state
```

## The result set

| vendor_state | vendor_name | sum_of_invoices |
|---|---|---|
| AZ | Wells Fargo Bank | 662.00 |
| CA | Digital Dreamworks | 7125.34 |
| DC | Reiter's Scientific & Pro Books | 600.00 |
| MA | Dean Witter Reynolds | 1367.50 |
| MI | Malloy Lithographing Inc | 119892.41 |
| NV | United Parcel Service | 23177.96 |
| OH | Edward Data Services | 207.78 |
| PA | Cardinal Business Media, Inc. | 265.36 |

(10 rows)

## Description

- A *common table expression (CTE)* is a SELECT statement that creates one or more named temporary result sets that can be used by the query that follows.
- To use a CTE, you code the WITH keyword followed by the definition of the CTE. Then, immediately after the CTE, you code the statement that uses it.
- To code multiple CTEs, separate them with commas. Then, each CTE can refer to itself and any previously defined CTEs in the same WITH clause.
- To code a recursive CTE, include the RECURSIVE keyword after the WITH keyword as shown in figure 7-14.
- Although you can use CTEs with INSERT, UPDATE, and DELETE statements, you're most likely to use them with SELECT statements.

Figure 7-13 How to code a CTE

## How to code a recursive CTE

A *recursive query* is a query that is able to loop through a result set and perform processing to return a final result set. Recursive queries are commonly used to return hierarchical data such as an organizational chart in which a parent element may have one or more child elements, and each child element may have one or more child elements. Prior to MySQL 8.0, a recursive query required using inline views, cursors, and logic to control the flow of the recursive steps. With MySQL 8.0 and later, you can use a *recursive CTE* to code recursive queries more easily. Figure 7-14 shows how.

The top of this figure shows an Employees table where the manager_id column is used to identify the manager for each employee. Here, Cindy Smith is the top level manager since she doesn't have a manager, Elmer Jones and Paulo Locario report to Cindy, and so on.

The recursive CTE shown in this figure returns each employee according to their level in the organization chart for the company. To do that, this statement begins by defining a CTE named employees_cte. Note here that the WITH clause includes the RECURSIVE keyword. This is required for recursive common table expressions. If you forget this keyword, you'll get error code 1146: "Table 'table_name' doesn't exist".

Within the CTE, two SELECT statements are joined by the UNION ALL operator. Here, the first SELECT statement uses the IS NULL operator to return the first row of the result set. Because this statement doesn't refer to the name of the CTE, it is non-recursive.

The second SELECT statement creates a loop by referring to the name of the CTE. Specifically, this statement joins the Employees table to the employees_cte result set that's defined by the CTE. Because of that, it is a recursive SELECT statement that loops through each row in the Employees table. With each loop, it adds 1 to the ranking column and appends the current result set to the final result set. For example, on the first loop, it appends Elmer Jones and Paulo Locario to the final result set. On the second loop, it appends Ralph Simonian, Thomas Hardy, Olivia Hernandez, and Rhea O'Leary to the final result set. And so on.

When coding a recursive CTE, you must follow some rules. First, you must supply a name for each column defined by the CTE. To do that, you just need to make sure to specify a name for each column in the non-recursive query. Second, the rules for coding a union that you learned in chapter 4 still apply. In particular, the two SELECT statements must have the same number of columns and the columns must have compatible data types.

Most of the time, that's all you need to know to be able to work with recursive CTEs. However, the goal of this topic is to show a simple recursive CTE to give you a general idea of how they work. For more information about working with recursive CTEs, you can start by looking up "WITH Syntax (Common Table Expressions)" in the documentation for MySQL and then clicking on the "Recursive Common Table Expressions" link.

## The Employees table

| employee_id | last_name | first_name | department_number | manager_id |
|---|---|---|---|---|
| 1 | Smith | Cindy | 2 | NULL |
| 2 | Jones | Elmer | 4 | 1 |
| 3 | Simonian | Ralph | 2 | 2 |
| 4 | Hernandez | Olivia | 1 | 9 |
| 5 | Aaronsen | Robert | 2 | 4 |
| 6 | Watson | Denise | 6 | 8 |
| 7 | Hardy | Thomas | 5 | 2 |
| 8 | O'Leary | Rhea | 4 | 9 |
| 9 | Locario | Paulo | 6 | 1 |

## A recursive CTE that returns hierarchical data

```
WITH RECURSIVE employees_cte AS
(
        -- Nonrecursive query
        SELECT employee_id,
            CONCAT(first_name, ' ', last_name) AS employee_name,
            1 AS ranking
        FROM employees
        WHERE manager_id IS NULL
    UNION ALL
        -- Recursive query
        SELECT employees.employee_id,
            CONCAT(first_name, ' ', last_name),
            ranking + 1
        FROM employees
            JOIN employees_cte
            ON employees.manager_id = employees_cte.employee_id
)
SELECT *
FROM employees_cte
ORDER BY ranking, employee_id
```

## The final result set

| employee_id | employee_name | ranking |
|---|---|---|
| 1 | Cindy Smith | 1 |
| 2 | Elmer Jones | 2 |
| 9 | Paulo Locario | 2 |
| 3 | Ralph Simonian | 3 |
| 4 | Olivia Hernandez | 3 |
| 7 | Thomas Hardy | 3 |
| 8 | Rhea O'Leary | 3 |
| 5 | Robert Aaronsen | 4 |
| 6 | Denise Watson | 4 |

## Description

- A *recursive query* is a query that can loop through a result set and perform processing to return a final result set. A *recursive CTE* can be used to create a recursive query.
- A recursive CTE contains a non-recursive SELECT statement followed by a recursive SELECT statement, and these two statements must be connected by the UNION or UNION ALL operator.

Figure 7-14 How to code a recursive CTE

# Perspective

Subqueries are a powerful tool that you can use to solve difficult problems. Before you use a subquery, however, remember that a subquery can often be restated more clearly by using a join. If so, you'll typically want to use a join instead of a subquery.

If you find yourself coding the same subqueries in multiple places, you should consider creating a view for that subquery as described in chapter 12. This will help you develop queries more quickly since you can use the view instead of coding the subquery again. In addition, since views typically execute more quickly than subqueries, this may improve the performance of your queries.

## Terms

subquery
introduce a subquery
nested subquery
correlated subquery
uncorrelated subquery
inline view
comment
pseudocode
common table expression (CTE)
recursive query
recursive CTE

## Exercises

1. Write a SELECT statement that returns the same result set as this SELECT statement, but don't use a join. Instead, use a subquery in a WHERE clause that uses the IN keyword.

```
SELECT DISTINCT vendor_name
FROM vendors JOIN invoices
    ON vendors.vendor_id = invoices.vendor_id
ORDER BY vendor_name
```

2. Write a SELECT statement that answers this question: Which invoices have a payment total that's greater than the average payment total for all invoices with a payment total greater than 0?

   Return the invoice_number and invoice_total columns for each invoice. This should return 20 rows.

   Sort the results by the invoice_total column in descending order.

3. Write a SELECT statement that returns two columns from the General_Ledger_Accounts table: account_number and account_description.

   Return one row for each account number that has never been assigned to any line item in the Invoice_Line_Items table. To do that, use a subquery introduced with the NOT EXISTS operator. This should return 54 rows.

   Sort the results by the account_number column.

4. Write a SELECT statement that returns four columns: vendor_name, invoice_id, invoice_sequence, and line_item_amount.

   Return a row for each line item of each invoice that has more than one line item in the Invoice_Line_Items table. *Hint: Use a subquery that tests for invoice_sequence > 1.* This should return 6 rows.

   Sort the results by the vendor_name, invoice_id, and invoice_sequence columns.

5. Write a SELECT statement that returns two columns: vendor_id and the largest unpaid invoice for each vendor. To do this, you can group the result set by the vendor_id column. This should return 7 rows.

   Write a second SELECT statement that uses the first SELECT statement in its FROM clause. The main query should return a single value that represents the sum of the largest unpaid invoices for each vendor.

6. Write a SELECT statement that returns the name, city, and state of each vendor that's located in a unique city and state. In other words, don't include vendors that have a city and state in common with another vendor. This should return 38 rows.

   Sort the results by the vendor_state and vendor_city columns.

7. Use a correlated subquery to return one row per vendor, representing the vendor's oldest invoice (the one with the earliest date). Each row should include these four columns: vendor_name, invoice_number, invoice_date, and invoice_total. This should return 34 rows.

   Sort the results by the vendor_name column.

8. Rewrite exercise 7 so it gets the same result but uses an inline view instead of a correlated subquery.

9. Rewrite exercise 5 so it uses a common table expression (CTE) instead of an inline view.

# 8

# How to work with data types

So far, you have been using SQL statements to work with the three most common types of data: strings, numbers, and dates. Now, this chapter takes a more in-depth look at the data types that are available with MySQL and shows some basic skills for working with them. When you complete this chapter, you'll have a thorough understanding of the data types, and you'll know how to use some functions to convert one data type to another.

# The data types

A column's *data type* specifies the kind of information the column is intended to store. In addition, a column's data type determines the operations that can be performed on the column.

## Overview

The MySQL data types can be divided into the categories shown in figure 8-1. To start, the *character data types* are intended for storing a string of one or more characters, which can include letters, numbers, symbols, or special characters. The terms *character*, *string*, and *text* are used interchangeably to describe this type of data.

The *numeric data types* are intended for storing numbers that can be used for mathematical calculations. As you'll see in this chapter, MySQL can store numbers in a variety of formats. At a basic level, you can divide numbers into two categories: integers and real numbers. *Integers* are numbers that don't have a decimal point, and *real numbers* are numbers that have a decimal point.

The *date and time data types* are intended for storing dates, times, or both dates and times. These data types are typically referred to as *date/time* or *temporal data types*.

Since the first three categories are the most widely used, this book focuses on these data types. However, MySQL also provides *binary data types* that are useful for storing encryption keys and hash values, as well as smaller image, audio, and video files. It also provides *large object (LOB) data types* that are useful for storing larger image, audio, and video files, as well as large amounts of character data. And it provides *spatial data types* that are useful for storing geographical values such as *global positioning system* (*GPS*) data. These data types are referred to as *geometry types* because they define a point or group of points that represent any location or area in the world.

Finally, MySQL provides the *JSON data type*, which is used to store *JavaScript Object Notation* (*JSON*) documents. Although you can store JSON documents in a character column, the JSON data type provides two advantages. First, when you store a JSON document in a JSON column, the document is automatically validated. Then, if it's invalid, an error occurs. Second, the internal storage format provides for quick access to the document.

## Data types

| Category | Description |
|---|---|
| Character | Strings of character data |
| Numeric | Numbers that don't include a decimal point (integers) and numbers that include a decimal point (real numbers) |
| Date and time | Dates, times, or both |
| Binary | Strings of binary data (bytes) |
| Large Object (LOB) | Large strings of character or binary data |
| Spatial | Geographical values |
| JSON | JSON documents |

## Description

- MySQL provides *data types* for storing many types of data.
- Numbers that don't include a decimal point are known as *integers*.
- Numbers that include a decimal point are known as *real numbers*.
- The *date and time data types* are often referred to as the *date/time* or *temporal data types*.
- The *binary data types* are useful for storing bytes of data that can't be represented as character strings, such as encryption keys, hash values, and smaller image, audio, and video files.
- The *large object (LOB) data types* are useful for storing images, audio, video, and large amounts of text.
- The *spatial data types* are useful for storing geometric or geographical values such as *global positioning system (GPS)* data. These data types are referred to as *geometry types*.
- The *JSON data type* is used for storing *JavaScript Object Notation (JSON)* documents.

Figure 8-1 Data type overview

## The character types

Figure 8-2 presents the two most common character data types supported by MySQL: CHAR and VARCHAR. These data types store strings of characters.

You use the CHAR type to store *fixed-length strings*. Data stored using this data type always occupies the same number of bytes regardless of the actual length of the string. To do that, MySQL appends spaces to the string if necessary so it is the correct length.

The CHAR data type is typically used to define columns that have a fixed number of characters. For example, the vendor_state column in the Vendors table is defined as CHAR(2) because it always contains 2 characters. However, if 2 characters are stored in a CHAR(10) column, MySQL appends eight spaces to the string so it contains 10 characters.

You use the VARCHAR data type to store *variable-length strings*. Data stored using this data type occupies only the number of bytes needed to store the string plus an extra byte to store the length of the string. This data type is typically used to define columns whose lengths vary from one row to the next. For example, the vendor_name column in the Vendors table is defined as VARCHAR(50) because the length of each vendor's name varies.

With MySQL 8.0 and later, the CHAR and VARCHAR types use the *utf8mb4 character set* by default. This character set uses up to four bytes to store each character. As a result, it's referred to as a *multiple-byte character set*. This allows the utf8mb4 character set to support the characters specified by the *Unicode standard*, which includes most characters from most of the world's languages.

When you use the utf8mb4 character set with a CHAR type, MySQL must reserve 4 bytes for each character. As a result, MySQL uses 8 bytes for the CHAR(2) type, and 40 bytes for the CHAR(10) type.

However, when you use the VARCHAR type, MySQL doesn't need to reserve space for each character. As a result, if you are using English letters, MySQL only uses 1 byte per character, plus 1 byte to store the length of the string. For example, when you store a string of 'CA', MySQL only uses 3 bytes. This shows that you can typically save storage space by using the VARCHAR type.

With MySQL 5.6 and 5.7, the CHAR and VARCHAR types used the *utf8mb3 character set*. This character set is similar to the utf8mb4 character set, but it can only use up to 3 bytes to store each character. Because of that, it's not able to store supplemental characters and emojis. Note that this character set is deprecated in MySQL 8.0 and will be removed in a future release.

With MySQL 5.5 and earlier, the CHAR and VARCHAR types used the *latin1 character set* by default. This character set uses one byte to store each character. As a result, it's referred to as a *single-byte character set*. This character set supports all of the characters that are used in English and by most western European languages. However, it doesn't support other characters such as Middle Eastern script letters and Korean, Chinese, and Japanese ideographs.

### The character types

| Type | Bytes | Description |
|---|---|---|
| `CHAR(M)` | Mx4 | Fixed-length strings of character data where M is the number of characters, between 0 and 255. With the utf8mb4 character set, MySQL must reserve four bytes for each character in a CHAR column because that's the maximum possible length. |
| `VARCHAR(M)` | L+1 | Variable-length strings of character data where M is the maximum number of characters, between 0 and 255. For English and Latin characters, the number of bytes used to store the string is equal to length of the string (L) plus 1 byte to record its length. |

### How the character types work with utf8mb4

| Data type | Original value | Value stored | Bytes used |
|---|---|---|---|
| `CHAR(2)` | `'CA'` | `'CA'` | 8 |
| `CHAR(10)` | `'CA'` | `'CA        '` | 40 |
| `VARCHAR(10)` | `'CA'` | `'CA'` | 3 |
| `VARCHAR(20)` | `'California'` | `'California'` | 11 |
| `VARCHAR(20)` | `'New York'` | `'New York'` | 9 |
| `VARCHAR(20)` | `"Murach's MySQL"` | `"Murach's MySQL"` | 15 |

### How the utf8mb4 character set works

- Basic Latin letters (A-Z), digits, and punctuation signs use 1 byte.
- Most European and Middle East script letters use 2 bytes.
- Most Korean, Chinese, and Japanese ideographs use 3 bytes.
- Supplemental characters and emojis use 4 bytes.

### Description

- The CHAR type is used for *fixed-length strings*. A column with this type uses the same amount of storage for each value regardless of the actual length of the string.
- The VARCHAR type is used for *variable-length strings*. A column with this type uses a varying amount of storage for each value depending on the length of the string.
- By default, MySQL 8.0 uses the *utf8mb4 character set* for the CHAR and VARCHAR types. This character set is a *multiple-byte character set*. It typically uses 1 byte per character, but can use up to 4 bytes per character. However, the utf8mb4 format provides for all characters in most languages by providing support for all of the characters in the *Unicode standard*.
- By default, MySQL 5.6 and 5.7 use the *utf8mb3 character set* for the CHAR and VARCHAR types, which can use up to 3 bytes per character.
- By default, MySQL 5.5 and earlier use the *latin1 character set* for the CHAR and VARCHAR types. This character set is a *single-byte character set* that supports all of the characters that are used in English and by most western European languages.
- To learn how to change the character set, see chapter 11.

Figure 8-2 The character types

In most cases, it makes sense to use the utf8mb4 character set. That way, your database supports most characters in most languages as well as emojis. However, if you want to use the CHAR type and you only need to support English and western European languages, you may want to use the latin1 character set to keep storage requirements to a minimum. In chapter 11, you'll learn how to change the character set for a database.

Although you typically store numeric values using numeric types, the character types may be a better choice for some numeric values. For example, you typically store zip codes, telephone numbers, and social security numbers in character columns even if they contain only numbers. That's because their values aren't used in numeric operations. In addition, if you store these numbers in numeric columns, MySQL may strip leading zeros in some situations, which isn't what you want.

In figure 8-2, the first five examples use single quotes to specify a string literal. However, the sixth example uses double quotes to specify a string literal. This allows the string literal to include a single quote, and it shows that you can use single or double quotes for string literals. Although it's common to use single quotes, double quotes are useful if you need to include a single quote in the string.

## The integer types

Figure 8-3 shows the *integer types*, which are numbers that don't include a decimal point. The integer data types differ in the amount of storage they use and the range of values they can store. Since the INT type can store a wide range of numbers and only requires 4 bytes of storage, it's the most commonly used of the integer types.

By default, the integer types can store positive and negative numbers. However, you can include the UNSIGNED attribute for an integer type to prevent negative values from being stored in the column. In that case, the range of acceptable positive values for the column is doubled.

The INTEGER type is a synonym for the INT type. As a result, you can use these types interchangeably. However, it's a common programming practice to use INT as an abbreviation for INTEGER.

The BOOL and BOOLEAN types are synonyms for TINYINT. When you work with these types, you can use a value of 0 to store false values and a value of 1 to store true values. To make that more intuitive, you can use the FALSE keyword, which is an alias for 0, and the TRUE keyword, which is an alias for 1.

### The integer types

| Type | Bytes | Value ranges |
|---|---|---|
| BIGINT | 8 | Signed: -9,223,372,036,854,775,808 to 9,223,372,036,854,775,807<br>Unsigned: 0 to 18,446,744,073,709,551,615 |
| INT | 4 | Signed: -2,147,483,648 to 2,147,483,647<br>Unsigned: 0 to 4,294,967,295 |
| MEDIUMINT | 3 | Signed: -8,388,608 5to 8,388,607<br>Unsigned: 0 to 16,777,215 |
| SMALLINT | 2 | Signed: -32,768 and 32,767<br>Unsigned: 0 to 65,535 |
| TINYINT | 1 | Signed: -128 to 127<br>Unsigned: 0 to 255 |

### How the UNSIGNED attribute works

| Data type | Original value | Value stored | Value displayed |
|---|---|---|---|
| INT | 99 | 99 | 99 |
| INT | -99 | -99 | -99 |
| INT UNSIGNED | 99 | 99 | 99 |
| INT UNSIGNED | -99 | (error) | (error) |

### Description

- The *integer types* store numbers without any digits to the right of the decimal point.
- If the UNSIGNED attribute for the integer is set, it changes the range of acceptable values. If you try to store a negative integer in a column with the UNSIGNED attribute, an error occurs.
- The INTEGER type is a synonym for the INT type.
- The BOOL and BOOLEAN types are synonyms for TINYINT. You can use these types to store true and false values, where 0 represents a false value and any non-zero number represents a true value.
- The TRUE and FALSE keywords are aliases for 1 and 0 respectively.

Figure 8-3 The integer types

## The fixed-point and floating-point types

Figure 8-4 presents the data types for storing *real numbers*, which are numbers that have digits to the right of the decimal point. To start, you can use the DECIMAL type to store *fixed-point numbers*, which are numbers that have a fixed number of digits to the right of the decimal point.

The number of digits a value has to the right of the decimal point is called its *scale*, and the total number of digits is called its *precision*. You can customize the precision and scale of the DECIMAL type so they're right for the data to be stored. For instance, if you need to store monetary values, it's common to use two digits to the right of the decimal place as shown in the first three examples.

When you use the DECIMAL type, MySQL uses a varying number of bytes to store the value. In general, it packs 9 digits into 4 bytes. However, it stores the digits to the left and right of the decimal point separately, and it can use fewer than 4 bytes if there are fewer than 9 digits. As a result, DECIMAL(9, 2) requires 5 bytes, while DECIMAL(18, 9) requires 8 bytes.

In contrast to the DECIMAL type, the DOUBLE and FLOAT types store *floating-point numbers*. These data types provide for very large and very small numbers, but with a limited number of *significant digits*. The FLOAT type can be used to store a *single-precision number*, which provides for numbers with up to 7 significant digits. The DOUBLE type can be used to store a *double-precision number*, which provides for numbers with up to 15 significant digits.

To express the value of a floating-point number, you can use *scientific notation*. To use this notation, you type the letter E followed by a power of 10. For instance, 3.65E+9 is equal to $3.65 \times 10^{9}$, or 3,650,000,000. Conversely, 3.65E-9 is equal to $3.65 \times 10^{-9}$, or 0.00000000365. If you have a mathematical background, of course, you're already familiar with this notation.

Because the precision of the integer types and the DECIMAL type is exact, these data types are considered *exact numeric types*. In contrast, the DOUBLE and FLOAT types are considered *approximate numeric types* because they may not represent a value exactly. That can happen, for example, when a number is rounded to the appropriate number of significant digits. In this figure, for instance, the last example shows that the FLOAT type rounds the original value and only stores 7 significant digits. For business applications, you typically use the exact numeric types, as there's seldom the need to work with the very large and very small numbers that the floating-point data types are designed for. However, for scientific applications, you may sometimes need to use the DOUBLE and FLOAT types.

The DECIMAL, DOUBLE, and FLOAT types have numerous synonyms. Sometimes these synonyms are helpful because they make it easier to work with data from other databases. However, when working with a MySQL database, most programmers use the DECIMAL, DOUBLE, and FLOAT types.

## The fixed-point type

| Type | Bytes | Description |
|---|---|---|
| DECIMAL(M, D) | Vary | Fixed-precision numbers where M specifies the maximum number of total digits (the precision) and D specifies the number of digits to the right of the decimal (the scale). M can range from 1 to 65. D can range from 0 to 30 but can't be larger than M. The default for D is 0. |

## The floating-point types

| Type | Bytes | Description |
|---|---|---|
| DOUBLE | 8 | Double-precision floating-point numbers from $-1.7976\times10^{308}$ to $1.7976\times10^{308}$. |
| FLOAT | 4 | Single-precision floating-point numbers from $-3.4028\times10^{38}$ to $3.4028\times10^{38}$. |

## How the fixed-point (exact) and floating-point (approximate) types work

| Data type | Original value | Value stored | Bytes used |
|---|---|---|---|
| DECIMAL(9,2) | 1.2 | 1.20 | 5 |
| DECIMAL(9,2) | 1234567.89 | 1234567.89 | 5 |
| DECIMAL(9,2) | -1234567.89 | -1234567.89 | 5 |
| DECIMAL(18,9) | 1234567.89 | 1234567.890000000 | 8 |
| DOUBLE | 1234567.89 | 1234567.89 | 8 |
| FLOAT | 1234567.89 | 1234570 | 4 |

## Description

- *Real numbers* can include digits to the right of the decimal point. The *precision* of a real number indicates the total number of digits that can be stored, and the *scale* indicates the number of digits that can be stored to the right of the decimal point.
- The DECIMAL type is considered an *exact numeric type* because its precision is exact.
- The DOUBLE and FLOAT types store *floating-point numbers*, which have a limited number of *significant digits*. These data types are considered *approximate numeric data types* because they may not represent a value exactly.
- The DEC, NUMERIC, and FIXED types are synonyms for the DECIMAL type.
- The REAL and DOUBLE PRECISION types are synonyms for the DOUBLE type.

Figure 8-4 The fixed-point and floating-point types

## The date and time types

Part 1 of figure 8-5 presents the five date and time types supported by MySQL. You can use the DATE type to store a date without a time. You can use the TIME type to store a time without a date. And you can use either the DATETIME or TIMESTAMP types to store both a date and a time.

You typically use the TIMESTAMP type to keep track of when a row was inserted or last updated. For example, you might use this type to keep track of the entries on a blog. MySQL makes that easy by automatically setting the TIMESTAMP column to the current date and time whenever a row is inserted or updated. If that's not what you want, you can use the DATETIME type instead.

The problem with the TIMESTAMP type is that it can only store dates up to the year 2038. This is known as the *year 2038 problem*, the *Y2K38 problem*, and the *Unix Millennium bug*. As a result, if you want your database to be able to store dates that go beyond 2038, you should use the DATETIME type instead of the TIMESTAMP type. Otherwise, you can use the TIMESTAMP type since it only requires 4 bytes to store a TIMESTAMP value, compared to 8 bytes for a DATETIME value.

If you need to store a year without any other temporal data, you can use the YEAR type. Prior to MySQL 5.7.5, a YEAR column could store a 2-digit year, and 1-digit entries were converted to two digits. With MySQL 5.7.5 and later, however, the YEAR type only stores 4-digit years from 1901 to 2155. Entries with one and two digits are still acceptable, but they are converted to 4-digit years as indicated in this figure. Note that, by default, a numeric literal of 0 or 00 is converted to 0000. To store the value 2000 in a YEAR column, you must code it as a string.

## The date and time types

| Type | Bytes | Description |
|---|---|---|
| DATE | 3 | Dates from January 1, 1000 through December 31, 9999. The default format for display and entry is "yyyy-mm-dd". |
| TIME | 3 | Times in the range -838:59:59 through 838:59:59. The default format for display and entry is "hh:mm:ss". |
| DATETIME | 8 | Combination date and time from midnight January 1, 1970 to December 31, 9999. The default format for display and entry is "yyyy-mm-dd hh:mm:ss". |
| TIMESTAMP | 4 | Combination date and time from midnight January 1, 1970 to January 19, 2038. The default format is "yyyy-mm-dd hh:mm:ss". |
| YEAR | 1 | Years in 4-digit format. Allowable values are from 1901 to 2155. |

## Description

- A column of the TIMESTAMP type is automatically updated to the current date and time when a row is inserted or updated. If a table has multiple TIMESTAMP columns, only the first one is updated automatically.
- The TIMESTAMP type can only store dates up to the year 2038. This is known as the *year 2038 problem*, the *Y2K38 problem*, and the *Unix Millennium bug*. To fix this problem, use the DATETIME type instead of the TIMESTAMP type and update the value manually as needed.
- MySQL 5.7.5 and later support only 4-digit years. If you enter a 1-digit or 2-digit year, it will be converted to a 4-digit year. Values from 0 to 69 are converted to 2000 to 2069, and values from 70 to 99 are converted to 1970 to 1999.
- For a value of 0 or 00 to be stored as 2000 in a YEAR column, you must enter it as a string. Otherwise, it's stored as 0000.

Figure 8-5 The date and time types (part 1 of 2)

When you work with the date and time types, you need to know how to code date and time literals. Part 2 of figure 8-5 shows how to do that. The default date format for MySQL is "yyyy-mm-dd", which is why we've used this format in most of the examples in this book. By default, MySQL doesn't support other common date formats such as "mm-dd-yy". If you attempt to use an unsupported format, MySQL returns an error.

You also need to be aware of the two-digit year cutoff that's defined on your system. When you code a two-digit year, the two-digit year cutoff determines how MySQL interprets the year. By default, MySQL interprets the years 00 through 69 as 2000 through 2069, and it interprets the years 70 through 99 as 1970 through 1999. Usually, that's what you want. However, the two-digit year cutoff can be modified if necessary. In general, it's considered a good coding practice to use four-digit years. That way, you can be sure that MySQL is interpreting the year correctly.

Prior to MySQL 8.0.29, you could use almost any punctuation character as a delimiter between date and time parts. For example, it was common to use a slash as a separator between date parts. With MySQL 8.0.29 and later, however, you should only use a hyphen as a separator between date parts and a colon as a separator between time parts. That's because the use of other punctuation characters has been deprecated. If you don't use delimiters, you can code a DATE or TIME value as a numeric literal. In that case, you don't need to use single quotes.

When storing a date in a DATE column, the values are loosely checked for valid data. For instance, months must be in the range 0-12 and days must be in the range 0-31. For illegal dates, such as February 31, MySQL returns an error. However, MySQL allows you to store unconventional date values, such as "2018-12-00", which represents a month and year without a specific day.

The default time format for MySQL is "hh:mm:ss", using a 24-hour clock. Many of the same rules for coding date literals also apply to time literals. Like dates, MySQL checks times for validity. For illegal times, such as "19:61:11", MySQL returns an error.

The default date/time format for MySQL is a combination of the date and time formats. Most of the rules for coding date/time literals are a combination of the rules for coding date and time literals. In addition, if you don't specify a time when storing a TIMESTAMP or DATETIME value, the time defaults to 00:00:00, which is midnight.

## How MySQL interprets literal date/time values

| Literal value | Value stored in DATE column |
|---|---|
| '2022-08-15' | 2022-08-15 |
| '2022-8-15' | 2022-08-15 |
| '22-8-15' | 2022-08-15 |
| '20220815' | 2022-08-15 |
| 20220815 | 2022-08-15 |
| '8-15-22' | (error) |
| '2022-02-31' | (error) |
| **Literal value** | **Value stored in TIME column** |
| '7:32' | 07:32:00 |
| '19:32:11' | 19:32:11 |
| '193211' | 19:32:11 |
| 193211 | 19:32:11 |
| '19:61:11' | (error) |
| **Literal value** | **Value stored in DATETIME or TIMESTAMP column** |
| '2022-08-15 19:32:11' | 2022-08-15 19:32:11 |
| '2022-08-15' | 2022-08-15 00:00:00 |

## Description

- You can specify date and time values by coding a literal value. In most cases, you enclose the literal value in single quotes.
- For dates, MySQL uses the "yyyy-mm-dd" format. For times, MySQL uses the "hh:mm:ss" format, using a 24-hour clock.
- By default, MySQL does not support common date formats used by other systems such as "mm/dd/yy" and "mon/dd/yyyy".
- By default, MySQL interprets 2-digit years from 00 to 69 as 2000 to 2069 and the years from 70 to 99 as 1970 to 1999.
- MySQL interprets hyphens and colons as delimiters between date and time parts respectively. If you don't use any delimiters, you can code values as numeric literals without quotes.
- If you don't specify a time when storing a DATETIME or TIMESTAMP value, MySQL stores a time value of 00:00:00 (12:00 midnight).
- If you don't specify seconds when storing a TIME value, MySQL stores 00 for the seconds.
- When storing date and time values, MySQL loosely checks the values to make sure they are valid. For example, months must be in the range 0-12, days must be in the range 0-31, and so on. If MySQL determines that a date or time isn't valid, it returns an error.
- If MySQL can't interpret a date or time value, it returns an error or a warning.

Figure 8-5 The date and time types (part 2 of 2)

## The ENUM and SET types

The ENUM and SET types can be considered character data types since they allow you to restrict the values for a column to a set of strings that you specify when you create the column. Although these types represent strings, MySQL stores these values internally as integers, which reduces the number of bytes needed to store each string. Figure 8-6 shows how these types work.

The main difference between the ENUM and SET types is that an ENUM column stores an integer that represents exactly one value, but a SET column stores an integer that can represent from zero to 64 different values. In other words, an ENUM column can consist of only one member in a set of values, while the SET column may consist of none, any, or all, members in a set. Another difference is that an ENUM column can specify up to 65,535 acceptable values, but a SET column is limited to 64 values.

Because it's difficult to change the acceptable values for an ENUM or SET column, it's a best practice to use these types only when you're sure that the acceptable values won't change. In addition, because using these types with a large number of acceptable values makes them unwieldy, it's a best practice to use them only with a manageable number of acceptable values.

You can use the ENUM type to store values that are mutually exclusive. For example, yes, no, or maybe; delivery or pickup; cash, credit, or debit; small, medium, or large; paper or plastic.

When you define an ENUM column, each acceptable value is assigned an index that represents the position of the value in the set, starting at 1. In the second table in this figure, for example, the index values for a column defined as ENUM('Yes','No',Maybe') are 1, 2, and 3. So if the string 'Maybe' is inserted into the column, a value of 3 is stored in the column.

To store a value in an ENUM column, you code a single text string. If the string is one of the acceptable values for the column, MySQL stores the index of that value. Otherwise, an error occurs and the row isn't inserted.

You can also add a row to a table without specifying a value for an ENUM column. Then, MySQL assigns a null value if they're allowed or the first value in the set of acceptable values if they're not. As a result, if you want MySQL to use a specific value as the default value for a column that doesn't allow null values, you should code that value as the first value in the set.

You can use a SET column when you want to choose more than one value from a set of values, such as the toppings on a pizza, the software on a computer, or the features of a car. To store values in a SET column, you code a single string with one or more values separated by commas but no spaces. Then, if all the values are acceptable, MySQL stores a representation of those values. Otherwise, an error occurs and the row isn't inserted. Since commas are used to separate values, you can't use commas within a value when you define the SET column.

Each acceptable value in a SET column is represented by a binary number. For example, the first value is represented by the binary number 1, which is equivalent to the decimal number 1; the second value by the binary number 10, which is equivalent to the decimal number 2; and the third value by the binary number 100, which is equivalent to the decimal number 4.

## The ENUM and SET types

| Type | Bytes | Description |
|---|---|---|
| `ENUM(val1,val2,...)` | 1-2 | Stores an integer from 1 to 65,535 that represents the index of one string value from a list of acceptable values where the first string value has an index of 1. |
| `SET(val1,val2,...)` | 1-8 | Stores the decimal equivalent of a binary number that represents from 0 to 64 acceptable string values. |

## How an ENUM('Yes','No','Maybe') column works

| Value | Value stored | Value displayed |
|---|---|---|
| 'Yes' | 1 | 'Yes' |
| 'No' | 2 | 'No' |
| 'Maybe' | 3 | 'Maybe' |
| 'Possibly' | (error) | |
| '' | (error) | |

## How a SET('Pepporoni','Mushrooms','Olives') column works

| Value | Value stored (binary) | Value displayed |
|---|---|---|
| 'Pepperoni' | 1 (00000001) | 'Pepperoni' |
| 'Mushrooms' | 2 (00000010) | 'Mushrooms' |
| 'Olives' | 4 (00000100) | 'Olives' |
| 'Olives,Pepperoni' | 5 (00000101) | Pepperoni, Olives |
| 'Olives,Olives,Mushrooms' | 6 (00000110) | 'Mushrooms,Olives' |
| '' | 0 (00000000) | '' |
| 'Pepperoni,Sausage' | (error) | |

## Description

- The ENUM and SET types restrict the values you can store to the set of values specified when the column is created.
- To specify a value for an ENUM column, you code a single text string. If the string contains an unacceptable value, an error occurs and the row isn't inserted.
- If you don't specify a value for an ENUM column when you insert a row, MySQL assigns a default value. If the column allows null values, MySQL assigns a null value. If it doesn't allow null values, MySQL assigns the first value in the set of acceptable values.
- To specify values for a SET column, you code a single string with the values separated by commas but no spaces. If any of the values are unacceptable, the row isn't inserted.
- If you don't specify a value for a SET column when you insert a row, MySQL assigns a null value if the column allows null values. Otherwise, an error occurs and the row isn't inserted.
- MySQL stores the values you specify for a SET column using the order specified in the column definition, and it does not store duplicate values.

Figure 8-6 The ENUM and SET types

Note that each binary number consists of only 0's and 1's. Because a SET column has a minimum of one byte and each byte contains 8 bits that can each store the value 0 or 1, each byte can represent up to eight values. If a bit has a value of 1, it indicates that the associated string value is stored in the column. If it has a value of zero, the string value isn't stored in the column.

The third table in figure 8-6 illustrates how this works. Here, the SET column has three possible values: Pepperoni, Mushrooms, and Olives. If the value 'Pepperoni' is inserted into this column, a value of 1 is stored in the column, which is represented by a single byte with its bits set to 00000001. If two values are stored in the column, the bits for each value are added together. So Olives (100) and Pepperoni (1) is stored in a single byte with its bits set to 00000101, which is equivalent to a decimal value of 5.

When storing multiple values in a SET column, the order of the values doesn't matter. That's because MySQL stores the values in the same order as in the column definition. It also doesn't matter if you repeat a value because MySQL doesn't store duplicate values. Because you don't have to store any values in a SET column, you can also assign an empty string to it.

## The binary types

Figure 8-7 presents the binary types, BINARY and VARBINARY. These types are like the CHAR and VARCHAR types, except they store strings of fixed- and variable-length binary data instead of character data. They are often used to stored encryption keys and hash values, but they can also be used to store small image, audio, and video files.

If you insert a value that is shorter than the specified number of bytes into a BINARY column, it's padded on the right. Because that requires extra storage and can cause problems with retrieval operations, VARBINARY columns are typically preferred over BINARY columns.

## The large object types

Figure 8-7 also presents the large object (LOB) types. These data types are designed to store large amounts of binary or character data.

The *BLOB (binary large object)* types store strings of binary data. These data types are often used to store images, audio, and video. However, the BLOB types can be used to store any type of binary data, including the binary data that's normally stored in application files such as PDF files or Word files.

The TEXT types work similarly to the BLOB types, but they store strings of characters. As a result, they are sometimes referred to as *character large object (CLOB)* types. These data types can be used to store large amounts of character data, including data that's normally stored in text, XML, or JSON files, although MySQL provides a data type specifically for JSON.

To read and write data from a column defined with a BLOB or TEXT type, you typically use another programming language such as Java or PHP. As a result, we don't use these types in this book. To learn more about these types, you can refer to the MySQL Reference Manual.

## The binary data types

| Type | Bytes | Description |
|---|---|---|
| `BINARY(M)` | M | Fixed-length strings of binary data, where M is the number of bytes between 0 and 255. |
| `VARBINARY(M)` | L+1 | Variable-length strings of binary data, where M is the maximum number of bytes between 0 and 255. The number of bytes used to store the string is equal to length of the string (L) plus 1 byte to record its length. |

## The large object types

| Type | Bytes | Description |
|---|---|---|
| `LONGBLOB` | L+4 | Variable-length strings of binary data up to 4GB. |
| `MEDIUMBLOB` | L+3 | Variable-length strings of binary data up to 16MB. |
| `BLOB` | L+2 | Variable-length strings of binary data up to 65KB. |
| `TINYBLOB` | L+1 | Variable-length strings of binary data up to 255 bytes. |
| `LONGTEXT` | L+4 | Variable-length strings of characters up to 4GB. |
| `MEDIUMTEXT` | L+3 | Variable-length strings of characters up to 16MB. |
| `TEXT` | L+2 | Variable-length strings of characters up to 65KB. |
| `TINYTEXT` | L+1 | Variable-length strings of characters up to 255 bytes. |

## Description

- The BINARY and VARBINARY types store strings of fixed- and variable-length binary data respectively.
- If you store a string in a BINARY column and its length is less than the maximum size of the column, MySQL pads the string on the right so it contains the specified number of bytes.
- The BLOB types store strings of binary data and are referred to as *binary large object (BLOB)* types.
- The TEXT types store strings of character data and are sometimes referred to as *character large object (CLOB)* types.
- The data in BLOB and TEXT types is never padded.

Figure 8-7 The large object types

# How to convert data

As you work with the various data types, you'll find that you frequently need to convert data from one type to another. Although MySQL performs many conversions automatically, it doesn't always perform the conversion the way you want. Because of that, you need to be aware of how data conversion works, and you need to know when and how to specify the type of conversion you want.

## How implicit data conversion works

Before MySQL can operate on two values, it must convert those values to the same data type. To understand how this works, consider the three expressions shown in figure 8-8.

In the first example, the second column joins a string literal of "$" to the invoice_total column, which is defined with the DECIMAL type. As a result, MySQL converts the DECIMAL value to its corresponding characters, appends those characters to the $ character, and stores them as a CHAR type.

In the second example, the second column divides the INT literal of 989319 by the VARCHAR type that's stored in the invoice_number column. As a result, MySQL attempts to convert the invoice_number column to an INT type before it performs the division operation. If the invoice_number column contains only numbers, this works as you would expect. However, if the invoice_number column contains letters or special characters, MySQL converts only the numeric characters that precede the letters or special characters. For example, in the first row in the result set, MySQL only converts the numbers before the dash in the invoice_number column.

In the third example, the second column adds an INT literal of 1 to the invoice_date column, which is defined with the DATE type. As a result, MySQL converts the DATE value in the invoice_date column to an INT value before it performs the addition. In the result set, the first column uses the DATE type, which includes dashes between the parts of the date. The second column, on the other hand, uses the INT type, which doesn't include dashes between parts of the date.

Notice in the third row of this result set that after 1 is added to the date, the date is invalid. Because MySQL doesn't check if the resulting date is valid when you perform an arithmetic operation like this, you're not likely to use the arithmetic operators with dates. Instead, you'll use the functions for performing calculations on dates that are presented in the next chapter.

When MySQL performs a conversion automatically, it's called an *implicit conversion*. However, if you want to control how a conversion is performed, you can code an *explicit conversion*. To do that, you can use the CAST and CONVERT functions shown in the next figure.

## SELECT statements that implicitly convert data from one type to another

### Number to string

```
SELECT invoice_total, CONCAT('$', invoice_total)
FROM invoices
```

| invoice_total | CONCAT('$', invoice_total) |
| --- | --- |
| 3813.33 | $3813.33 |
| 40.20 | $40.20 |
| 138.75 | $138.75 |
| 144.70 | $144.70 |

### String to number

```
SELECT invoice_number, 989319/invoice_number
FROM invoices
```

| invoice_number | 989319/invoice_number |
| --- | --- |
| 989319-457 | 1 |
| 263253241 | 0.0037580505988908225 |
| 963253234 | 0.0010270601385803393 |
| 2-000-2993 | 494659.5 |
| 963253251 | 0.0010270601204542418 |

### Date to number

```
SELECT invoice_date, invoice_date + 1
FROM invoices
```

| invoice_date | invoice_date + 1 |
| --- | --- |
| 2022-08-02 | 20220803 |
| 2022-08-01 | 20220802 |
| 2022-07-31 | 20220732 |
| 2022-07-30 | 20220731 |
| 2022-07-28 | 20220729 |

## Description

- When MySQL automatically converts one data type to another, it's known as an *implicit conversion*.
- If you code an expression that involves values with different data types, MySQL implicitly converts them when it evaluates the expression.
- If you use a string in a numeric expression, MySQL attempts to convert the string to a number before evaluating the expression. If the string starts with a letter or special character, MySQL returns a value of zero. If it starts with a number, MySQL returns that number and each successive number until it encounters a letter or special character.
- If you add or subtract an integer to or from a DATE value, MySQL implicitly converts the DATE value to an integer value.

Figure 8-8 How implicit data conversion works

## How to convert data using the CAST and CONVERT functions

Because MySQL's rules for implicit conversion are more flexible than those for other SQL databases, you generally don't need to explicitly convert data from one type to another. However, whenever necessary, you can use the CAST and CONVERT functions to convert, or *cast*, an expression to the data type you specify as shown in figure 8-9. Since CAST is an ANSI-standard function, it is used more frequently than CONVERT, but both functions work equally well for most tasks.

The first SELECT statement shows how to use the CAST function. Here, the fourth column in the result set casts the DATE values of the invoice_date column to CHAR values. Although the fourth column looks the same as the second column, it stores a CHAR value, not a DATE value. In this case, MySQL converted all of the characters in the DATE value to a CHAR value. If that's not what you want, you can truncate the number of characters in the result by specifying a value less than 10 after the CHAR keyword.

The fifth column in the result set casts the DECIMAL values in the invoice_total column to signed INT values. Before the digits to the right of the decimal point are dropped, the numbers are rounded to the nearest whole number. For brevity, this statement only uses the SIGNED keyword. For clarity, it could also include the optional INTEGER keyword immediately after the SIGNED keyword.

The second SELECT statement in this figure shows how to use the CONVERT function. If you compare this statement to the first SELECT statement, you'll see that it uses a slightly different syntax. However, both SELECT statements accomplish the same task.

## The syntax of the CAST function

```
CAST(expression AS cast_type)
```

## The syntax of the CONVERT function

```
CONVERT(expression, cast_type)
```

## The cast types you can use in the CAST and CONVERT functions

| Cast type | Description |
|---|---|
| `CHAR[(N)]` | A string of characters where N is the maximum number of characters. |
| `DATE` | A DATE value. |
| `DATETIME` | A DATETIME value. |
| `TIME` | A TIME value. |
| `SIGNED [INTEGER]` | A signed INT value. The INTEGER keyword is optional. |
| `UNSIGNED [INTEGER]` | An unsigned INT value. The INTEGER keyword is optional. |
| `DECIMAL[(M[,D])]` | A DECIMAL value where M specifies the precision and D specifies the scale. |

## A statement that uses the CAST function

```
SELECT invoice_id, invoice_date, invoice_total,
    CAST(invoice_date AS CHAR(10)) AS char_date,
    CAST(invoice_total AS SIGNED) AS integer_total
FROM invoices
```

| invoice_id | invoice_date | invoice_total | char_date | integer_total |
|---|---|---|---|---|
| 1 | 2022-04-08 | 3813.33 | 2022-04-08 | 3813 |
| 2 | 2022-04-10 | 40.20 | 2022-04-10 | 40 |
| 3 | 2022-04-13 | 138.75 | 2022-04-13 | 139 |
| 4 | 2022-04-16 | 144.70 | 2022-04-16 | 145 |
| 5 | 2022-04-16 | 15.50 | 2022-04-16 | 16 |

## A statement that uses the CONVERT function

```
SELECT invoice_id, invoice_date, invoice_total,
    CONVERT(invoice_date, CHAR(10)) AS char_date,
    CONVERT(invoice_total, SIGNED) AS integer_total
FROM invoices
```

| invoice_id | invoice_date | invoice_total | char_date | integer_total |
|---|---|---|---|---|
| 1 | 2022-04-08 | 3813.33 | 2022-04-08 | 3813 |
| 2 | 2022-04-10 | 40.20 | 2022-04-10 | 40 |
| 3 | 2022-04-13 | 138.75 | 2022-04-13 | 139 |
| 4 | 2022-04-16 | 144.70 | 2022-04-16 | 145 |
| 5 | 2022-04-16 | 15.50 | 2022-04-16 | 16 |

## Description

- You can use the CAST or CONVERT function to perform an *explicit conversion*. This allows you to convert, or *cast*, an expression from one data type to another.
- CAST is an ANSI-standard function and is used more frequently than CONVERT.

Figure 8-9 How to convert data using the CAST and CONVERT functions

## How to convert data using the FORMAT and CHAR functions

In addition to the CAST and CONVERT functions, MySQL provides some functions that perform other types of data conversion. In particular, it provides the FORMAT and CHAR functions shown in figure 8-10.

You can use the FORMAT function to convert a number to a string of characters. This function uses commas to group the thousands to the left of the decimal point. This makes large numbers easier to read. In addition, the FORMAT function rounds the number to the specified number of decimal places. If you specify 0 decimal places, the function returns a string that doesn't include a decimal point.

The CHAR function returns a binary string for each specified integer. This function is typically used to output *ASCII (American Standard Code for Information Interchange)* control characters that can't be typed on your keyboard. The three most common control characters are presented in this figure. These characters can be used to format output so it's easy to read. In this figure, for example, the SELECT statement uses the CHAR(13) and CHAR(10) control characters to start new lines after the vendor name and vendor address in the output.

### The FORMAT and CHAR functions

| Function | Description |
|---|---|
| `FORMAT(number,decimal)` | Converts the specified number to a character string with grouped digits separated by commas, rounded to the specified number of decimal digits. If decimal is zero, then the decimal point is omitted. |
| `CHAR(value1[,value2]...)` | Converts one or more numbers to a binary string. Each number is interpreted as an integer between 0 and 255. |

### The FORMAT function

| Function | Result |
|---|---|
| `FORMAT(1234567.8901,2)` | `1,234,567.89` |
| `FORMAT(1234.56,4)` | `1,234.5600` |
| `FORMAT(1234.56,0)` | `1,235` |

### The CHAR function for common control characters

| Function | Control character |
|---|---|
| `CHAR(9)` | Tab |
| `CHAR(10)` | Line feed |
| `CHAR(13)` | Carriage return |

### A statement that uses the CHAR function to format output

```
SELECT CONCAT(vendor_name, CHAR(13,10), vendor_address1, CHAR(13,10),
       vendor_city, ', ', vendor_state, ' ', vendor_zip_code)
FROM vendors
WHERE vendor_id = 1
```

```
US Postal Service
Attn:  Supt. Window Services
Madison, WI 53707
```

### Description

- The CHAR function is typically used to insert control characters into a character string.

Figure 8-10 How to convert data using the FORMAT and CHAR functions

# Perspective

In this chapter, you learned about the different MySQL data types. In addition, you learned how to use some functions to convert data from one type to another. In the next chapter, you'll learn some of the additional functions for working with data.

## Terms

data type
character data types
string
text
numeric data types
integer
real number
date and time data types
date/time data types
temporal data types
large object (LOB) data types
spatial data types
global positioning system (GPS)
geometry types
JSON data type
JavaScript Object Notation (JSON)
fixed-length string
variable-length string
utf8mb4 character set
multiple-byte character set
Unicode standard
utf8mb3 character set
single-byte character set
latin1 character set
integer types
fixed-point number
scale
precision
floating-point number
significant digits
single-precision number
double-precision number
scientific notation
exact numeric types
approximate numeric types
year 2038 problem
Y2K38 problem
Unix Millennium bug
BLOB (Binary Large Object)
character large object (CLOB)
implicit conversion
explicit conversion
cast
ASCII (American Standard Code for Information Interchange)

## Exercises

1. Write a SELECT statement that returns these columns from the Invoices table:

   The invoice_total column

   A column that uses the FORMAT function to return the invoice_total column with 1 digit to the right of the decimal point

   A column that uses the CONVERT function to return the invoice_total column as an integer

   A column that uses the CAST function to return the invoice_total column as an integer

2. Write a SELECT statement that returns these columns from the Invoices table:

   The invoice_date column

   A column that uses the CAST function to return the invoice_date column with its full date and time

   A column that uses the CAST function to return the invoice_date column with just the year and the month

# 9

# How to use functions

In chapter 3, you were introduced to some of the scalar functions that you can use in a SELECT statement. Now, this chapter expands on that coverage by presenting many more of the scalar functions, as well as some specialized window functions. When you complete this chapter, you'll have a thorough understanding of the functions that you can use with MySQL.

# How to work with string data

The figures that follow show how to use the most useful functions that MySQL provides for working with string data. In addition, it shows how to solve two common problems that can occur when you work with string data.

## A summary of the string functions

Figure 9-1 summarizes the most useful string functions that are available with MySQL. To start, it summarizes the CONCAT function that you learned about in chapter 3. Then, it summarizes a related function, the CONCAT_WS function, that you can use to specify a separator string that goes between the other strings that you are concatenating. (WS stands for "with separator".)

The next three functions allow you to remove, or *trim*, characters from the beginning or end of the string. To remove spaces from the left or right side of a string, you can use the LTRIM or RTRIM function. To remove spaces from both sides of a string, you can use the TRIM function. You can also use the TRIM function to remove characters other than the space character from the left or right side of a string.

To find the number of characters in a string, you can use the LENGTH function. However, this function counts spaces at the beginning of the string (leading spaces), but not spaces at the end of the string (trailing spaces). As a result, you need to take this into account if the string ends with spaces.

To locate the first occurrence of a substring within another string, you can use the LOCATE function. This function returns an integer value that indicates the position of the substring. Note that you can start the search at a position other than the beginning of the string by including the optional start argument. This function is often used within other functions such as the SUBSTRING function.

The next four functions return a substring of the specified string. To start, you can use the LEFT and RIGHT functions to get the specified number of characters from the left or right side of a string. You can also use the SUBSTRING_INDEX function to get characters from the left or right side of a string. This function returns the characters before or after a delimiter string occurs the specified number of times. Or, you can use the SUBSTRING function to get the specified number of characters from anywhere in a string.

You can use the next two functions to modify the specified string. First, you can use the REPLACE function to replace a substring within the string with another substring. Second, you can use the INSERT function to insert another string into the string.

Finally, you can use the last seven functions to transform the string in other ways. To start, you can use the REVERSE function to reverse the order of the characters in a string. You can use the LOWER and UPPER functions to convert the characters in a string to lower or uppercase. You can use the LPAD and RPAD functions to pad a string on the left or right until it's a specified length. You can use the SPACE function to return a string that repeats the space character the specified number of times. And you can use the REPEAT function to repeat any string the specified number of times.

## Some of the string functions

| Function | Description |
|---|---|
| `CONCAT(str1[,str2]...)` | Concatenates the specified strings. If one of the strings is null, then the result is null. |
| `CONCAT_WS(sep,str1[,str2]...)` | Concatenates the strings with the specified separator string added in between. If one of the strings is null or empty, it's ignored. If the separator is null, then the result is null. |
| `LTRIM(str)` | Returns the string with any leading spaces removed. |
| `RTRIM(str)` | Returns the string with any trailing spaces removed. |
| `TRIM([[BOTH\|LEADING\|TRAILING] [remove] FROM] str)` | Returns the string without leading or trailing occurrences of the specified remove string. If remove string is omitted, spaces are removed. |
| `LENGTH(str)` | Returns the number of characters in the string. |
| `LOCATE(find,search[,start])` | Returns the position of the first occurrence of the find string in the search string, starting at the specified start position. If the start position is omitted, the search starts at the beginning of the string. If the string isn't found, the function returns zero. |
| `LEFT(str,length)` | Returns the specified number of characters from the beginning of the string. |
| `RIGHT(str,length)` | Returns the specified number of characters from the end of the string. |
| `SUBSTRING_INDEX(str,delimiter, count)` | Returns the substring before the specified number of occurrences of the specified delimiter string. If count is positive, it returns from the beginning of the string. If count is negative, it returns from the end of the string. |
| `SUBSTRING(str,start[,length])` | Returns the specified number of characters from the string starting at the specified start position. If length is omitted, it returns from the start position to the end of the string. |
| `REPLACE(search,find,replace)` | Returns the search string with all occurrences of the find string replaced with the replace string. |
| `INSERT(str,start,length,insert)` | Returns the string with the specified insert string inserted into it starting at the specified start position and replacing the specified length. |
| `REVERSE(str)` | Returns the string with the characters in reverse order. |
| `LOWER(str)` | Returns the string converted to lowercase letters. |
| `UPPER(str)` | Returns the string converted to uppercase letters. |
| `LPAD(str,length,pad)` | Returns the string padded on the left with the specified pad string until it's the specified length. If the string is longer than the length, it's truncated. |
| `RPAD(str,length,pad)` | Returns the string padded on the right with the specified pad string until it's the specified length. If the string is longer than the length, it's truncated. |
| `SPACE(count)` | Returns the space character repeated count times. |
| `REPEAT(str,count)` | Returns the specified string repeated count times. |

Figure 9-1 A summary of the string functions

## Examples that use string functions

The table in figure 9-2 presents examples of most of the string functions. Then, the SELECT statement below the table shows how you can use the CONCAT_WS and RIGHT functions to format columns in a result set. In this case, the second column uses the CONCAT_WS function to retrieve two columns from the Vendors table and separate them with a comma and a space.

The third column in the result set lists the vendor's phone number without an area code. To accomplish that, this column uses the RIGHT function to extract the eight rightmost characters of the vendor_phone column. This assumes that the area code is enclosed in parentheses and that all of the phone numbers are stored in the same format. Since the vendor_phone column is defined with the VARCHAR(50) data type, this isn't necessarily the case.

This SELECT statement also shows how you can use a function in a WHERE clause. This WHERE clause uses the LEFT function to select only those rows that begin with an area code of "(559". Again, this assumes that the area code is enclosed in parentheses and that the phone numbers are all in the same format.++

### String function examples

| Function | Result |
|---|---|
| `CONCAT('Last', 'First')` | `'LastFirst'` |
| `CONCAT_WS(', ', 'Last', 'First')` | `'Last, First'` |
| | |
| `LTRIM('  MySQL  ')` | `'MySQL  '` |
| `RTRIM('  MySQL  ')` | `'  MySQL'` |
| `TRIM('  MySQL  ')` | `'MySQL'` |
| `TRIM(BOTH '*' FROM '****MySQL****')` | `'MySQL'` |
| | |
| `LOWER('MySQL')` | `'mysql'` |
| `UPPER('ca')` | `'CA'` |
| | |
| `LEFT('MySQL', 3)` | `'MyS'` |
| `RIGHT('MySQL', 3)` | `'SQL'` |
| | |
| `SUBSTRING('(559) 555-1212', 7, 8)` | `'555-1212'` |
| `SUBSTRING_INDEX('http://www.murach.com', '.', -2)` | `'murach.com'` |
| | |
| `LENGTH('MySQL')` | 5 |
| `LENGTH('  MySQL  ')` | 9 |
| | |
| `LOCATE('SQL', '  MySQL')` | 5 |
| `LOCATE('-', '(559) 555-1212')` | 10 |
| | |
| `REPLACE(RIGHT('(559) 555-1212', 13),') ', '-')` | `'559-555-1212'` |
| `INSERT("MySQL", 1, 0, "Murach's ")` | `"Murach's MySQL"` |
| `INSERT('MySQL', 1, 0, 'Murach''s ')` | `"Murach's MySQL"` |

### A SELECT statement that uses three functions

```
SELECT vendor_name,
       CONCAT_WS(', ', vendor_contact_last_name,
                 vendor_contact_first_name) AS contact_name,
       RIGHT(vendor_phone, 8) AS phone
FROM vendors
WHERE LEFT(vendor_phone, 4) = '(559'
ORDER BY contact_name
```

| vendor_name | contact_name | phone |
|---|---|---|
| Dristas Groom & McCormick | Aaronsen, Thom | 555-8484 |
| Yale Industrial Trucks-Fresno | Alexis, Alexandro | 555-2993 |
| Lou Gentile's Flower Basket | Anum, Trisha | 555-6643 |
| Pollstar | Aranovitch, Robert | 555-2631 |

Figure 9-2 Examples that use string functions

## How to sort by a string column that contains numbers

Figure 9-3 presents solutions to a common problem that can occur when you attempt to sort numeric data that's stored in a column with a character data type. To illustrate the problem, look at the first example in this figure. Here, the emp_id column in the String_Sample table, which contains numeric IDs, is defined with a character type. Because of that, when you sort by this column, the rows aren't in numeric sequence. That's because MySQL interprets the values as characters, not as numbers.

One way to solve this problem is to convert the values in the emp_id column to integers for sorting purposes. This is illustrated in the second SELECT statement in this figure, which uses the CAST function. As you can see, the rows are now sorted in numeric sequence. The third example is similar, but it implicitly casts the character values to integers by adding 0 to the values.

Another way to solve this problem is to pad the numbers with leading zeros or spaces, as shown by the last example. Here, the LPAD function is used to pad the emp_id column with zeros so the result always contains two digits. Then, the numbers that start with a zero appear at the beginning of the sort sequence, so the rows are returned in numeric sequence.

Of course, if you know that a column will always contain numbers, you'll typically define it with a numeric type. If that isn't possible, though, you can solve the sorting problem by using one of the techniques shown in this figure.

## How to sort by a string column that contains numbers

### Sorted by the emp_id column

```
SELECT *
FROM string_sample
ORDER BY emp_id
```

| emp_id | emp_name |
|---|---|
| 1 | Lizbeth Darien |
| 17 | Lance Pinos-Potter |
| 2 | Darnell O'Sullivan |
| 20 | Jean Paul Renard |
| 3 | Alisha von Strump |

### Sorted by the emp_id column explicitly cast as an integer

```
SELECT *
FROM string_sample
ORDER BY CAST(emp_id AS SIGNED)
```

| emp_id | emp_name |
|---|---|
| 1 | Lizbeth Darien |
| 2 | Darnell O'Sullivan |
| 3 | Alisha von Strump |
| 17 | Lance Pinos-Potter |
| 20 | Jean Paul Renard |

### Sorted by the emp_id column implicitly cast as an integer

```
SELECT *
FROM string_sample
ORDER BY emp_id + 0
```

| emp_id | emp_name |
|---|---|
| 1 | Lizbeth Darien |
| 2 | Darnell O'Sullivan |
| 3 | Alisha von Strump |
| 17 | Lance Pinos-Potter |
| 20 | Jean Paul Renard |

### Sorted by the emp_id column after it has been padded with leading zeros

```
SELECT LPAD(emp_id, 2, '0') AS emp_id, emp_name
FROM string_sample
ORDER BY emp_id
```

| emp_id | emp_name |
|---|---|
| 01 | Lizbeth Darien |
| 02 | Darnell O'Sullivan |
| 03 | Alisha von Strump |
| 17 | Lance Pinos-Potter |
| 20 | Jean Paul Renard |

## Description

- The emp_id column in the String_Sample table used in the examples above is defined with the type VARCHAR(3). Therefore, the numeric values it contains are stored as character strings.

Figure 9-3 How to sort by a string column that contains numbers

## How to parse a string

Another problem you may encounter when working with string data occurs when two or more values are stored in the same string. For example, the emp_name column in the String_Sample table contains both a first and a last name. If you want to work with the first and last names independently, you have to parse the string using the string functions. Figure 9-4 shows how this works.

The first example uses the SUBSTRING_INDEX function to parse the first and last names. To start, the second column uses the SUBSTRING_INDEX function to return all characters from the start of the string in the emp_name column up to the first space in that column. Then, the third column uses the SUBSTRING_INDEX function to return all characters from the end of the string in the emp_name column up to the last space in that column. To do that, a negative value is coded for the count parameter.

Unfortunately, this example doesn't work correctly for all rows. In particular, the last name for the fifth row should probably be "von Strump" not "Strump". To solve this problem, you can sometimes use the SUBSTRING function as shown by the third example.

But first, it's helpful to understand how the LOCATE function works as illustrated by the second example. Here, the second column returns an integer value for the location of the first space. Then, the third column returns the location of the second space. To get the location of the second space, this LOCATE function uses a nested LOCATE function as its third parameter. This starts the search at the character after the first space.

The third example uses the SUBSTRING function to parse a string. To start, the second column uses the SUBSTRING and LOCATE functions to return all characters from the beginning of the string to the first space. Then, the third column uses the SUBSTRING and LOCATE functions to return all characters after the first space to the end of the string.

Unfortunately, this example also doesn't work correctly for all rows. In particular, the last name for the fourth row should probably be "Renard" not "Paul Renard". However, this example does return "von Strump" not "Strump" for the last row, which is probably correct.

As you review these examples, you can focus on how the string functions are used. As I've indicated, though, this code doesn't work correctly for all names. This illustrates the importance of designing a database so this type of problem doesn't occur. You'll learn more about that in the next chapter. For now, just realize that if a database is designed correctly, you won't have to worry about this type of problem. Instead, this problem should occur only if you're importing data from another file or database system.

## How to use the SUBSTRING_INDEX function to parse a string

```
SELECT emp_name,
    SUBSTRING_INDEX(emp_name, ' ', 1) AS first_name,
    SUBSTRING_INDEX(emp_name, ' ', -1) AS last_name
FROM string_sample
```

| emp_name | first_name | last_name |
|---|---|---|
| Lizbeth Darien | Lizbeth | Darien |
| Darnell O'Sullivan | Darnell | O'Sullivan |
| Lance Pinos-Potter | Lance | Pinos-Potter |
| Jean Paul Renard | Jean | Renard |
| Alisha von Strump | Alisha | Strump |

## How to use the LOCATE function to find a character in a string

```
SELECT emp_name,
    LOCATE(' ', emp_name) AS first_space,
    LOCATE(' ', emp_name, LOCATE(' ', emp_name) + 1) AS second_space
FROM string_sample
```

| emp_name | first_space | second_space |
|---|---|---|
| Lizbeth Darien | 8 | 0 |
| Darnell O'Sullivan | 8 | 0 |
| Lance Pinos-Potter | 6 | 0 |
| Jean Paul Renard | 5 | 10 |
| Alisha von Strump | 7 | 11 |

## How to use the SUBSTRING function to parse a string

```
SELECT emp_name,
    SUBSTRING(emp_name, 1, LOCATE(' ', emp_name) - 1) AS first_name,
    SUBSTRING(emp_name, LOCATE(' ', emp_name) + 1) AS last_name
FROM string_sample
```

| emp_name | first_name | last_name |
|---|---|---|
| Lizbeth Darien | Lizbeth | Darien |
| Darnell O'Sullivan | Darnell | O'Sullivan |
| Lance Pinos-Potter | Lance | Pinos-Potter |
| Jean Paul Renard | Jean | Paul Renard |
| Alisha von Strump | Alisha | von Strump |

## Description

- If a string consists of two or more components, you can parse it into its individual components. To do that, you can use the SUBSTRING_INDEX, SUBSTRING, and LOCATE functions.

Figure 9-4 How to parse a string

# How to work with numeric data

In addition to the string functions, MySQL provides several functions for working with numeric data. Although you'll probably use only a couple of these functions regularly, you should be aware of them in case you ever need them.

## How to use the numeric functions

Figure 9-5 summarizes some of the numeric functions that MySQL provides. The function you'll probably use most often is the ROUND function that you saw back in chapter 3. This function rounds a number to the precision specified by the length argument. Note that you can round the digits to the left of the decimal point by coding a negative value for this argument. However, you're more likely to code a positive number to round the digits to the right of the decimal point.

Another function that you might use regularly is the TRUNCATE function. This function works like the ROUND function, but it truncates the number instead of rounding to the nearest number. In other words, this function chops off the end of the number without doing any rounding. For example, if you round 19.99 to the nearest integer, you get a value of 20. However, if you truncate 19.99, you get a value of 19.

You can use the next two functions, CEILING and FLOOR, to get the smallest integer greater than or equal to a number and the largest integer less than or equal to a number. You can use the ABS function to get the absolute value of a number. And you can use the SIGN function to return a value that indicates if a number is positive, negative, or zero.

You can use the next two functions, SQRT and POWER, to calculate the square root of a number or raise a number to a specified power. And you can use the last function, RAND, to generate a floating-point number with a random value between 0 and 1.

In addition to the functions shown in this figure, MySQL provides many other functions for performing mathematical calculations, including trigonometric calculations. If you need a function that isn't shown here, you can search for the function in the MySQL Reference Manual.

## Some of the numeric functions

| Function | Description |
|---|---|
| `ROUND(number[,length])` | Returns the number rounded to the precision specified by length. If length is 0, the decimal digits are omitted. This is the default. If length is negative, the digits to the left of the decimal point are rounded. |
| `TRUNCATE(number,length)` | Returns the number truncated to the precision specified by length. If length is 0, the decimal digits are omitted. |
| `CEILING(number)` | Returns the smallest integer that is greater than or equal to the number. |
| `FLOOR(number)` | Returns the largest integer that is less than or equal to the number. |
| `ABS(number)` | Returns the absolute value of the number. |
| `SIGN(number)` | Returns -1 for a negative number, 1 for a positive number, and 0 if the number is zero. |
| `SQRT(number)` | Returns the square root of the number. |
| `POWER(number,power)` | Returns the number raised to the specified power. |
| `RAND([integer])` | Returns a random floating-point number between 0 and 1. If integer is omitted, the function returns a series of different numbers every time. Otherwise, integer supplies a seed value, and the function returns the same series of numbers. |

## Examples that use the numeric functions

| Function | Result |
|---|---|
| `ROUND(12.49,0)` | 12 |
| `ROUND(12.50,0)` | 13 |
| `ROUND(12.49,1)` | 12.5 |
| `TRUNCATE(12.51,0)` | 12 |
| `TRUNCATE(12.49,1)` | 12.4 |
| | |
| `CEILING(12.5)` | 13 |
| `CEILING(-12.5)` | -12 |
| `FLOOR(-12.5)` | -13 |
| `FLOOR(12.5)` | 12 |
| `ABS(-1.25)` | 1.25 |
| `ABS(1.25)` | 1.25 |
| `SIGN(-1.25)` | -1 |
| `SIGN(1.25)` | 1 |
| | |
| `SQRT(125.43)` | 11.199553562530964 |
| `POWER(9,2)` | 81 |
| | |
| `RAND()` | 0.2444132019248 |

## Note

- If an error occurs, each of the numeric functions returns a null value.

Figure 9-5 How to use the numeric functions

## How to search for floating-point numbers

In n chapter 8, you learned that floating-point types such as the DOUBLE and FLOAT types store approximate values, not exact values. That means that you don't want to search for exact values when you're working with floating-point numbers. If you do, you'll miss values that are approximately equal to the value you're looking for.

To illustrate, consider the Float_Sample table from the EX database shown in figure 9-6. This table includes a column named float_value that's defined with the DOUBLE type. Now, consider what would happen if you selected all the rows where the value of float_value is equal to 1 as shown by the first SELECT statement. In that case, the result set includes only the second row, even though the table contains two other rows that have values approximately equal to 1.

This figure shows two ways to search for approximate values. First, you can search for a range of values. In this figure, for example, the second SELECT statement searches for values between .99 and 1.01. Second, you can search for values that round to an exact value. This is illustrated by the third SELECT statement. Both of these statements return the three rows from the Float_Sample table that are approximately equal to 1.

Note that both of these statements only check whether the numbers are equal down to two decimal places. However, if you want, you can modify these statements to check for more decimal places.

## The Float_Sample table

| float_id | float_value |
|---|---|
| 1 | 0.999999999999999 |
| 2 | 1 |
| 3 | 1.000000000000001 |
| 4 | 1234.56789012345 |
| 5 | 999.04440209348 |
| 6 | 24.04849 |

## A search for an exact value

```
SELECT *
FROM float_sample
WHERE float_value = 1
```

| float_id | float_value |
|---|---|
| 2 | 1 |

## How to search for approximate values

### Search for a range of values

```
SELECT *
FROM float_sample
WHERE float_value BETWEEN 0.99 AND 1.01
```

| float_id | float_value |
|---|---|
| 1 | 0.999999999999999 |
| 2 | 1 |
| 3 | 1.000000000000001 |

### Search for rounded values

```
SELECT *
FROM float_sample
WHERE ROUND(float_value, 2) = 1.00
```

| float_id | float_value |
|---|---|
| 1 | 0.999999999999999 |
| 2 | 1 |
| 3 | 1.000000000000001 |

## Description

- Because floating-point values are approximate, you'll want to search for approximate values when working with floating-point data types such as the DOUBLE and FLOAT types.

Figure 9-6 How to search for floating-point numbers

# How to work with date/time data

In the topics that follow, you'll learn how to use some of the functions that MySQL provides for working with dates and times. As you'll see, these include functions for extracting different parts of a date/time value and for performing operations on dates and times. In addition, you'll learn how to perform different types of searches on date/time values.

## How to get the current date and time

Figure 9-7 presents some of the date/time functions and shows how they work. The NOW, CURDATE, and CURTIME functions return the local dates and/or times based on your system's clock. However, if a session time zone has been set, the value returned by the CURDATE and CURTIME functions is adjusted to accommodate that time zone.

The UTC_DATE and UTC_TIME functions work similarly, but they return the *Universal Time Coordinate* (*UTC*) date, also known as *Greenwich Mean Time* (*GMT*). Although you probably won't use the UTC functions often, they're useful if your system operates in different time zones. That way, the date/time values always reflect Greenwich Mean Time, regardless of the time zone in which they're entered. For example, a date/time value entered at 11:00 a.m. Los Angeles time is given the same value as a date/time value entered at 2:00 p.m. New York time. That makes it easy to compare and operate on these values.

When you use functions to get the current date and time, you should be aware that the SYSDATE and CURRENT_TIMESTAMP functions are synonymous with the NOW function, and the CURRENT_DATE and CURRENT_TIME functions are synonymous with the CURDATE and CURTIME functions. In practice, the NOW, CURDATE, and CURTIME functions are typically used by MySQL programmers because they've been around the longest and because they're shorter, which makes them easier to type. However, the CURRENT_TIMESTAMP, CURRENT_DATE, and CURRENT_TIME functions are the ANSI standard, so they're more likely to work with other databases. As a result, if portability is a priority for you, you might want to use these functions..

When you use the NOW, SYSDATE, CURDATE, and CURTIME functions, you must enter an empty set of parentheses after the name of the function as shown by this figure. However, when you use the other functions shown in this figure, the parentheses are optional. For example, you can code the CURRENT_DATE function like this:

```
CURRENT_DATE
```

The advantage of coding the empty set of parentheses is that it clearly indicates that the code is calling a function. The disadvantage is that it requires a little more typing.

## Functions that get the current date and time

| Function | Description |
|---|---|
| NOW()<br>SYSDATE()<br>CURRENT_TIMESTAMP() | Returns the current local date and time based on the system's clock. |
| CURDATE()<br>CURRENT_DATE() | Returns the current local date. |
| CURTIME()<br>CURRENT_TIME() | Returns the current local time. |
| UTC_DATE() | Returns the current date in Coordinated Universal Time (UTC). |
| UTC_TIME() | Returns the current time in Coordinated Universal Time (UTC). |

## Examples

| Function | Result |
|---|---|
| NOW() | 2022-12-06 14:12:04 |
| SYSDATE() | 2022-12-06 14:12:04 |
| CURDATE() | 2022-12-06 |
| CURTIME() | 14:12:04 |
| UTC_DATE() | 2022-12-06 |
| UTC_TIME() | 21:12:04 |
| CURRENT_TIMESTAMP() | 2022-12-06 14:12:04 |
| CURRENT_DATE() | 2022-12-06 |
| CURRENT_TIME() | 14:12:04 |

## Description

- Parentheses are required after the NOW, SYSDATE, CURDATE, and CURTIME functions.
- Parentheses are optional after the UTC_DATE, UTC_TIME, CURRENT_TIMESTAMP, CURRENT_DATE, and CURRENT_TIME functions.

Figure 9-7 How to get the current date and time

## How to parse dates and times with date/time functions

Figure 9-8 shows you how to use some of MySQL's functions to parse dates and times. When you use these functions, you can retrieve any of the date or time parts listed in this figure.

If you need to get an integer value for part of a date/time value, you can use the first group of functions as shown by the first group of examples in this figure. For example, you can use the DAYOFWEEK function to return a number that represents the day of the week. You can use the MONTH function to return a number that represents the month. And you can use the HOUR function to return a number that represents the hour. However, if you need to get the name of a day or month as a string, you can use the DAYNAME or MONTHNAME functions as shown by the second group of examples in this figure.

## Some of the date/time parsing functions

| Function | Description |
|---|---|
| `DAYOFMONTH(date)` | Returns the day of the month as an integer. |
| `MONTH(date)` | Returns the month as an integer. |
| `YEAR(date)` | Returns the 4-digit year as an integer. |
| `HOUR(time)` | Returns the hours as an integer. |
| `MINUTE(time)` | Returns the minutes as an integer. |
| `SECOND(time)` | Returns the seconds as an integer. |
| `DAYOFWEEK(date)` | Returns the day of the week as an integer where 1=Sunday, 2=Monday, etc. |
| `QUARTER(date)` | Returns the quarter of the year as an integer between 1 and 4. |
| `DAYOFYEAR(date)` | Returns the day of the year as an integer. |
| `WEEK(date[,first])` | Returns the week of the year as an integer. If the *first* argument is 0, the week starts on Sunday. If the *first* argument is 1, the week starts on Monday. |
| `LAST_DAY(date)` | Returns the last day of the month as an integer. |
| `DAYNAME(date)` | Returns the name of the day of the week as a string. |
| `MONTHNAME(date)` | Returns the name of the month as a string. |

## Examples

| Function | Result |
|---|---|
| `DAYOFMONTH('2022-12-03')` | `3` |
| `MONTH('2022-12-03')` | `12` |
| `YEAR('2022-12-03')` | `2022` |
| `HOUR('11:35:00')` | `11` |
| `MINUTE('11:35:00')` | `35` |
| `SECOND('11:35:00')` | `0` |
| `DAYOFWEEK('2022-12-03')` | `7` |
| `QUARTER('2022-12-03')` | `4` |
| `DAYOFYEAR('2022-12-03')` | `337` |
| `WEEK('2022-12-03')` | `48` |
| `LAST_DAY('2022-12-03')` | `31` |
| `DAYNAME('2022-12-03')` | `Saturday` |
| `MONTHNAME('2022-12-03')` | `December` |

## Description

- The argument for the date functions can be either a DATE value or a DATETIME value.
- The argument for the time functions can be either a TIME value or a DATETIME value.

Figure 9-8 How to parse dates and times with date/time functions

## How to parse dates and times with the EXTRACT function

In the previous figure, you learned about some common date/time functions for parsing dates and times. In addition to these functions, you can use the EXTRACT function to parse dates and times as shown by figure 9-9. Because this function is part of the ANSI standard, you may want to use it to make your code more portable. Or, you may just prefer how this function works.

When you use the EXTRACT function, you can code any of the date/time units shown in this figure, followed by the FROM keyword and a date/time value. Then, MySQL extracts the specified unit from the date/time value and returns an integer value that corresponds to that unit. For example, you can use the MONTH unit to get an integer for the month. You can also use some units to get multiple parts of the date. For example, you can use the HOUR_SECOND unit to get an integer that represents the hours, minutes, and seconds parts of a date/time value. In that case, the returned integer contains one or two digits for the hour (a leading zero is dropped), two digits for the minute, and two digits for the second.

Of course, the EXTRACT function won't work correctly if you don't specify a date/time value that makes sense for the specified unit. For example, if you specify the SECOND unit for a DATE value, the EXTRACT function won't work correctly. Conversely, if you specify the MONTH unit for a TIME value, the EXTRACT function won't work correctly. However, if you specify a DATETIME value as shown by this figure, the EXTRACT function should always work correctly.

### The EXTRACT function

| Function | Description |
|---|---|
| `EXTRACT(unit FROM date)` | Returns an integer that corresponds to the specified unit for the specified date/time. |

### Date/time units

| Unit | Description |
|---|---|
| `SECOND` | Seconds |
| `MINUTE` | Minutes |
| `HOUR` | Hours |
| `DAY` | Day |
| `MONTH` | Month |
| `YEAR` | Year |
| `MINUTE_SECOND` | Minutes and seconds |
| `HOUR_MINUTE` | Hour and minutes |
| `DAY_HOUR` | Day and hours |
| `YEAR_MONTH` | Year and month |
| `HOUR_SECOND` | Hours, minutes, and seconds |
| `DAY_MINUTE` | Day, hours, and minutes |
| `DAY_SECOND` | Day, hours, minutes, and seconds |

### Examples that use the EXTRACT function

| Function | Result |
|---|---|
| `EXTRACT(SECOND FROM '2022-12-03 11:35:00')` | 0 |
| `EXTRACT(MINUTE FROM '2022-12-03 11:35:00')` | 35 |
| `EXTRACT(HOUR FROM '2022-12-03 11:35:00')` | 11 |
| `EXTRACT(DAY FROM '2022-12-03 11:35:00')` | 3 |
| `EXTRACT(MONTH FROM '2022-12-03 11:35:00')` | 12 |
| `EXTRACT(YEAR FROM '2022-12-03 11:35:00')` | 2022 |
| `EXTRACT(MINUTE_SECOND FROM '2022-12-03 11:35:00')` | 3500 |
| `EXTRACT(HOUR_MINUTE FROM '2022-12-03 11:35:00')` | 1135 |
| `EXTRACT(DAY_HOUR FROM '2022-12-03 11:35:00')` | 311 |
| `EXTRACT(YEAR_MONTH FROM '2022-12-03 11:35:00')` | 202212 |
| `EXTRACT(HOUR_SECOND FROM '2022-12-03 11:35:00')` | 113500 |
| `EXTRACT(DAY_MINUTE FROM '2022-12-03 11:35:00')` | 31135 |
| `EXTRACT(DAY_SECOND FROM '2022-12-03 11:35:00')` | 3113500 |

Figure 9-9 How to parse dates and times with the EXTRACT function

## How to format dates and times

Figure 9-10 shows how to use the DATE_FORMAT function to format dates and times. This function accepts two parameters. The first parameter specifies the DATE or DATETIME value that you want to format. Then, the second parameter specifies a *format string* that includes special codes for formatting the various parts of the date or time. To use one of these codes within the format string, you code the percent sign (%) followed by a single case-sensitive letter.

In this figure, for instance, the first example uses the %m code to get the numeric month, the %d code to get the numeric day, and the %y code to get the two-digit year. This example also uses front slashes (/) to separate the month, day, and year.

The next three examples use other formatting codes, but they work similarly to the first example. Namely, the format string contains some date/time formatting codes to display the different parts of the date. In addition, it contains other characters such as spaces, commas, or dashes to separate the different parts of the date.

This figure also shows how to use the TIME_FORMAT function to format TIME values. This function is illustrated by the last two examples. Although you can also use the TIME_FORMAT function to format the time part of a DATETIME value, it's more common to use the DATE_FORMAT function to do that as shown by the fourth example.

## Two functions for formatting dates and times

| Function | Description |
|---|---|
| DATE_FORMAT(date,format) | Returns a string for the specified DATE or DATETIME value with the formatting specified by the format string. |
| TIME_FORMAT(time,format) | Works like the DATE_FORMAT function but accepts TIME or DATETIME values, and the format string can only specify times, not dates. |

## Common codes for date/time format strings

| Code | Description |
|---|---|
| %m | Month, numeric (01…12) |
| %c | Month, numeric (1…12) |
| %M | Month name (January…December) |
| %b | Abbreviated month name (Jan…Dec) |
| %d | Day of the month, numeric (00…31) |
| %e | Day of the month, numeric (0…31) |
| %D | Day of the month with suffix (1st, 2nd, 3rd, etc.) |
| %y | Year, numeric, 2 digits |
| %Y | Year, numeric, 4 digits |
| %W | Weekday name (Sunday…Saturday) |
| %a | Abbreviated weekday name (Sun…Sat) |
| %H | Hour (00…23) |
| %k | Hour (0…23) |
| %h | Hour (01…12) |
| %l | Hour (1…12) |
| %i | Minutes (00…59) |
| %r | Time, 12-hour (hh:mm:ss AM or PM) |
| %T | Time, 24-hour (hh:mm:ss) |
| %S | Seconds (00…59) |
| %p | AM or PM |

## Examples

| Function | Result |
|---|---|
| DATE_FORMAT('2022-12-03', '%m/%d/%y') | 08/03/22 |
| DATE_FORMAT('2022-12-03', '%W, %M %D, %Y') | Saturday, December 3rd, 2022 |
| DATE_FORMAT('2022-12-03', '%e-%b-%y') | 3-Dec-22 |
| DATE_FORMAT('2022-12-03 16:45', '%r') | 04:45:00 PM |
| TIME_FORMAT('16:45', '%r') | 04:45:00 PM |
| TIME_FORMAT('16:45', '%l:%i %p') | 4:45 PM |

Figure 9-10 How to format dates and times

## How to perform calculations on dates and times

Figure 9-11 shows you how to use the DATE_ADD, DATE_SUB and DATEDIFF functions to perform calculations on dates and times. You can use the DATE_ADD function to add a specified number of date parts to a date. In this figure, for instance, the first three examples show how you can add days, months, or seconds to a date/time value.

You can also use the DATE_ADD function to subtract date parts from a date/time value. To do that, you code the expression argument as a negative value as shown by the fourth example. This performs the same calculation as the DATE_SUB function shown in the fifth example.

When you use these date functions, MySQL checks for dates that include leap years and returns a null value if a date doesn't exist. For example, 2020 was a leap year, so it has a day for February 29. However, 2022 wasn't a leap year, so it doesn't have a day for February 29. As a result, when the sixth example adds one year to February 29, 2020, MySQL returns February 28, 2021. On the other hand, the seventh example tries to add one year to an invalid date (February 29, 2022). As a result, MySQL returns a null value.

The eighth example shows how to use the DATE_ADD function with the DAY_HOUR unit to add the specified number of days and hours to a date/time value. Here, the example adds 2 days and 12 hours to the specified date.

If you need to find the number of days between two date/time values, you can use the DATEDIFF function as shown by the second group of examples. Note that this function only returns days, not hours, minutes, or seconds. This is true even if the arguments are DATETIME values that include time values, as shown by the second DATEDIFF example. When you use the DATEDIFF function, you typically specify the later date as the first argument and the earlier date as the second argument. That way, the result of the function is a positive value. If you code the earlier date as the first argument, the result is a negative value as shown by the third DATEDIFF example.

The last group of examples shows how to use the TO_DAYS and TIME_TO_SEC functions to perform calculations on dates and times. To start, the TO_DAYS example shows how you can use this function to calculate the number of days between two dates. This performs the same calculation as the first two DATEDIFF examples. Since the DATEDIFF function is easier to write and read, you'll typically use it instead of the TO_DAYS function for this type of calculation.

The last example shows how to use the TIME_TO_SEC function to calculate the number of seconds between two times. This type of calculation can be useful when you're working with time values.

### Some of the functions for calculating dates and times

| Function | Description |
|---|---|
| `DATE_ADD(date,INTERVAL expression unit)` | Returns a DATE or DATETIME value equal to the specified date plus the specified interval. |
| `DATE_SUB(date,INTERVAL expression unit)` | Returns a DATE or DATETIME value equal to the date minus the specified interval. |
| `DATEDIFF(date1, date2)` | Returns the number of days from one date to the other. For DATETIME values, this function ignores the time parts of the value. |
| `TO_DAYS(date)` | Returns the number of days since the year 0. This function does not return reliable results for dates before 1582. |
| `TIME_TO_SEC(time)` | Returns the number of seconds elapsed since midnight, which is useful for calculating elapsed time. |

### Examples

| Function | Result |
|---|---|
| `DATE_ADD('2022-12-31', INTERVAL 1 DAY)` | `2023-01-01` |
| `DATE_ADD('2022-12-31', INTERVAL 3 MONTH)` | `2023-03-31` |
| `DATE_ADD('2022-12-31 23:59:59', INTERVAL 1 SECOND)` | `2023-01-01 00:00:00` |
| `DATE_ADD('2023-01-01', INTERVAL -1 DAY)` | `2022-12-31` |
| `DATE_SUB('2023-01-01', INTERVAL 1 DAY)` | `2022-12-31` |
| `DATE_ADD('2020-02-29', INTERVAL 1 YEAR)` | `2021-02-28` |
| `DATE_ADD('2022-02-29', INTERVAL 1 YEAR)` | `NULL` |
| `DATE_ADD('2022-12-31 12:00', INTERVAL '2 12' DAY_HOUR)` | `2023-01-03 00:00:00` |
| | |
| `DATEDIFF('2022-12-30', '2022-12-03')` | `27` |
| `DATEDIFF('2022-12-30 23:59:59', '2022-12-03')` | `27` |
| `DATEDIFF('2022-12-03', '2022-12-30')` | `-27` |
| | |
| `TO_DAYS('2022-12-30') - TO_DAYS('2022-12-03')` | `27` |
| `TIME_TO_SEC('10:00') - TIME_TO_SEC('09:59')` | `60` |

### Description

- If the expression you specify in the DATE_ADD function is a negative integer, the interval is subtracted from the date.
- If the expression you specify in the DATE_SUB function is a negative integer, the interval is added to the date.

Figure 9-11 How to perform calculations on dates and times

## How to search for a date

Figure 9-12 illustrates a problem you can encounter when searching for dates in a column that's defined with the DATETIME data type. The examples in this figure use a table named Date_Sample. This table includes a date_id column that's defined with the INT type and a start_date column that's defined with the DATETIME type. The time components in the first three rows in this table have a zero value. In contrast, the time components in the next three rows have non-zero time components.

The problem occurs when you try to search for a date value. In this figure, for instance, the first SELECT statement searches for rows in the Date_Sample table with a date of '2022-02-28'. Because this code doesn't specify a time component, MySQL adds a zero time component ('00:00:00') when it converts the date string to a DATETIME value. However, because the row with this date has a non-zero time value, MySQL doesn't return any rows for this statement.

To solve this problem, you can use one of the three techniques shown in this figure. First, you can search for a range of dates that includes only the date you're looking for as shown by the second SELECT statement in this figure. The WHERE clause in this statement searches for dates that are greater than or equal to the date you're looking for and less than the date that follows the date you're looking for. Because a time component of zero is implicitly added to both of the dates in the search condition, this statement returns the one row with the date you want.

Because this SELECT statement doesn't use any functions in the WHERE clause, it provides the most efficient technique for searching for dates. That's particularly true if the start_date column is indexed. By contrast, the second technique uses the MONTH, DAYOFMONTH, and YEAR functions in the WHERE clause to search for just for those components. And the third technique uses the DATE_FORMAT function in the WHERE clause to return a formatted string that only contains the month, day, and year.

If you want, you can use other date functions to search for a date. For example, you can use the EXTRACT function shown earlier in this chapter. Whenever possible, though, you should avoid using functions so the search is as efficient as possible.

## The contents of the Date_Sample table

| date_id | start_date |
|---|---|
| 1 | 1986-03-01 00:00:00 |
| 2 | 2006-02-28 00:00:00 |
| 3 | 2010-10-31 00:00:00 |
| 4 | 2022-02-28 10:00:00 |
| 5 | 2023-02-28 13:58:32 |
| 6 | 2023-03-01 09:02:25 |

## A SELECT statement that fails to return a row

```
SELECT *
FROM date_sample
WHERE start_date = '2022-02-28'
```

| date_id | start_date |
|---|---|

## Three techniques for ignoring time values

### Search for a range of dates

```
SELECT *
FROM date_sample
WHERE start_date >= '2022-02-28' AND start_date < '2022-03-01'
```

| date_id | start_date |
|---|---|
| 4 | 2022-02-28 10:00:00 |

### Search for month, day, and year integers

```
SELECT *
FROM date_sample
WHERE MONTH(start_date) = 2 AND
      DAYOFMONTH(start_date) = 28 AND
      YEAR(start_date) = 2022
```

| date_id | start_date |
|---|---|
| 4 | 2022-02-28 10:00:00 |

### Search for a formatted date

```
SELECT *
FROM date_sample
WHERE DATE_FORMAT(start_date, '%m-%d-%Y') = '02-28-2022'
```

| date_id | start_date |
|---|---|
| 4 | 2022-02-28 10:00:00 |

## Description

- You can search for a date in a DATETIME column by searching for a range of dates, by using functions to specify the month, day, and year of the date, or by searching for a formatted date. Of these techniques, searching for a range of dates is the most efficient.

Figure 9-12 How to search for a date

## How to search for a time

Just like when you search for a date in a DATETIME column, you can encounter problems when you search for a time in a DATETIME column. In the first SELECT statement in figure 9-13, for example, you can see that searching for a time value in a DATETIME column without specifying a date component causes an error. At least that's what happens with MySQL 8.0.16 and later. With earlier versions of MySQL, this statement caused a warning and MySQL used the default date of January 1, 1990. In that case, though, the SELECT statement didn't return a row even though one row matches the specified time.

The second SELECT statement shows one way to search for a time in a DATETIME column. Here, the WHERE clause uses the DATE_FORMAT function to return a string for the start_date column in the hh:mm:ss format. Then, the WHERE clause compares this string to a literal string of 10:00:00.

The third SELECT statement in this figure shows another way to search for a time. This statement works similarly to the second statement, but it uses the EXTRACT function to extract an integer that represents the hours, minutes, and seconds in the start_date column. Then, the WHERE clause compares this integer to an integer value of 100000. Although this approach might run slightly faster, it's also more difficult to read. As a result, I recommend using the first approach unless performance is critical.

The fourth and fifth SELECT statements show that you can use a similar technique to search for a range of times. Here, the fourth statement uses the HOUR function to search for a particular hour of the day, and the fifth statement uses the EXTRACT function to search for times between two times. Of course, you could also use the DATE_FORMAT function to get the same results.

Before I go on, you should realize that many of the problems that can occur when searching for dates and times can be avoided by designing the database properly. For example, if you know that only the date portion of a date/time value is significant, you can store the date in a column with the DATE type. Conversely, if you know that only the time portion of a date/time value is significant, you can store the time in a column with the TIME type. That way, you won't need to use functions in your searches, and you can create an index for the search column to significantly speed searches.

However, if both the date and time are significant, you can store them in a column with the DATETIME type. Then, you can use the techniques shown in this figure and the previous figure to search for dates and times. Remember, though, that if you need to use functions in your searches, MySQL can't use the column's index and the search will run significantly slower.

### The contents of the Date_Sample table

| date_id | start_date |
|---|---|
| 1 | 1986-03-01 00:00:00 |
| 2 | 2006-02-28 00:00:00 |
| 3 | 2010-10-31 00:00:00 |
| 4 | 2022-02-28 10:00:00 |
| 5 | 2023-02-28 13:58:32 |
| 6 | 2023-03-01 09:02:25 |

### A SELECT statement that causes an error

```
SELECT * FROM date_sample
WHERE start_date = '10:00:00'
```

#### Error

```
Error Code: 1525. Incorrect DATETIME value: '10:00:00'
```

### Examples that ignore date values

#### Search for a time that has been formatted

```
SELECT * FROM date_sample
WHERE DATE_FORMAT(start_date, '%T') = '10:00:00'
```

| date_id | start_date |
|---|---|
| 4 | 2022-02-28 10:00:00 |

#### Search for a time that hasn't been formatted

```
SELECT * FROM date_sample
WHERE EXTRACT(HOUR_SECOND FROM start_date) = 100000
```

| date_id | start_date |
|---|---|
| 4 | 2022-02-28 10:00:00 |

#### Search for an hour of the day

```
SELECT * FROM date_sample
WHERE HOUR(start_date) = 9
```

| date_id | start_date |
|---|---|
| 6 | 2023-03-01 09:02:25 |

#### Search for a range of times

```
SELECT * FROM date_sample
WHERE EXTRACT(HOUR_MINUTE FROM start_date) BETWEEN 900 AND 1200
```

| date_id | start_date |
|---|---|
| 4 | 2022-02-28 10:00:00 |
| 6 | 2023-03-01 09:02:25 |

### Description

- You can search for a time in a DATETIME column without specifying a date by using date/time functions to get the time part of the DATETIME value. Then, you can use the time parts in your WHERE clause.

Figure 9-13 How to search for a time

# Other functions you should know about

This topic describes other functions that you should know about. That includes the CASE, IF, IFNULL, and COALESCE functions. It also includes the regular expression and specialized window functions that are new with MySQL 8.0.

## How to use the CASE function

Figure 9-14 presents the two versions of the CASE function. This function returns a value that's determined by the conditions you specify. The easiest way to describe how this function works is to look at the two examples shown in this figure.

The first example uses a simple CASE function. When you use this function, MySQL compares the input expression you code in the CASE clause with the expressions you code in the WHEN clauses. In this example, the input expression is a value in the terms_id column of the Invoices table, and the when expressions are the valid values for this column. When MySQL finds an expression in a WHEN clause that's equal to the input expression, it returns the expression specified in the matching THEN clause. For example, if the value of the terms_id column is 3, this function returns a value of "Net due 30 days." Although it's not shown in this example, you can also code an ELSE clause at the end of the CASE function. Then, if none of the expressions in the WHEN clause are equal to the input expression, the function returns the value specified in the ELSE clause.

The second example uses a searched CASE function to determine the status of the invoices in the Invoices table. To do that, the CASE function uses the DATEDIFF and NOW functions to get the number of days between the current date and the invoice due date. If the difference is greater than 30, the CASE function returns the value "Over 30 days past due." Otherwise, if the difference is greater than 0, the function returns the value "1 to 30 days past due." Note that if the condition in the first WHEN clause is true, the condition in the second WHEN clause is also true. In that case, the function returns the expression associated with the first condition since this condition is evaluated first. In other words, the sequence of the conditions is critical to getting the correct results. If neither of the conditions is true, the function returns the value "Current."

The simple CASE function is typically used with columns that can contain a limited number of values, such as the terms_id column used in the first example. By contrast, the searched CASE function can be used for a wide variety of purposes. For example, this function can be used to test for conditions other than equal, such as greater than or less than. This is shown in the second example, which couldn't be coded using the simple syntax. In addition, each condition in a searched CASE function can be based on a different column or expression. Of course, CASE functions can be more complicated than the ones that are shown here, but this should give you an idea of what you can do with this function.

### The syntax of the simple CASE function

```
CASE input_expression
    WHEN when_expression_1 THEN result_expression_1
   [WHEN when_expression_2 THEN result_expression_2]...
   [ELSE else_result_expression]
END
```

### A SELECT statement that uses a simple CASE function

```
SELECT invoice_number, terms_id,
    CASE terms_id
        WHEN 1 THEN 'Net due 10 days'
        WHEN 2 THEN 'Net due 20 days'
        WHEN 3 THEN 'Net due 30 days'
        WHEN 4 THEN 'Net due 60 days'
        WHEN 5 THEN 'Net due 90 days'
    END AS terms
FROM invoices
```

| invoice_number | terms_id | terms |
|---|---|---|
| 989319-457 | 3 | Net due 30 days |
| 263253241 | 3 | Net due 30 days |
| 963253234 | 3 | Net due 30 days |
| 2-000-2993 | 3 | Net due 30 days |
| 963253251 | 3 | Net due 30 days |

### The syntax of the searched CASE function

```
CASE
    WHEN conditional_expression_1 THEN result_expression_1
   [WHEN conditional_expression_2 THEN result_expression_2]...
   [ELSE else_result_expression]
END
```

### A SELECT statement that uses a searched CASE function

```
SELECT invoice_number, invoice_total, invoice_date, invoice_due_date,
    CASE
      WHEN DATEDIFF(NOW(), invoice_due_date) > 30
        THEN 'Over 30 days past due'
      WHEN DATEDIFF(NOW(), invoice_due_date) > 0
        THEN '1 to 30 days past due'
      ELSE 'Current'
    END AS invoice_status
FROM invoices
WHERE invoice_total - payment_total - credit_total > 0
```

| invoice_number | invoice_total | invoice_date | invoice_due_date | invoice_status |
|---|---|---|---|---|
| 39104 | 85.31 | 2022-07-10 | 2022-08-09 | Over 30 days past due |
| 963253264 | 52.25 | 2022-07-18 | 2022-08-17 | Over 30 days past due |
| 31361833 | 579.42 | 2022-07-21 | 2022-08-10 | Over 30 days past due |
| 263253268 | 59.97 | 2022-07-21 | 2022-08-20 | Over 30 days past due |
| 263253270 | 67.92 | 2022-07-22 | 2022-08-21 | Over 30 days past due |

### Description

- The CASE function returns a value that's determined by the specified conditions.

Figure 9-14 How to use the CASE function

## How to use the IF, IFNULL, and COALESCE functions

Figure 9-15 presents three functions: IF, IFNULL, and COALESCE. To start, you can use the IF function to test a condition and return one value if the condition is true or another value if the condition is false. For instance, the first example uses the IF function to return a string value of "Yes" if the vendor_city column is equal to a value of "Fresno". Otherwise, the IF function returns a value of "No".

Both the IFNULL and COALESCE functions let you substitute non-null values for null values. Although these functions are similar, the COALESCE function is more flexible because it lets you specify a list of values. Then, it returns the first non-null value in the list. In contrast, the IFNULL function only lets you specify two expressions. If the first expression is not null, it returns that expression. Otherwise, it returns the second expression.

The second example uses the IFNULL function to return the value of the payment_date column if that column doesn't contain a null value. Otherwise, it returns a string that says "No Payment". The third example performs the same operation using the COALESCE function.

## The syntax of the IF function

```
IF(test_expression, if_true_expression, else_expression)
```

## A SELECT statement that uses the IF function

```
SELECT vendor_name,
       IF(vendor_city = 'Fresno', 'Yes', 'No') AS is_city_fresno
FROM vendors
```

| vendor_name | is_city_fresno |
|---|---|
| Towne Advertiser's Mailing Svcs | No |
| BFI Industries | Yes |
| Pacific Gas & Electric | No |
| Robbins Mobile Lock And Key | Yes |
| Bill Marvin Electric Inc | Yes |

## The syntax of the IFNULL function

```
IFNULL(test_expression, replacement_value)
```

## A SELECT statement that uses the IFNULL function

```
SELECT payment_date,
       IFNULL(payment_date, 'No Payment') AS new_date
FROM invoices
```

| payment_date | new_date |
|---|---|
| NULL | No Payment |
| 2022-08-13 | 2022-08-13 |
| 2022-08-20 | 2022-08-20 |
| 2022-08-07 | 2022-08-07 |
| NULL | No Payment |

## The syntax of the COALESCE function

```
COALESCE(expression_1[, expression_2]...)
```

## A SELECT statement that uses the COALESCE function

```
SELECT payment_date,
       COALESCE(payment_date, 'No Payment') AS new_date
FROM invoices
```

| payment_date | new_date |
|---|---|
| NULL | No Payment |
| 2022-08-13 | 2022-08-13 |
| 2022-08-20 | 2022-08-20 |
| 2022-08-07 | 2022-08-07 |
| NULL | No Payment |

## Description

- The IF function returns one value if the test expression is true and another value if the test expression is false.
- The IFNULL and COALESCE functions let you substitute non-null values for null values.
- The IFNULL function returns the first expression if it isn't null. Otherwise, it returns the replacement value you specify.
- The COALESCE function returns the first expression in the list that isn't null. If all of the expressions are null, this function returns a null value.

Figure 9-15 How to use the IF, IFNULL, and COALESCE functions

## How to use the regular expression functions

In chapter 3, you learned how to use the REGEXP operator to work with *string patterns* known as *regular expressions* to determine which values in a column satisfy a condition. With MySQL 8.0, you can also use the *regular expression functions* shown in the first table in figure 9-16 to work with string patterns. Although these functions have arguments in addition to the ones shown here, these are the ones you'll use most often.

All of the regular expression functions use a pattern to search a string expression. The REGEXP_LIKE function works like the REGEXP operator. It returns 1 if the pattern is found or 0 if it isn't. Because of that, you can use this function in a Boolean expression.

If you use the REGEXP_INSTR function and the pattern is found, the index of the first character in the matching substring is returned. If the pattern isn't found, 0 is returned.

The REGEXP_SUBSTR function returns the first substring that matches the pattern. If a matching substring isn't found, it returns a null value. And the REGEXP_REPLACE function replaces any occurrences of the pattern it finds with another string.

To create a string pattern, you can use the special characters and constructs shown in the second table in this figure. The first six are the same as the ones presented in chapter 3. However, the last two constructs weren't presented in chapter 3. The first one lets you match zero or more occurrences of a single character, and the second one lets you match zero or more occurrences of a sequence of characters.

The third table in this figure shows how the regular expression functions work. Here, all five of the functions operate on the string expression "abc123". Then, the first example uses the REGEXP_LIKE function to determine if this expression contains the substring "123". Since it does, the result is 1. The second example is similar, but it checks if the substring "123" is at the beginning of the expression. Since it's not, this function returns 0.

The third example uses the REGEXP_INSTR function to get the index of the first character of the substring 123 that occurs in the string expression. In this case, the substring starts at the fourth character in the expression, so the function returns 4.

The fourth example uses the REGEXP_SUBSTR function to get a substring of the characters in the string expression. Here, the pattern indicates that the substring consists of any letter, followed by any number of digits at the end of the string expression. That returns the value "c123".

The last example uses the REGEXP_REPLACE function to replace the number 1 or 2 with the number 3. That returns the value "abc333".

## The syntax of the regular expression functions

| Function | Description |
|---|---|
| `REGEXP_LIKE(expr, pattern)` | Returns 1 (true) if the string expression matches the pattern. Otherwise, returns 0 (false). |
| `REGEXP_INSTR(expr, pattern [, start])` | Returns the index of the first character of the substring in the string expression that matches the pattern, starting at the specified start position. If the start position is omitted, the search starts at the beginning of the string. If the pattern isn't found, the function returns 0. |
| `REGEXP_SUBSTR(expr, pattern [, start])` | Returns the first substring of the string expression that matches the pattern starting at the specified position. If the start position is omitted, the first substring is returned. If the pattern isn't found, the function returns a null value. |
| `REGEXP_REPLACE(expr, pattern, replace[, start])` | Returns the string expression with all occurrences of the pattern replaced with the replace string. |

## Regular expression special characters and constructs

| Character/Construct | Description |
|---|---|
| `^` | Matches the pattern to the beginning of the value being tested. |
| `$` | Matches the pattern to the end of the value being tested. |
| `.` | Matches any single character. |
| `[charlist]` | Matches any single character listed within the brackets. |
| `[char1-char2]` | Matches any single character within the given range. |
| `\|` | Separates two string patterns and matches either one. |
| `char*` | Matches zero or more occurrences of the character. |
| `(charlist)*` | Matches zero or more occurrences of the sequence of characters in parentheses. |

## Examples of the regular expression functions

| Example | Result |
|---|---|
| `REGEXP_LIKE('abc123', '123')` | 1 |
| `REGEXP_LIKE('abc123', '^123')` | 0 |
| `REGEXP_INSTR('abc123', '123')` | 4 |
| `REGEXP_SUBSTR('abc123', '[A-Z][1-9]*$')` | c123 |
| `REGEXP_REPLACE('abc123', '1\|2', '3')` | abc333 |

## Description

- The *regular expression functions* use a *string pattern* to search a string expression. These patterns can use special characters and constructs, which are case-insensitive by default.

Figure 9-16 How to use the regular expression functions (part 1 of 2)

To help you understand how you can use the regular expression functions in SQL statements, part 2 of figure 9-16 presents three SELECT statements that use them. The first example uses the REGEXP_INSTR function in the SELECT clause to return the index of the first space in the vendor_city column. The same REGEXP_INSTR function is also used in the WHERE clause so only the cities that have a space in their names are included in the result set.

The second example uses the REGEXP_SUBSTR function in the SELECT clause to get the substring "San" or "Los" that appears at the beginning of the vendor_city column. Then, it uses the same function in the WHERE clause so if the function returns a null value, the row isn't included in the result. In other words, only the cities that start with "San" or "Los" are included.

The third example uses the REGEXP_REPLACE function in the SELECT clause to replace the value "Street" that occurs anywhere in the vendor_address1 column with the value "St". Note that because patterns are case-insensitive by default, the pattern STREET will match both uppercase and lowercase letters as shown here. This example also uses the REGEXP_LIKE function in the WHERE clause so only vendors with a vendor_address1 column that contains the pattern are included in the result set. As you saw in chapter 3, this WHERE clause can also be coded using the REGEXP operator like this:

```
WHERE vendor_address1 REGEXP 'STREET'
```

Although these examples are relatively simple, they should give you an idea of what you can do with the regular expression functions. For more information on these functions and the special characters and constructs you can use with them, see the documentation for MySQL.

## A statement that uses the REGEXP_INSTR function

```
SELECT DISTINCT vendor_city, REGEXP_INSTR(vendor_city, ' ') AS space_index
FROM vendors
WHERE REGEXP_INSTR(vendor_city, ' ') > 0
ORDER BY vendor_city
```

| vendor_city | space_index |
|---|---|
| Ann Arbor | 4 |
| Auburn Hills | 7 |
| Carol Stream | 6 |
| East Brunswick | 5 |
| Fort Washington | 5 |
| Los Angeles | 4 |

(17 rows)

## A statement that uses the REGEXP_SUBSTR function

```
SELECT vendor_city, REGEXP_SUBSTR(vendor_city, '^SAN|LOS') AS city_match
FROM vendors
WHERE REGEXP_SUBSTR(vendor_city, '^SAN|LOS') IS NOT NULL
```

| vendor_city | city_match |
|---|---|
| Los Angeles | Los |
| Santa Ana | San |
| San Francisco | San |
| San Diego | San |

(12 rows)

## A statement that uses the REGEXP_REPLACE and REGEXP_LIKE functions

```
SELECT vendor_name, vendor_address1,
       REGEXP_REPLACE(vendor_address1, 'STREET', 'St') AS new_address1
FROM Vendors
WHERE REGEXP_LIKE(vendor_address1, 'STREET')
```

| vendor_name | vendor_address1 | new_address1 |
|---|---|---|
| Expedata Inc | 4420 N. First Street, Suite 108 | 4420 N. First St, Suite 108 |
| Fresno Photoengraving Company | 1952 "H" Street | 1952 "H" St |
| Nat Assoc of College Stores | 500 East Lorain Street | 500 East Lorain St |
| The Fresno Bee | 1626 E Street | 1626 E St |
| The Presort Center | 1627 "E" Street | 1627 "E" St |
| Reiter's Scientific & Pro Books | 2021 K Street Nw | 2021 K St Nw |

(4 rows)

## Description

- The REGEXP_LIKE function works just like the REGEXP operator that you learned about in chapter 3.
- The REGEXP_REPLACE function replaces the occurrences of the regular expression pattern only in the result set. The database table remains unchanged.

Figure 9-16 How to use the regular expression functions (part 2 of 2)

## How to use the ranking functions

If you've read chapter 6, you already know how to code aggregate window functions. In addition to those window functions, you can code non-aggregate window functions, sometimes called *specialized window functions*. These functions can be divided into two groups: the ranking functions you'll learn about in this figure and the analytical functions you'll learn about in the next figure.

Figure 9-17 shows how to use the four *ranking functions* that were introduced with MySQL 8.0. These functions provide a variety of ways for ranking the rows that are returned by a result set. All four of these functions have a similar syntax and work similarly.

The first example shows how to use the ROW_NUMBER function. Here, the SELECT statement retrieves two columns from the Vendors table. The first column uses the ROW_NUMBER function to sort the result set by the vendor_name column and to number each row in the result set. To show that the first column has been sorted and numbered correctly, the second column displays the vendor name.

To accomplish the sorting and numbering, you code the name of the ROW_NUMBER function, followed by a set of parentheses and an OVER clause. If you read chapter 6, you know that the OVER clause can include a PARTITION BY clause and an ORDER BY clause. When you code a ROW_NUMBER function or any of the other ranking functions, the ORDER BY clause is required. It specifies the sequence of the rows within each partition. In this example, for instance, the ORDER BY clause sorts by the vendor_name column in ascending sequence.

Of course, you can code more complex ORDER BY clauses whenever that's necessary. In addition, you can code an ORDER BY clause that applies to the entire result set. In that case, the ORDER BY clause within the ranking function is used to number the rows and the ORDER BY clause outside the ranking function is used to sort the rows after the numbering has been applied.

The second example shows how to use the optional PARTITION BY clause of a ranking function. This clause specifies a column that's used to divide the result set into groups called *partitions*. In this example, for instance, the PARTITION BY clause uses the vendor_state column to group vendors by state. Then, the ORDER BY clause sorts these vendors by name within each state.

You can also use the PARTITION BY clause when a SELECT statement joins one or more tables like this:

```
SELECT vendor_name, invoice_number,
    ROW_NUMBER() OVER(PARTITION BY vendor_name
    ORDER BY invoice_number) AS 'row_number'
FROM vendors JOIN invoices
    ON vendors.vendor_id = invoices.vendor_id;
```

Here, the invoices will be grouped by vendor and sorted within each vendor by invoice number. As a result, if a vendor has three invoices, these invoices will be sorted by invoice number and numbered from 1 to 3.

### The syntax of the four ranking functions

```
ROW_NUMBER()                OVER([partition_clause] order_clause)
RANK()                      OVER([partition_clause] order_clause)
DENSE_RANK()                OVER([partition_clause] order_clause)
NTILE(integer_expression)   OVER([partition_clause] order_clause)
```

### A query that uses the ROW_NUMBER function

```
SELECT ROW_NUMBER() OVER(ORDER BY vendor_name) AS 'row_number',
       vendor_name
FROM vendors
```

| row_number | vendor_name |
|---|---|
| 1 | Abbey Office Furnishings |
| 2 | American Booksellers Assoc |
| 3 | American Express |
| 4 | ASC Signs |
| 5 | Ascom Hasler Mailing Systems |

### A query that uses the PARTITION BY clause

```
SELECT ROW_NUMBER() OVER(PARTITION BY vendor_state
    ORDER BY vendor_name) AS 'row_number', vendor_name, vendor_state
FROM vendors
```

| row_number | vendor_name | vendor_state |
|---|---|---|
| 1 | AT&T | AZ |
| 2 | Computer Library | AZ |
| 3 | Wells Fargo Bank | AZ |
| 1 | Abbey Office Furnishings | CA |
| 2 | American Express | CA |
| 3 | ASC Signs | CA |

### Description

- The ROW_NUMBER, RANK, DENSE_RANK, and NTILE functions were introduced with MySQL 8.0. They are sometimes referred to as *ranking functions*.
- The ORDER BY clause determines the sequence of the rows within the partitions.
- The optional PARTITION BY clause specifies the column that's used to divide the result set into groups called *partitions*.
- The ROW_NUMBER function returns the number of the current row within its partition, starting at 1 for the first row in each partition.

Figure 9-17 How to use the ranking functions (part 1 of 2)

The first example in part 2 of figure 9-17 shows how the RANK and DENSE_RANK functions work. You can use these functions to rank the rows in a result set. In this example, both the RANK and the DENSE_RANK functions sort all invoices in the Invoices table by the invoice_total column. Since the first three rows have the same invoice total, both of these functions give these three rows the same rank, 1. However, the fourth row has a different value. To calculate the value for this row, the RANK function adds 1 to the total number of previous rows. In other words, since the first three rows are tied for first place, the fourth row gets fourth place and is assigned a rank of 4.

The DENSE_RANK function, on the other hand, calculates the value for the fourth row by adding 1 to the rank for the previous row. As a result, this function assigns a rank of 2 to the fourth row. In other words, since the first three rows are tied for first place, the fourth row gets second place.

The second example shows how the NTILE function works. You can use this function to divide the rows in a partition into the specified number of groups. When the rows can be evenly divided into groups, this function is easy to understand. For example, if a result set returns 100 rows, you can use the NTILE function to divide this result set into 10 groups of 10. However, when the rows can't be evenly divided into groups, this function is a little more difficult to understand.

In this figure, for example, the NTILE function is used to divide a result set that contains 5 rows. Here, the first NTILE function divides this result set into 2 groups with the first having 3 rows and the second having 2 rows. The second NTILE function divides this result set into 3 groups with the first having 2 rows, the second having 2 rows, and the third having 1 row. And so on. Although this doesn't result in groups with even numbers of rows, the NTILE function creates the number of groups specified by its argument.

In this figure, the examples for the RANK, DENSE_RANK, and NTILE functions don't include PARTITION BY clauses. As a result, these functions are applied to the entire result set. However, whenever necessary, you can use the PARTITION BY clause to divide the result set into groups as shown by the second example for the ROW_NUMBER function.

Although it's not shown here, you should know that you can also code a frame clause on the OVER clause for any of the ranking functions. However, you're not likely to do that. If you haven't already read chapter 6 and you want to learn more about how frames work with window functions, though, you can refer back to that chapter.

## A query that uses the RANK and DENSE_RANK functions

```
SELECT RANK() OVER (ORDER BY invoice_total) AS 'rank',
       DENSE_RANK() OVER (ORDER BY invoice_total) AS 'dense_rank',
       invoice_total, invoice_number
FROM invoices
```

| rank | dense_rank | invoice_total | invoice_number |
|---|---|---|---|
| 1 | 1 | 6.00 | 25022117 |
| 1 | 1 | 6.00 | 24863706 |
| 1 | 1 | 6.00 | 24780512 |
| 4 | 2 | 9.95 | 21-4748363 |
| 4 | 2 | 9.95 | 21-4923721 |

### Description

- The RANK and DENSE_RANK functions both return the rank of each row within the partition of a result set.
- If there is a tie, both of these functions give the same rank to all rows that are tied.
- To determine the rank for the next distinct row, the RANK function adds 1 to the total number of rows, while the DENSE_RANK function adds 1 to the rank for the previous row.

## A query that uses the NTILE function

```
SELECT terms_description,
    NTILE(2) OVER (ORDER BY terms_id) AS tile2,
    NTILE(3) OVER (ORDER BY terms_id) AS tile3,
    NTILE(4) OVER (ORDER BY terms_id) AS tile4
FROM terms
```

| terms_description | tile2 | tile3 | tile4 |
|---|---|---|---|
| Net due 10 days | 1 | 1 | 1 |
| Net due 20 days | 1 | 1 | 1 |
| Net due 30 days | 1 | 2 | 2 |
| Net due 60 days | 2 | 2 | 3 |
| Net due 90 days | 2 | 3 | 4 |

### Description

- The NTILE function divides the rows in a partition into the specified number of groups and returns the group number of each row.
- If the rows can't be evenly divided into groups, the later groups may have one less row than the earlier groups.

Figure 9-17 How to use the ranking functions (part 2 of 2)

## How to use the analytic functions

Figure 9-18 shows how to use the *analytic functions* that were introduced with MySQL 8.0. These functions let you perform calculations on ordered sets of data. Note that all of the examples in this figure use the Sales_Reps and Sales_Totals tables in the EX database. These tables are related by the rep_id column in each table.

The FIRST_VALUE, LAST_VALUE, and NTH_VALUE functions let you return the first, last, and nth values in an ordered set of values. The first example uses these functions to return the name of the sales rep with the highest, second highest, and lowest sales for each year. To do that, the OVER clause is used to group the result set by year and sort the rows within each year by sales total in descending sequence. Then, the expression that's specified for the functions causes the name for the first, second, and last rep within each year to be returned.

When you code the NTH_VALUE function, you include a numeric literal as the second argument of the function to indicate which row you want to retrieve the value from. In this example, the value is returned from the second row in the partition. To return this value for all rows in the partition, you have to include the RANGE clause as shown here. If you don't include this clause, the NTH_VALUE function returns NULL for all rows before the nth row. In this figure, for example, the NTH_VALUE function would return NULL for the first row for each year, but it would return the second highest sales for the second row and all following rows.

You also have to include the RANGE clause for the LAST_VALUE function to return the value you want. If you don't include this clause, the LAST_VALUE function will return the last value for each group specified by the ORDER BY clause. In this case, that means that the function would return the last rep name for each sales total. Since all of the sales totals are different, though, the function would simply return the name of the rep in each row, which isn't what you want. So, if you sorted the result set by a column that contains duplicate values, you would typically include the RANGE clause but not the PARTITION BY clause.

Instead of the RANGE clause, you can code a ROWS clause on a FIRST_VALUE, LAST_VALUE, or NTH_VALUE function. This clause lets you specify the rows to include relative to the current row. If you haven't already read chapter 6, you can refer to that chapter to learn how to code the ROWS and RANGE clauses.

## The syntax of the analytic functions

```
{FIRST_VALUE|LAST_VALUE|NTH_VALUE}(scalar_expression[, numeric_literal])
    OVER ([partition_clause] order_clause [frame_clause])
{LEAD|LAG}(scalar_expression [, offset [, default]])
    OVER ([partition_clause] order_clause)
{PERCENT_RANK()|CUME_DIST()} OVER ([partition_clause] order_clause)
```

## The columns in the Sales_Reps and Sales_Totals tables

| Column name | Data type | Column name | Data type |
|---|---|---|---|
| rep_id | INT | rep_id | INT |
| rep_first_name | VARCHAR(50) | sales_year | YEAR |
| rep_last_name | VARCHAR(50) | sales_total | DECIMAL(9,2) |

## A query that uses the FIRST_VALUE, NTH_VALUE, and LAST_VALUE functions

```
SELECT sales_year, CONCAT(rep_first_name, ' ', rep_last_name) AS rep_name,
    sales_total,
    FIRST_VALUE(CONCAT(rep_first_name, ' ', rep_last_name))
        OVER (PARTITION BY sales_year ORDER BY sales_total DESC)
        AS highest_sales,
    NTH_VALUE(CONCAT(rep_first_name, ' ', rep_last_name), 2)
        OVER (PARTITION BY sales_year ORDER BY sales_total DESC
        RANGE BETWEEN UNBOUNDED PRECEDING AND UNBOUNDED FOLLOWING)
        AS second_highest_sales,
    LAST_VALUE(CONCAT(rep_first_name, ' ', rep_last_name))
        OVER (PARTITION BY sales_year ORDER BY sales_total DESC
        RANGE BETWEEN UNBOUNDED PRECEDING AND UNBOUNDED FOLLOWING)
        AS lowest_sales
FROM sales_totals JOIN sales_reps ON sales_totals.rep_id = sales_reps.rep_id
```

| sales_year | rep_name | sales_total | highest_sales | second_highest_sales | lowest_sales |
|---|---|---|---|---|---|
| 2020 | Jonathon Thomas | 1274856.38 | Jonathon Thomas | Andrew Markasian | Sonja Martinez |
| 2020 | Andrew Markasian | 1032875.48 | Jonathon Thomas | Andrew Markasian | Sonja Martinez |
| 2020 | Sonja Martinez | 978465.99 | Jonathon Thomas | Andrew Markasian | Sonja Martinez |
| 2021 | Andrew Markasian | 1132744.56 | Andrew Markasian | Sonja Martinez | Lydia Kramer |
| 2021 | Sonja Martinez | 974853.81 | Andrew Markasian | Sonja Martinez | Lydia Kramer |
| 2021 | Jonathon Thomas | 923746.85 | Andrew Markasian | Sonja Martinez | Lydia Kramer |
| 2021 | Philip Winters | 655786.92 | Andrew Markasian | Sonja Martinez | Lydia Kramer |
| 2021 | Lydia Kramer | 422847.86 | Andrew Markasian | Sonja Martinez | Lydia Kramer |
| 2022 | Jonathon Thomas | 998337.46 | Jonathon Thomas | Sonja Martinez | Lydia Kramer |
| 2022 | Sonja Martinez | 887695.75 | Jonathon Thomas | Sonja Martinez | Lydia Kramer |
| 2022 | Philip Winters | 72443.37 | Jonathon Thomas | Sonja Martinez | Lydia Kramer |
| 2022 | Lydia Kramer | 45182.44 | Jonathon Thomas | Sonja Martinez | Lydia Kramer |

## Description

- The FIRST_VALUE, LAST_VALUE, NTH VALUE, LEAD, LAG, PERCENT_RANK, and CUME_DIST functions are sometimes referred to as *analytic functions*. They were introduced with MySQL 8.0.
- The FIRST_VALUE, LAST_VALUE, and NTH_VALUE functions return the first, last, and nth value in a sorted set of values. When you use the PARTITION BY clause with LAST_VALUE or NTH_VALUE, you typically include the ROWS or RANGE clause as well to define a subset of the current partition.

Figure 9-18 How to use the analytic functions (part 1 of 2)

The LEAD and LAG functions let you refer to values in other rows of the result set. The LAG function is illustrated by the first example in part 2 of figure 9-18. Here, the OVER clause is used to group the result set by the rep_id column and sort it by the sales_year column. Then, the LAG function in the fourth column gets the sales total from one row prior to the current row (the offset). Since the rows are sorted by year for each sales rep, that means that the function retrieves the sales rep's sales for the previous year. The fifth column uses the same function, but it subtracts the result of this function from the current sales to show the change in sales from the previous year. The LEAD function is similar, but it lets you refer to values in following rows rather than previous rows.

Notice that the value of the LAG function for the first row for each sales rep is 0.00. That's because there isn't a row for the prior year. By default, this value is null. Because I wanted to calculate the change for each row in the result set, though, I used the third argument of the LAG function to set the default to 0.

The second example shows how to use the PERCENT_RANK and CUME_DIST functions. Both of these functions groups the rows by year and sorts them by sales total in ascending sequence.

The PERCENT_RANK function calculates a percent that indicates the rank of each row within a partition. The result of this function is always a value between 0 and 1.

The CUME_DIST function is similar, but it calculates the percent of values that are less than or equal to the current value. This function represents the *cumulative distribution* of the values. The cumulative distribution is calculated by dividing the number of rows with the current value or a lower value by the total number of rows in the partition.

### A query that uses the LAG function

```
SELECT rep_id, sales_year, sales_total AS current_sales,
  LAG(sales_total, 1, 0) OVER (PARTITION BY rep_id ORDER BY sales_year)
        AS last_sales,
  sales_total - LAG(sales_total, 1, 0)
        OVER (PARTITION BY rep_id ORDER BY sales_year) AS 'change'
FROM sales_totals
```

| rep_id | sales_year | current_sales | last_sales | change |
|---|---|---|---|---|
| 1 | 2020 | 1274856.38 | 0.00 | 1274856.38 |
| 1 | 2021 | 923746.85 | 1274856.38 | -351109.53 |
| 1 | 2022 | 998337.46 | 923746.85 | 74590.61 |
| 2 | 2020 | 978465.99 | 0.00 | 978465.99 |
| 2 | 2021 | 974853.81 | 978465.99 | -3612.18 |

### A query that uses the PERCENT_RANK and CUME_DIST functions

```
SELECT sales_year, rep_id, sales_total,
  PERCENT_RANK() OVER (PARTITION BY sales_year ORDER BY sales_total)
        AS pct_rank,
  CUME_DIST() OVER (PARTITION BY sales_year ORDER BY sales_total)
        AS 'cume_dist'
FROM sales_totals
```

| sales_year | rep_id | sales_total | pct_rank | cume_dist |
|---|---|---|---|---|
| 2020 | 2 | 978465.99 | 0 | 0.3333333333333333 |
| 2020 | 3 | 1032875.48 | 0.5 | 0.6666666666666666 |
| 2020 | 1 | 1274856.38 | 1 | 1 |
| 2021 | 5 | 422847.86 | 0 | 0.2 |
| 2021 | 4 | 655786.92 | 0.25 | 0.4 |
| 2021 | 1 | 923746.85 | 0.5 | 0.6 |
| 2021 | 2 | 974853.81 | 0.75 | 0.8 |
| 2021 | 3 | 1132744.56 | 1 | 1 |
| 2022 | 5 | 45182.44 | 0 | 0.25 |
| 2022 | 4 | 72443.37 | 0.3333333333333333 | 0.5 |
| 2022 | 2 | 887695.75 | 0.6666666666666666 | 0.75 |
| 2022 | 1 | 998337.46 | 1 | 1 |

### Description

- The LEAD function retrieves data from a following row in a result set, and the LAG function retrieves data from a previous row in a result set.
- The PERCENT_RANK function calculates the rank of the values in a sorted set of values as a percent. The CUME_DIST function calculates the percent of the values in a sorted set of values that are less than or equal to the current value.

Figure 9-18 How to use the analytic functions (part 2 of 2)

# Perspective

In this chapter, you learned about the different functions that you can use to operate on MySQL data. At this point, you have all of the skills you need to develop SQL code at a professional level.

However, there's a lot more to learn about MySQL. In the next section of this book, then, you'll learn the basic skills for designing a database. Even if you never need to design your own database, understanding this material will help you work more efficiently with databases that have been designed by others.

## Terms

UTC (Coordinated Universal Time)
GMT (Greenwich Mean Time)
format string
string pattern
regular expression
regular expression functions
specialized window functions
ranking functions
partition
analytic functions
cumulative distribution

## Exercises

1. Write a SELECT statement that returns these columns from the Invoices table:

   The invoice_total column

   A column that uses the ROUND function to return the invoice_total column with 1 decimal digit

   A column that uses the ROUND function to return the invoice_total column with no decimal digits

   A column that uses the TRUNCATE function to return the invoice_total column with no decimal digits

2. Write a SELECT statement that returns these columns from the Date_Sample table in the EX database:

   The start_date column

   A column that uses the DATE_FORMAT function to return the start_date column with its month name abbreviated and its month, day, and two-digit year separated by slashes

   A column that uses the DATE_FORMAT function to return the start_date column with its month and day returned as integers with no leading zeros, a two-digit year, and all date parts separated by slashes

3. Write a SELECT statement that returns these columns from the Vendors table:

   The vendor_name column

   The vendor_name column in all capital letters

   The vendor_phone column

   A column that displays the last four digits of each phone number

   When you get that working right, add the columns that follow to the result set. This is more difficult because these columns require the use of functions within functions.

   The vendor_phone column with the parts of the number separated by dots, as in 555.555.5555

   A column that displays the second word in each vendor name if there is one and blanks if there isn't

4. Write a SELECT statement that returns these columns from the Invoices table:

   The invoice_number column

   The invoice_date column

   The invoice_date column plus 30 days

   The payment_date column

   A column named days_to_pay that shows the number of days between the invoice date and the payment date

   The number of the invoice date's month

   The four-digit year of the invoice date

   When you have this working, add a WHERE clause that retrieves just the invoices for the month of May based on the invoice date, not the number of the invoice month.

5. Write a SELECT statement that returns these columns from the String_Sample table of the EX database:

   The emp_name column

   A column that displays each employee's first name

   A column that displays each employee's last name

   Use regular expression functions to get the first and last name. If a name contains three parts, everything after the first part should be considered part of the last name. Be sure to provide for last names with hyphens and apostrophes.

   *Hint: To include an apostrophe in a pattern, you can code a \ in front of it or you can enclose the pattern in double quotes.*

6. Write a SELECT statement that returns these columns from the Invoice table of the AP database:

   The invoice_number column

   The balance due for each invoice with a balance due greater than zero

   A column that uses the RANK() function to rank the balance due in descending sequence

# Section 3

## Database design and implementation

For large applications, a developer who specializes in database design may be responsible for designing and creating the databases that are used by production applications. This developer may also be responsible for designing and creating the databases that are used for testing those applications. Then, a database administrator (DBA) may be responsible for maintaining these databases. For smaller applications, programmers are often asked to fill one or both of these roles. In other words, programmers often need to design, create, and maintain the databases that are used for testing and production.

So, whether you're a database designer, a database administrator, or a SQL programmer, you need the skills and knowledge presented in this section. That's true even if you aren't ever called upon to design, create, or maintain a database. By understanding what's going on behind the scenes, you'll be able to use SQL more effectively.

In chapter 10, you'll learn how to design a database. In chapter 11, you'll learn how to use the Data Definition Language (DDL) statements to create and maintain databases, tables, and indexes. Finally, in chapter 12, you'll learn how to create and maintain views, which are database objects that provide another way to look at tables.

# 10

# How to design a database

In this chapter, you'll learn how to design a new database. This is useful information whether or not you ever design a database on your own. To illustrate this process, I'll use the accounts payable (AP) database that you've seen throughout this book.

# How to design a data structure

Databases are often designed by database administrators (DBAs) or design specialists. This is especially true for large, multiuser databases. How well this is done can directly affect your job as a MySQL programmer. In general, a well-designed database is easy to understand and query, while a poorly designed database is difficult to work with. In fact, when you work with a poorly designed database, you will often need to figure out how it is designed before you can code your queries appropriately.

The topics that follow present a basic approach for designing a *data structure*. We use that term to refer to a model of the database rather than the database itself. Once you design the data structure, you can use the techniques presented in the next two chapters to create a database with that design. By understanding the right way to design a database, you'll work more effectively as a MySQL programmer.

## The basic steps for designing a data structure

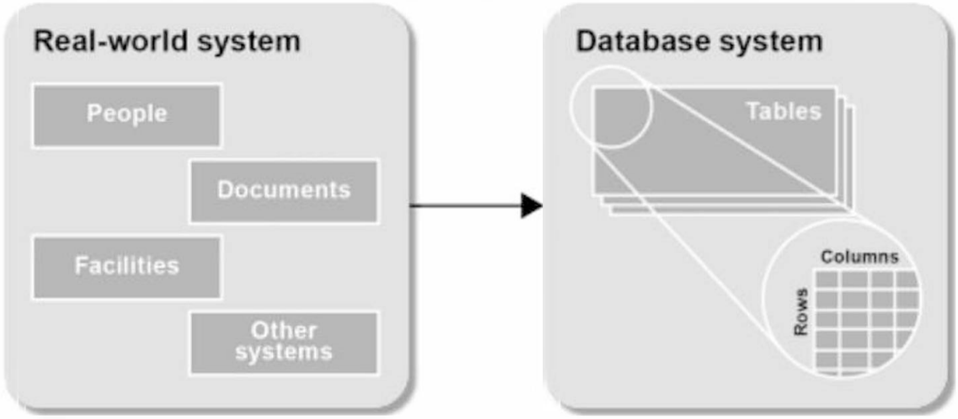
In many cases, you can design a data structure based on an existing real-world system. The illustration at the top of figure 10-1 presents a conceptual view of how this works. Here, you can see that all of the information about the people, documents, and facilities within a real-world system is mapped to the tables, columns, and rows of a database system.

As you design a data structure, each table represents one object, or *entity*, in the real-world system. Then, within each table, each column stores one item of information, or *attribute*, for the entity, and each row stores one occurrence, or *instance*, of the entity.

This figure also presents the six steps you can follow to design a data structure. You'll learn more about each of these steps in the topics that follow. In general, though, step 1 is to identify all the data elements that need to be stored in the database. Step 2 is to break complex elements down into smaller components whenever that makes sense. Step 3 is to identify the tables that will make up the system and to determine which data elements are assigned as columns in each table. Step 4 is to define the relationships between the tables by identifying the primary and foreign keys. Step 5 is to normalize the database to reduce data redundancy. And step 6 is to identify the indexes that are needed for each table.

To model a database system after a real-world system, you can use a technique called *entity-relationship (ER) modeling*. I have applied some of the basic elements of this technique to the diagrams presented in this chapter. As a result, you'll be learning some of the basics of this modeling technique as you read this chapter.

### A database system is modeled after a real-world system




### The six basic steps for designing a data structure

Step 1: Identify the data elements
Step 2: Subdivide each element into its smallest useful components
Step 3: Identify the tables and assign columns
Step 4: Identify the primary and foreign keys
Step 5: Review whether the data structure is normalized
Step 6: Identify the indexes

### Description

- A relational database system should model the real-world environment where it's used. The job of the designer is to analyze the real-world system and then map it onto a relational database system.
- A table in a relational database typically represents an object, or *entity*, in the real world. Each column of a table is used to store an *attribute* associated with the entity, and each row represents one *instance* of the entity.
- To model a database and the relationships between its tables after a real-world system, you can use a technique called *entity-relationship (ER) modeling*. Some of the diagrams you'll see in this chapter apply the basic elements of ER modeling.

Figure 10-1 The basic steps for designing a data structure

## How to identify the data elements

The first step for designing a data structure is to identify the data elements required by the system. You can use several techniques to do that, including analyzing the existing system if there is one, evaluating comparable systems, and interviewing anyone who will be using the system. One particularly good source of information is the documents used by an existing system.

In figure 10-2, for example, you can see an invoice that's used by an accounts payable system. We'll use this document as the main source of information for the database design presented in this chapter. Keep in mind, though, that you'll want to use all available resources when you design your own database.

If you study this document, you'll notice that it contains information about three different entities: vendors, invoices, and line items. First, the form itself has preprinted information about the vendor who issued the invoice, such as the vendor's name and address. If this vendor were to issue another invoice, this information wouldn't change.

This document also contains specific information about the invoice. Some of this information, such as the invoice number, invoice date, and invoice total, is general in nature. Although the actual information will vary from one invoice to the next, each invoice will include this information. In addition to this general information, each invoice includes information about the items that were purchased. Although each line item contains similar information, each invoice can contain a different number of line items.

One of the things you need to consider as you review a document like this is how much information your system needs to track. For an accounts payable system, for example, you may not need to store detailed data such as the information about each line item. Instead, you may just need to store summary data like the invoice total. As you think about what data elements to include in the database, then, you should have an idea of what information you'll need to get back out of the system.

## An invoice that can be used to identify data elements

**Acme Fabrication, Inc.**

*Custom Contraptions, Contrivances and Confabulations*

1234 West Industrial Way East Los Angeles California 90022

800.555.1212 fax 562.555.1213 www.acmefabrication.com

| | |
|---|---|
| Invoice Number: | 101-1088 |
| Invoice Date: | 10/05/18 |
| Terms: | Net 30 |

| Part No. | Qty. | Description | Unit Price | Extension |
|---|---|---|---|---|
| CUST345 | 12 | Design service, hr | 100.00 | 1200.00 |
| 457332 | 7 | Baling wire, 25x3ft roll | 79.90 | 559.30 |
| 50173 | 4375 | Duct tape, black, yd | 1.09 | 4768.75 |
| 328771 | 2 | Rubber tubing, 100ft roll | 4.79 | 9.58 |
| CUST281 | 7 | Assembly, hr | 75.00 | 525.00 |
| CUST917 | 2 | Testing, hr | 125.00 | 250.00 |
| | | Sales Tax | | 245.20 |

| | |
|---|---|
| Your salesperson: | Ruben Goldberg, ext 4512 |
| Accounts receivable: | Inigo Jones, ext 4901 |

$7,557.83

PLEASE PAY THIS AMOUNT

*Thanks for your business!*

## The data elements identified on the invoice document

| | | |
|---|---|---|
| Vendor name | Invoice date | Item extension |
| Vendor address | Invoice terms | Vendor sales contact name |
| Vendor phone number | Item part number | Vendor sales contact extension |
| Vendor fax number | Item quantity | Vendor AR contact name |
| Vendor web address | Item description | Vendor AR contact extension |
| Invoice number | Item unit price | Invoice total |

## Description

- Depending on the nature of the system, you can identify data elements in a variety of ways, including interviewing users, analyzing existing systems, and evaluating comparable systems.
- The documents used by a real-world system, such as the invoice shown above, can often help you identify the data elements of the system.
- As you identify the data elements of a system, you should begin thinking about the entities that those elements are associated with. That will help you identify the tables of the database later on.

Figure 10-2 How to identify the data elements

## How to subdivide the data elements

Some of the data elements you identify in step 1 of the design procedure will consist of multiple components. The next step, then, is to divide these elements into their smallest useful values. Figure 10-3 shows how you can do that.

The first example in this figure shows how you can divide the name of the sales contact for a vendor. Here, the name is divided into two elements: a first name and a last name. When you divide a name like this, you can easily perform operations like sorting by last name and using the first name in a salutation, such as "Dear Ruben." In contrast, if the full name is stored in a single column, you have to use the string functions to extract the component you need. But as you learned in the last chapter, that can lead to inefficient and complicated code.

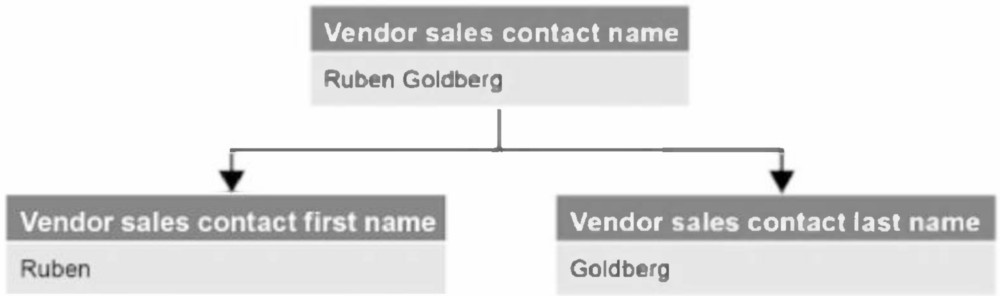
In general, then, you should separate a name like this whenever you'll need to use the name components separately. Later, when you need to use the full name, you can combine the first and last names using concatenation. However, you should also be aware that some cultures use different naming styles. Does your database need to distinguish between the presence of a middle name and a person with two last names? Deciding early on how your system will handle a name like Antoine Marie Jean-Baptiste Roger can save you a lot of headaches in the future.

The second example shows how you typically divide an address. Notice in this example that the street number and street name are stored in a single column. Although you could store these components in separate columns, that usually doesn't make sense since these values are typically used together. That's what I mean when I say that the data elements should be divided into their smallest *useful* values.

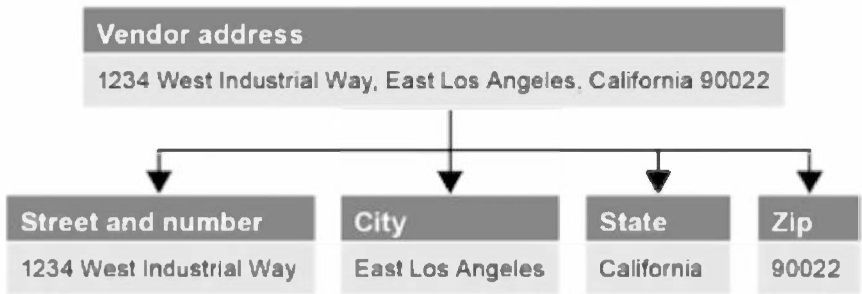
With that guideline in mind, you might even need to divide a single string into two or more components. A bulk mail system, for example, might require a separate column for the first three digits of the zip code. And a telephone number could require as many as four columns: one for the area code, one for the three-digit prefix, one for the four-digit number, and one for the extension.

As in the previous step, knowledge of the real-world system and of the information that will be extracted from the database is critical. In some circumstances, it may be okay to store data elements with multiple components in a single column. That can simplify your design and reduce the overall number of columns. In general, though, most designers divide data elements as much as possible. That way, it's easy to accommodate almost any query, and you don't have to change the database design later on when you realize that you need to use just part of a column value.

### A name that's divided into first and last names




### An address that's divided into street address, city, state, and zip code




### Description

- If a data element contains two or more components, you should consider subdividing the element into those components. That way, you won't need to parse the element each time you use it.
- The extent to which you subdivide a data element depends on how it will be used. Because it's difficult to predict all future uses for the data, most designers subdivide data elements as much as possible.
- When you subdivide a data element, you can easily rebuild it when necessary by concatenating the individual components.

Figure 10-3 How to subdivide the data elements

## How to identify the tables and assign columns

Figure 10-4 presents the three main entities for the accounts payable system and lists the possible data elements that can be associated with each one. In most cases, you'll recognize the main entities that need to be included in a data structure as you identify the data elements. As I reviewed the data elements represented on the invoice document in figure 10-2, for example, I identified the three entities shown in this figure: vendors, invoices, and invoice line items. Although you may identify additional entities later on in the design process, it's sufficient to identity the main entities at this point. These entities will become the tables of the database.

After you identify the main entities, you need to determine which data elements are associated with each entity. These elements will become the columns of the tables. In many cases, the associations are obvious. For example, it's easy to determine that the vendor name and address are associated with the vendors entity and the invoice date and invoice total are associated with the invoices entity. Some associations, however, aren't so obvious. In that case, you may need to list a data element under two or more entities. In this figure, for example, you can see that the invoice number is included in both the invoices and invoice line items entities and the account number is included in all three entities. Later, when you normalize the data structure, you may be able to remove these repeated elements. For now, though, it's okay to include them.

Before I go on, I want to point out the notation I used in this figure. To start, any data elements I included that weren't identified in previous steps are shown in italics. Although you should be able to identify most of the data elements in the first two steps of the design process, you'll occasionally think of additional elements during the third step. In this case, since the initial list of data elements was based on a single document, I added several data elements to this list.

Similarly, you may decide during this step that you don't need some of the data elements you've identified. For example, I decided that I didn't need the fax number or web address of each vendor. So I used strikethrough to indicate that these data elements should not be included.

Finally, I identified the data elements that are included in two or more tables by coding an asterisk after them. Although you can use any notation you like for this step of the design process, you'll want to be sure that you document your design decisions. For a complicated design, you will probably want to use a *CASE (computer-aided software engineering)* tool.

By the way, a couple of the new data elements I added may not be clear to you if you haven't worked with a corporate accounts payable system before. "Terms" refers to the payment terms that the vendor offers. For example, the terms might be net 30 (the invoice must be paid in 30 days) or might include a discount for early payment. "Account number" refers to the general ledger accounts that a company uses to track its expenses. For example, one account number might be assigned for advertising expenses, while another might be for office supplies. Each invoice that's paid is assigned to an account, and in some cases, different line items on an invoice are assigned to different accounts.

### Possible tables and columns for an accounts payable system

| Vendors | Invoices | Invoice line items |
|---|---|---|
| Vendor name | Invoice number* | Invoice number* |
| Vendor address | Invoice date | ~~Item part number~~ |
| Vendor city | Terms* | Item quantity |
| Vendor state | Invoice total | Item description |
| Vendor zip code | *Payment date* | Item unit price |
| Vendor phone number | *Payment total* | Item extension |
| ~~Vendor fax number~~ | *Invoice due date* | *Account number** |
| ~~Vendor web address~~ | *Credit total* | *Sequence number* |
| Vendor contact first name | *Account number** | |
| Vendor contact last name | | |
| ~~Vendor contact phone~~ | | |
| ~~Vendor AR first name~~ | | |
| ~~Vendor AR last name~~ | | |
| ~~Vendor AR phone~~ | | |
| *Terms** | | |
| *Account number** | | |

### Description

- After you identify and subdivide all of the data elements for a database, you should group them by the entities with which they're associated. These entities will later become the tables of the database, and the elements will become the columns.
- If a data element relates to more than one entity, you can include it under all of the entities it relates to. Then, when you normalize the database, you may be able to remove the duplicate elements.
- As you assign the elements to entities, you should omit elements that aren't needed, and you should add any additional elements that are needed.

### The notation used in this figure

- Data elements that were previously identified but aren't needed are crossed out.
- Data elements that were added are displayed in italics.
- Data elements that are related to two or more entities are followed by an asterisk.
- You can use a similar notation or develop one of your own. You can also use a *CASE (computer-aided software engineering)* tool if one is available to you.

Figure 10-4 How to identify the tables and assign columns

## How to identify the primary and foreign keys

Once you identify the entities and data elements of a system, the next step is to identify the relationships between the tables. To do that, you need to identify the primary and foreign keys as shown in figure 10-5.

As you know, a primary key is used to uniquely identify each row in a table. In some cases, you can use an existing column as the primary key. For example, you might consider using the vendor_name column as the primary key of the Vendors table. Because the values for this column can be long, however, and because it would be easy to enter a value like that incorrectly, that's not a good candidate for a primary key. Instead, an auto increment column is used as the primary key.

Similarly, you might consider using the invoice_number column as the primary key of the Invoices table. However, it's possible for different vendors to use the same invoice number, so this value isn't necessarily unique. Because of that, an auto increment column is used as the primary key of this table as well.

To uniquely identify the rows in the Invoice_Line_Items table, this design uses a composite key. This composite key uses two columns to identify each row. The first column is the invoice_id column from the Invoices table, and the second column is the invoice_sequence column. This is necessary because this table may contain more than one row (line item) for each invoice. And that means that the invoice_id value by itself may not be unique.

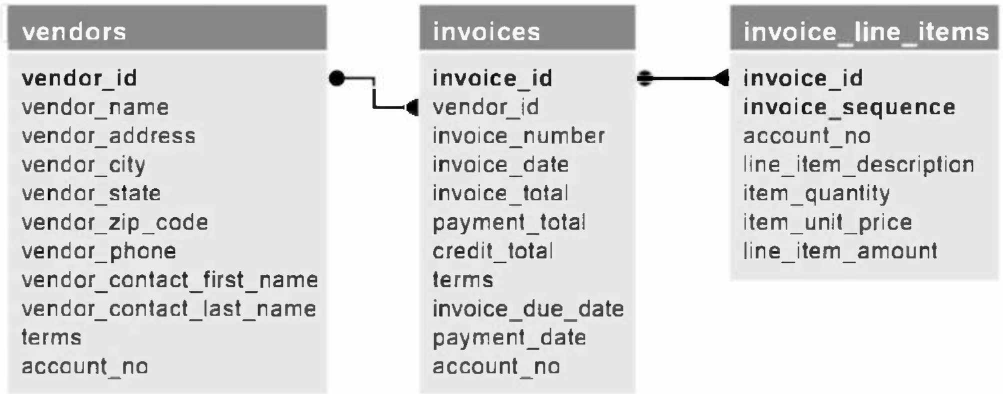
This book uses the composite key in the InvoiceLineItems table to show how to work with composite keys. However, it usually makes more sense to use a single column as the primary key. For example, the InvoiceLineItems table could start with an InvoiceLineItemID column that uniquely identifies each row in the table. Then, you could use that column as the primary key, and you could consider dropping the InvoiceSequence column.

After you identify the primary key of each table, you need to identify the relationships between the tables and add foreign key columns as necessary. In most cases, two tables will have a one-to-many relationship with each other. For example, each vendor can have many invoices, and each invoice can have many line items. To identify the vendor that each invoice is associated with, a vendor_id column is included in the Invoices table. Because the Invoice_Line_Items table already contains an invoice_id column, it's not necessary to add another column to this table.

The diagram at the top of this figure illustrates the relationships I identified between the tables in the accounts payable system. As you can see, the primary keys are displayed in bold. Then, the lines between the tables indicate how the primary key in one table is related to the foreign key in another table. Here, a small, round connector indicates the "one" side of the relationship, and the triangular connector indicates the "many" side of the relationship.

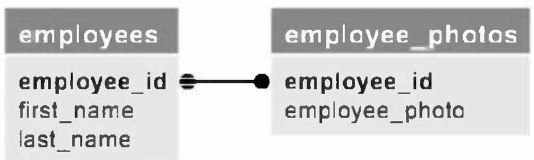
In addition to the one-to-many relationships shown in this diagram, you can also use many-to-many relationships and one-to-one relationships. The second diagram in this figure, for example, shows a many-to-many relationship between an Employees table and a Committees table. As you can see, this type of relation-

## The relationships between the tables in the accounts payable system




## Two tables with a many-to-many relationship


## Two tables with a one-to-one relationship




## Description

- Most tables should have a primary key that uniquely identifies each row. If necessary, you can use a composite key that uses two or more columns to uniquely identify each row.
- The values of the primary keys should seldom, if ever, change. The values should also be short and easy to enter correctly.
- If a suitable column doesn't exist for a primary key, you can create an auto increment column that can be used as the primary key.
- If two tables have a one-to-many relationship, you may need to add a foreign key column to the table on the "many" side. The foreign key column must have the same data type as the primary key column it's related to.
- If two tables have a many-to-many relationship, you'll need to define a *linking table* to relate them. Then, each of the tables in the many-to-many relationship will have a one-to-many relationship with the linking table. The linking table doesn't usually have a primary key.
- If two tables have a one-to-one relationship, they should be related by their primary keys. This type of relationship is typically used to improve performance. Then, columns with large amounts of data can be stored in a separate table.

Figure 10-5 How to identify the primary and foreign keys ship can be implemented by creating a *linking table*, also called a *connecting table* or an *associate table*. This table contains the primary key columns from the two tables. Then, each table has a one-to-many relationship with the linking table. Notice that the linking table doesn't have its own primary key. Because this table doesn't correspond to an entity and because it's used only in conjunction with the Employees and Committees tables, a primary key isn't needed.

The third example in figure 10-5 illustrates two tables that have a one-to-one relationship. With this type of relationship, both tables have the same primary key, which means that the information could be stored in a single table. This type of relationship is often used when a table contains one or more columns with large amounts of data. In this case, the Employee_Photos table contains a large binary column with a photo of each employee. Because this column is used infrequently, storing it in a separate table will make operations on the Employees table more efficient. Then, when this column is needed, it can be combined with the columns in the Employees table using a join.

## How to enforce the relationships between tables

Although the primary keys and foreign keys indicate how the tables in a database are related, the database management system doesn't always enforce those relationships automatically. In that case, any of the operations shown in the table at the top of figure 10-6 might violate the *referential integrity* of the tables. If you deleted a row from a primary key table, for example, and the foreign key table included rows related to that primary key, the referential integrity of the two tables would be destroyed. In that case, the rows in the foreign key table that no longer have a related row in the primary key table would be *orphaned*. Similar problems can occur when you insert a row into the foreign key table or update a primary key or foreign key value.

To enforce those relationships and maintain the referential integrity of the tables, MySQL provides for *declarative referential integrity*. To use it, you define *foreign key constraints* that indicate how the referential integrity between the tables is enforced. You'll learn more about defining foreign key constraints in the next chapter. For now, just realize that these constraints can prevent all of the operations listed in this figure that violate referential integrity.

## Operations that can violate referential integrity

| This operation... | Violates referential integrity if... |
|---|---|
| Delete a row from the primary key table | The foreign key table contains one or more rows related to the deleted row |
| Insert a row in the foreign key table | The foreign key value doesn't have a matching primary key value in the related table |
| Update the value of a foreign key | The new foreign key value doesn't have a matching primary key value in the related table |
| Update the value of a primary key | The foreign key table contains one or more rows related to the row that's changed |

## Description

- *Referential integrity* means that the relationships between tables are maintained correctly. That means that a table with a foreign key doesn't have rows with foreign key values that don't have matching primary key values in the related table.
- In MySQL, you can enforce referential integrity by using declarative referential integrity.
- To use *declarative referential integrity (DRI)*, you define *foreign key constraints*. You'll learn how to do that in the next chapter.
- When you define foreign key constraints, you can specify how referential integrity is enforced when a row is deleted from the primary key table. The options are to return an error, to delete the related rows in the foreign key table, or to set the foreign key values in the related rows to null.
- If referential integrity isn't enforced and a row is deleted from the primary key table that has related rows in the foreign key table, the rows in the foreign key table are said to be *orphaned*.

Figure 10-6 How to enforce the relationships between tables

## How normalization works

The next step in the design process is to review whether the data structure is *normalized*. To do that, you look at how the data is separated into related tables. If you follow the first four steps for designing a database that are presented in this chapter, your database will already be partially normalized when you get to this step. However, almost every design can be normalized further.

Figure 10-7 illustrates how *normalization* works. The first two tables in this figure show some of the problems caused by an *unnormalized data structure*. In the first table, you can see that each row represents an invoice. Because an invoice can have one or more line items, however, the item_description column must be repeated to provide for the maximum number of line items. But since most invoices have fewer line items than the maximum, this can waste storage space.

In the second table, each line item is stored in a separate row. That eliminates the problem caused by repeating the item_description column, but it introduces a new problem: the vendor name and invoice number must be repeated in each row. This, too, can cause storage problems, particularly if a repeated column is large. In addition, it can cause maintenance problems if a column contains a value that's likely to change. Then, when the value changes, each row that contains the value must be updated. And if a repeated value must be reentered for each new row, it would be easy for the value to vary from one row to another.

To eliminate the problems caused by *data redundancy*, you can normalize the data structure. To do that, you apply the *normal forms* you'll learn about later in this chapter. As you'll see, there are a total of seven normal forms. However, it's common to apply only the first three. The diagram in this figure, for example, shows the accounts payable system in third normal form. Although it may not be obvious at this point how this reduces data redundancy, that will become clearer as you learn about the different normal forms.

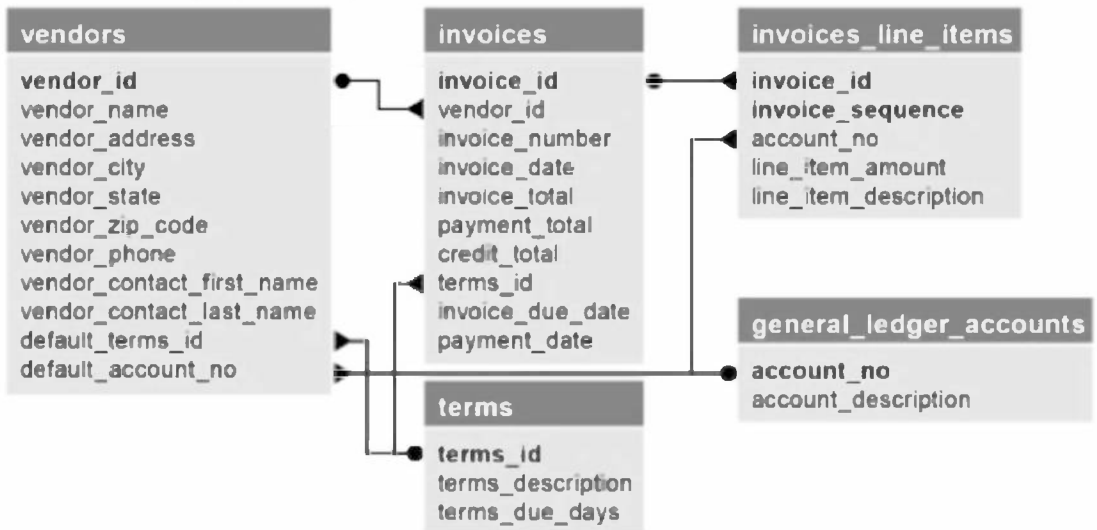
## A table that contains repeating columns

| | vendor_name | invoice_number | item_description_1 | item_description_2 | item_description_3 |
|---|---|---|---|---|---|
| ▶ | Cahners Publishing | 112897 | Android ad | MySQL ad | Library directory |
| | Zylka Design | 97/552 | Catalogs | MySQL flyer | NULL |
| | Zylka Design | 97/553B | Card revision | NULL | NULL |

## A table that contains redundant data

| | vendor_name | invoice_number | item_description |
|---|---|---|---|
| ▶ | Cahners Publishing | 112897 | Android ad |
| | Cahners Publishing | 112897 | MySQL ad |
| | Cahners Publishing | 112897 | Library directory |
| | Zylka Design | 97/522 | Catalogs |
| | Zylka Design | 97/522 | MySQL flyer |
| | Zylka Design | 97/533B | Card revision |

## The accounts payable system in third normal form




## Description

- *Normalization* is a formal process you can use to separate the data in a data structure into related tables. Normalization reduces *data redundancy*, which can cause storage and maintenance problems.
- In an *unnormalized data structure*, a table can contain information about two or more entities. It can also contain repeating columns, columns that contain repeating values, and data that's repeated in two or more rows.
- In a *normalized data structure*, each table contains information about a single entity, and each piece of information is stored in exactly one place.
- To normalize a data structure, you apply the *normal forms* in sequence. Although there are a total of seven normal forms, a data structure is typically considered normalized if the first three normal forms are applied.

Figure 10-7 How normalization works

## How to identify the columns to be indexed

The last step in the design process is to identify the columns that should be indexed. An *index* is a structure that provides for locating one or more rows directly. Without an index, a database management system has to perform a *table scan*, which involves searching through the entire table.

Just as the index of a book has page numbers that direct you to a specific subject, a database index has pointers that direct the system to a specific row. This can speed performance not only when you're searching for rows based on a search condition, but also when you're joining data from tables. If a join is done based on a primary key to foreign key relationship, for example, and an index is defined for the foreign key column, the database management system can use that index to locate the rows for each primary key value.

When you use MySQL, an index is automatically created for the primary and foreign keys in each table that you create. But you should also consider creating indexes for other columns based on the guidelines at the top of figure 10-8.

To start, you should index a column if it will be used frequently in search conditions or joins. The column should also contain mostly distinct values, and the values in the column should be updated infrequently. If these conditions aren't met, the overhead of maintaining the index will probably outweigh the advantages of using it.

When you create indexes, you should be aware that MySQL must update the indexes whenever you add, update, or delete rows. Because that can affect performance, you don't want to define more indexes than you need.

As you identify the indexes for a table, keep in mind that, like a key, an index can consist of two or more columns. This type of index is called a *composite index*.

### When to create an index

- When the column is used frequently in search conditions or joins
- When the column contains a large number of distinct values
- When the column is updated infrequently

### Description

- MySQL automatically creates an index for primary and foreign keys.
- An *index* provides a way for a database management system to locate information more quickly. When it uses an index, the database management system can go directly to a specific row rather than having to search through all the rows until it finds it.
- Indexes speed performance when searching and joining tables.
- You can create *composite indexes* that include two or more columns. You should use this type of index when the columns in the index are updated infrequently or when the index covers almost every search condition on the table.
- Because indexes must be updated each time you add, update, or delete a row, you shouldn't create more indexes than you need.

Figure 10-8 How to identify the columns to be indexed

# How to normalize a data structure

The topics that follow describe the seven normal forms and teach you how to apply the first three. As I said earlier, you apply these three forms to some extent in the first four database design steps, but these topics will give you more insight into the process. Then, the last topic explains when and how to denormalize a data structure. When you finish these topics, you'll have the basic skills for designing databases that are efficient and easy to use.

## The seven normal forms

Figure 10-9 summarizes the seven normal forms. Each normal form assumes that the previous forms have already been applied. Before you can apply the third normal form, for example, the design must already be in the second normal form.

Strictly speaking, a data structure isn't normalized until it's in the fifth or sixth normal form. However, the normal forms past the third normal form are applied infrequently. Because of that, I won't present those forms in detail here. Instead, I'll just describe them briefly so you'll have an idea of how to apply them if you need to.

The *Boyce-Codd normal form* is a slightly stronger version of the third normal form that can be used to eliminate *transitive dependencies*. With this type of dependency, one column depends on another column, which depends on a third column. Most tables that are in the third normal form are also in the Boyce-Codd normal form.

The fourth normal form can be used to eliminate multiple *multivalued dependencies* from a table. A multivalued dependency is one where a primary key column has a one-to-many relationship with a non-key column. This normal form gets rid of misleading many-to-many relationships.

To apply the fifth normal form, you continue to divide the tables of the data structure into smaller tables until all redundancy has been removed. When further splitting would result in tables that couldn't be used to reconstruct the original table, the data structure is in fifth normal form. In this form, most tables consist of little more than key columns with one or two data elements.

The *domain-key normal form*, sometimes called the sixth normal form, further reduces all tables to just one key column and no more than one additional column. Although it isn't commonly used for production databases, the sixth normal form is sometimes used in data warehousing systems.

This figure also lists the benefits of normalizing a data structure. To summarize, normalization produces smaller, more efficient tables. In addition, it reduces data redundancy, which makes the data easier to maintain and reduces the amount of storage needed for the database. Because of these benefits, you should always consider normalizing your data structures.

In the academic study of computer science, normalization is considered a form of design perfection that should always be strived for. In practice, though, database designers and DBAs tend to use normalization as a flexible design guideline.

## The seven normal forms

| Normal form | Description |
|---|---|
| First (1NF) | The value stored at the intersection of each row and column must be a scalar value, and a table must not contain any repeating columns. |
| Second (2NF) | Every non-key column must depend on the entire primary key. |
| Third (3NF) | Every non-key column must depend only on the primary key. |
| Boyce-Codd (BCNF) | A non-key column can't be dependent on another non-key column. This prevents *transitive dependencies*, where column A depends on column C and column B depends on column C. Since both A and B depend on C, A and B should be moved into another table with C as the key. |
| Fourth (4NF) | A table must not have more than one *multivalued dependency*, where the primary key has a one-to-many relationship to non-key columns. This form gets rid of misleading many-to-many relationships. |
| Fifth (5NF) | The data structure is split into smaller and smaller tables until all redundancy has been eliminated. If further splitting would result in tables that couldn't be joined to recreate the original table, the structure is in fifth normal form. |
| Domain-key (DKNF) or Sixth (6NF) | Every constraint on the relationship is dependent only on key constraints and domain constraints, where a *domain* is the set of allowable values for a column. This form prevents the insertion of any unacceptable data by enforcing constraints at the level of a relationship, rather than at the table or column level. |

## The benefits of normalization

- Since a normalized database has more tables than an unnormalized database, and since each table has an index on its primary key, the database has more indexes. That makes data retrieval more efficient.
- Since each table contains information about a single entity, each index has fewer columns (usually one) and fewer rows. That makes data retrieval and insert, update, and delete operations more efficient.
- Each table has fewer indexes, which makes insert, update, and delete operations more efficient.
- Data redundancy is minimized, which simplifies maintenance and reduces storage.

## Description

- Each normal form assumes that the design is already in the previous normal form.
- A database is typically considered to be normalized if it is in third normal form. The other four forms are not commonly used and are not covered in detail in this book.

Figure 10-9 The seven normal forms

## How to apply the first normal form

Figure 10-10 illustrates how you apply the first normal form to an unnormalized invoice data structure consisting of the data elements that are shown in figure 10-2. The first two tables in this figure illustrate structures that aren't in first normal form. Both of these tables contain a single row for each invoice. Because each invoice can contain one or more line items, though, the first table allows for repeating values in the item_description column. The second table is similar, except it includes a separate column for each line item description. Neither of these structures is acceptable in first normal form.

The third table in this figure has eliminated the repeating values and columns. To do that, it includes one row for each line item. Notice, however, that this has increased the data redundancy. Specifically, the vendor name and invoice number are now repeated for each line item. This problem can be solved by applying the second normal form.

Before I describe the second normal form, I want you to realize that I intentionally omitted many of the columns in the invoice data structure from the examples in this figure and the next figure. In addition to the columns shown here, for example, each of these tables would also contain the vendor address, invoice date, invoice total, etc. By eliminating these columns, it will be easier for you to focus on the columns that are affected by applying the normal forms.

### The invoice data with a column that contains repeating values

| vendor_name | invoice_number | item_description |
|---|---|---|
| Cahners Publishing | 112897 | Android ad, MySQL ad, Library directory |
| Zylka Design | 97/522 | Catalogs, MySQL Flyer |
| Zylka Design | 97/533B | Card revision |

### The invoice data with repeating columns

| vendor_name | invoice_number | item_description_1 | item_description_2 | item_description_3 |
|---|---|---|---|---|
| Cahners Publishing | 112897 | Android ad | MySQL ad | Library directory |
| Zylka Design | 97/552 | Catalogs | MySQL flyer | NULL |
| Zylka Design | 97/553B | Card revision | NULL | NULL |

### The invoice data in first normal form

| vendor_name | invoice_number | item_description |
|---|---|---|
| Cahners Publishing | 112897 | Android ad |
| Cahners Publishing | 112897 | MySQL ad |
| Cahners Publishing | 112897 | Library directory |
| Zylka Design | 97/522 | Catalogs |
| Zylka Design | 97/522 | MySQL flyer |
| Zylka Design | 97/533B | Card revision |

### Description

- For a table to be in first normal form, its columns must not contain repeating values. Instead, each column must contain a single, scalar value. In addition, the table must not contain repeating columns that represent a set of values.
- A table in first normal form often has repeating values in its rows. This can be resolved by applying the second normal form.

Figure 10-10 How to apply the first normal form

## How to apply the second normal form

Figure 10-11 shows how to apply the second normal form. To be in second normal form, every column in a table that isn't a key column must be dependent on the entire primary key. This form only applies to tables that have composite primary keys, which is often the case when you start with data that is completely unnormalized. The table at the top of this figure, for example, shows the invoice data in first normal form after key columns have been added. In this case, the primary key consists of the invoice_id and invoice_sequence columns. The invoice_sequence column is needed to uniquely identify each line item for an invoice.

Now, consider the three non-key columns shown in this table. Of these three, only one, item_description, depends on the entire primary key. The other two, vendor_name and invoice_number, depend only on the invoice_id column. Because of that, these columns should be moved to another table. The result is a data structure like the second one shown in this figure. Here, all of the information related to an invoice is stored in the Invoices table, and all of the information related to an individual line item is stored in the Invoice_Line_Items table.

Notice that the relationship between these tables is based on the invoice_id column. This column is the primary key of the Invoices table, and it's the foreign key in the Invoice_Line_Items table that relates the rows in that table to the rows in the Invoices table. This column is also part of the primary key of the Invoice_Line_Items table.

When you apply second normal form to a data structure, it eliminates some of the redundant row data in the tables. In this figure, for example, you can see that the invoice number and vendor name are now included only once for each invoice. In first normal form, this information was included for each line item.

### The invoice data in first normal form with keys added

| invoice_id | vendor_name | invoice_number | invoice_sequence | item_description |
|---|---|---|---|---|
| 1 | Cahners Publishing | 112897 | 1 | Android ad |
| 1 | Cahners Publishing | 112897 | 2 | MySQL ad |
| 1 | Cahners Publishing | 112897 | 3 | Library directory |
| 2 | Zylka Design | 97/522 | 1 | Catalogs |
| 2 | Zylka Design | 97/522 | 2 | MySQL flyer |
| 3 | Zylka Design | 97/5338 | 1 | Card revision |

### The invoice data in second normal form

| invoice_id | invoice_number | vendor_name |
|---|---|---|
| 1 | 112897 | Cahners Publishing |
| 2 | 97/522 | Zylka Design |
| 3 | 97/5338 | Zylka Design |

| invoice_id | invoice_sequence | item_description |
|---|---|---|
| 1 | 1 | Android ad |
| 1 | 2 | MySQL ad |
| 1 | 3 | Library directory |
| 2 | 1 | Catalogs |
| 2 | 2 | MySQL flyer |
| 3 | 1 | Card revision |

### Description

- For a table to be in second normal form, every non-key column must depend on the entire primary key. If a column doesn't depend on the entire key, it indicates that the table contains information for more than one entity. This can happen if the table contains a composite primary key.
- To apply second normal form, you move columns that don't depend on the entire primary key to another table and then establish a relationship between the two tables.
- Second normal form helps remove redundant row data, which can save storage space, make maintenance easier, and reduce the chance of storing inconsistent data.

Figure 10-11 How to apply the second normal form

## How to apply the third normal form

To apply the third normal form, you make sure that every non-key column depends *only* on the primary key. Figure 10-12 illustrates how you can apply this form to the data structure for the accounts payable system. At the top of this figure, you can see all of the columns in the Invoices and Invoice_Line_Items tables in second normal form. Then, you can see a list of questions that you might ask about some of the columns in these tables when you apply third normal form.

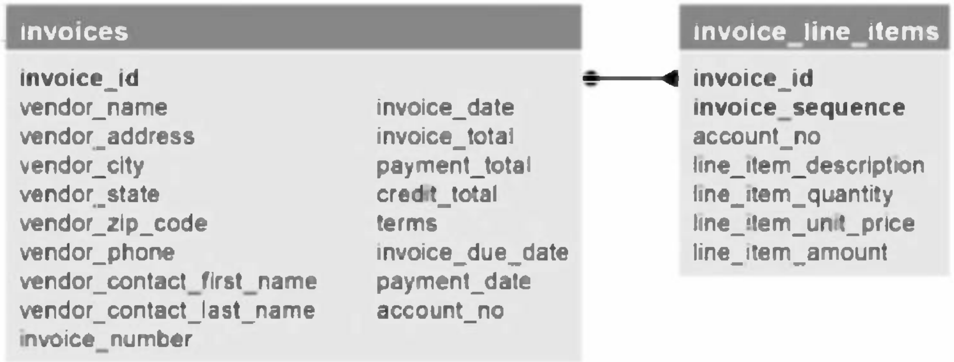
First, does the vendor information depend only on the invoice_id column? Another way to phrase this question is, "Will the information for the same vendor change from one invoice to another?" If the answer is no, the vendor information should be stored in a separate table. That way, can you be sure that the vendor information for each invoice for a vendor will be the same. In addition, you will reduce the redundancy of the data in the Invoices table. This is illustrated by the diagram in this figure that shows the accounts payable system in third normal form. Here, a Vendors table has been added to store the information for each vendor. This table is related to the Invoices table by the vendor_id column, which has been added as a foreign key to the Invoices table.

Second, does the terms column depend only on the invoice_id column? The answer to that question depends on how this column is used. In this case, I'll assume that this column is used not only to specify the terms for each invoice, but also to specify the default terms for a vendor. Because of that, the terms information could be stored in both the Vendors and the Invoices tables. To avoid redundancy, however, the information related to different terms can be stored in a separate table, as illustrated by the Terms table in this figure. As you can see, the primary key of this table is an auto increment column named terms_id. Then, a foreign key column named default_terms_id has been added to the Vendors table, and a foreign key column named terms_id has been added to the Invoices table.

Third, does the account_no column depend only on the invoice_id column? Again, that depends on how this column is used. In this case, it's used to specify the general ledger account number for each line item, so it depends on the invoice_id and the invoice_sequence columns. In other words, this column should be stored in the Invoice_Line_Items table. In addition, each vendor has a default account number, which should be stored in the Vendors table. Because of that, another table named General_Ledger_Accounts has been added to store the account numbers and account descriptions. Then, foreign key columns have been added to the Vendors and Invoice_Line_Items tables to relate them to this table.

Fourth, can the invoice_due_date column in the Invoices table and the line_item_amount column in the Invoice_Line_Items table be derived from other data in the database? If so, they depend on the columns that contain that data rather than on the primary key columns. In this case, the value of the line_item_amount column can always be calculated from the item_quantity and item_unit_price columns. Because of that, this column could be omitted. Alternatively, you could omit the item_quantity and item_unit_price columns

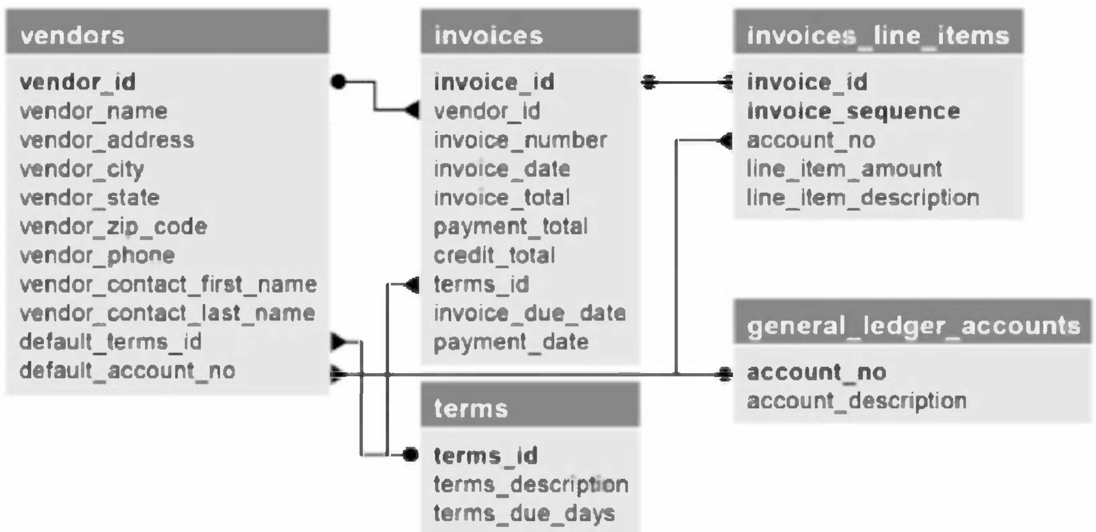
## The accounts payable system in second normal form




### Questions about the structure

1. Does the vendor information (vendor_name, vendor_address, etc.) depend only on the invoice_id column?
2. Does the terms column depend only on the invoice_id column?
3. Does the account_no column depend only on the invoice_id column?
4. Can the invoice_due_date and line_item_amount columns be derived from other data?

## The accounts payable system in third normal form




## Description

- For a table to be in third normal form, every non-key column must depend *only* on the primary key.
- If a column doesn't depend only on the primary key, it implies that the column is assigned to the wrong table or that it can be computed from other columns in the table. A column that can be computed from other columns contains *derived data*.

Figure 10-12 How to apply the third normal form and keep just the line_item_amount column. That's what I did in the data structure shown in this figure. The solution you choose, however, depends on how the data will be used.

In contrast, although the invoice_due_date column could be calculated from the invoice_date column in the Invoices table and the terms_due_days column in the related row of the Terms table, the system also allows this date to be overridden. Because of that, the invoice_due_date column should not be omitted. If the system didn't allow this value to be overridden, however, this column could be safely omitted.

## When and how to denormalize a data structure

*Denormalization* is the deliberate deviation from the normal forms. Most denormalization occurs beyond the third normal form. In contrast, the first three normal forms are almost universally applied.

To illustrate when and how to *denormalize* a data structure, figure 10-13 presents the design of the accounts payable system in fifth normal form. Here, the vendor zip codes are stored in a separate table that contains the city and state for each zip code. In addition, the area codes are stored in a separate table. Because of that, a query that retrieves vendor addresses and phone numbers would require two joins. In contrast, if you left the city, state, and area code information in the Vendors table, no joins would be required, but the Vendors table would be larger.

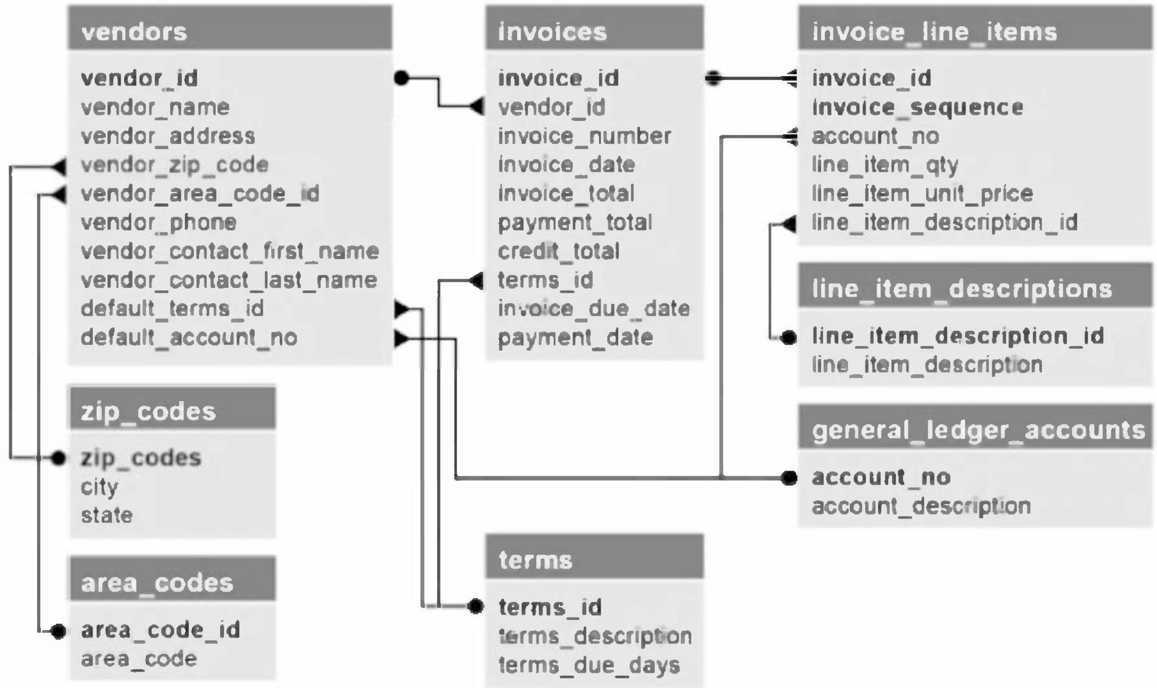
In general, you should denormalize based on the way the data will be used. In this case, we'll seldom need to query phone numbers without the area code. Likewise, we'll seldom need to query city and state without the zip code. For these reasons, I've denormalized my design by eliminating the Zip_Codes and Area_Codes tables.

You might also consider denormalizing a table if the data it contains is updated infrequently. In that case, redundant data isn't as likely to cause problems.

Finally, you should consider including derived data in a table if that data is used frequently in search conditions. For example, if you frequently query the Invoices table based on invoice balances, you might consider including a column that contains the balance due. That way, you won't have to calculate this value each time it's queried. Keep in mind, though, that if you store derived data, it's possible for it to deviate from the derived value. For this reason, you may need to protect the derived column so it can't be updated directly. Alternatively, you could update the table periodically to reset the value of the derived column.

Because normalization eliminates the possibility of data redundancy errors and optimizes the use of storage, you should carefully consider when and how to denormalize a data structure. In general, you should denormalize only when the increased efficiency outweighs the potential for redundancy errors and storage problems. Of course, your decision to denormalize should also be based on your knowledge of the real-world environment in which the system will be used. If you've carefully analyzed the real-world environment as outlined in this chapter, you'll have a good basis for making that decision.

## The accounts payable system in fifth normal form




## When to denormalize

- When a column from a joined table is used repeatedly in search criteria, you should consider moving that column to the primary key table if it will eliminate the need for a join.
- If a table is updated infrequently, you should consider denormalizing it to improve efficiency. Because the data remains relatively constant, you don't have to worry about data redundancy errors once the initial data is entered and verified.
- Include columns with derived values when those values are used frequently in search conditions. If you do that, you need to be sure that the column value is always synchronized with the value of the columns it's derived from.

## Description

- Data structures that are normalized to the fourth normal form and beyond typically require more joins than tables normalized to the third normal form and can therefore be less efficient.
- MySQL statements that work with tables that are normalized to the fourth normal form and beyond are typically more difficult to code and debug.
- Most designers *denormalize* data structures to some extent, usually to the third normal form.
- *Denormalization* can result in larger tables, redundant data, and reduced performance.
- Only denormalize when necessary. It is better to adhere to the normal forms unless it is clear that performance will be improved by denormalizing.

Figure 10-13 When and how to denormalize a data structure

# How to use MySQL Workbench for database design

When you're ready to create a database diagram, it usually makes sense to use a tool that's specifically designed for that purpose. Fortunately, dozens of tools for designing databases are available. This topic introduces you to the database design tools that are available from MySQL Workbench.

MySQL Workbench makes it easy to create one or more database diagrams from an *enhanced entity-relationship model* (*EER model*). This model extends the original *entity-relationship model* (*ER model*). In addition, you can create a visual representation of an EER model by creating one or more *EER diagrams* from that model.

When working with MySQL Workbench, you can generate an EER model from an existing MySQL database or SQL creation script. Conversely, you can generate a SQL creation script from an EER model. This makes it easy to implement your design when you're done with it.

## How to open an existing EER model

When you start MySQL Workbench, it displays the Welcome tab of the Home page. To work with EER models, you can display the Models tab that's shown in figure 10-14. Then, you can open an existing EER model that was created with MySQL Workbench. If you opened the model recently, it should be displayed in the list of recently opened models. In this figure, for example, two models are shown in this list. One is named OM, and the other is named AP. Then, you can open the model by clicking on it. If the model you want to open isn't displayed in this list, you can click the ⊜ icon to the right of the Models heading and use the resulting dialog box to select the file for the model.

## How to create a new EER model

If you're designing a new database from scratch, you can create a model that doesn't contain any tables. To do that, you can click the ⊕ icon to the right of the Models heading. Then, you can add tables to the model as shown in the next figure.

If you're redesigning an existing database, you can start by creating a model from that database. To do that, you can click the ⊙ icon to the right of the Models heading and select "Create EER Model from Database". Then, you can use the resulting dialog boxes to connect to the server and select a database. When you do, MySQL Workbench creates a model and a diagram that includes all of the tables and columns of the selected database.

If you don't have access to the database but you have access to the script that creates it, you can create a model from that script. To do that, you can click the ⊙ icon to the right of the Models heading and select "Create EER Model from Script". Then, you can use the resulting dialog box to select the script file.

## The Models tab of the MySQL Workbench Home page


## Description

- MySQL Workbench allows you to create an *enhanced entity-relationship model (EER model)*. This type of model extends the original *entity-relationship model (ER model)*.
- Once you have created or opened an EER model, you can work with one or more *EER diagrams* that are associated with that model.
- To open a recently used EER model, click on the model in the list of models.
- To open an EER model, click the icon to the right of the Models heading, or select File→Open Model. Then, use the resulting dialog box to select the file for the model.
- To create a new EER model that's blank, click the ⊕ icon to the right of the Models heading, or select File→New Model.
- To create an EER model from an existing database, click the icon to the right of the Models heading, select "Create EER Model from Database" and use the resulting dialog boxes to connect to the server and select the database.
- To create an EER model from a SQL creation script, click the icon to the right of the Models heading, select "Create EER Model from Script" and use the resulting dialog box to select the script file.
- To remove an existing model from the list of recently used models, right-click on the model and select "Remove Model File from List".

Figure 10-14 How to create and open an EER model

## How to work with an EER model

Figure 10-15 shows how to work with an EER model. In particular, it shows the MySQL Model tab for the AP database. From this tab, you can work with the tables of the database.

To edit one of these tables, you can double-click on it. When you do, MySQL Workbench displays a tab for the table at the bottom of the window. Within this tab are additional tabs that you can use to modify the columns, indexes, and foreign keys for the table. For example, this figure shows the Columns tab for the Vendors table. From this tab, you can modify the names, data types, and other attributes of the columns. You can also add a new column by entering the information for the column at the bottom of the table. And, you can modify the name of the table.

If you want to add a table to the model, you can double-click on the Add Table icon. Then, you can edit the table to set its name, columns, indexes, and foreign keys. You'll learn more about how to do that in the next chapter. Or, if you want to remove a table from the model, you can right-click on the table and select Delete.

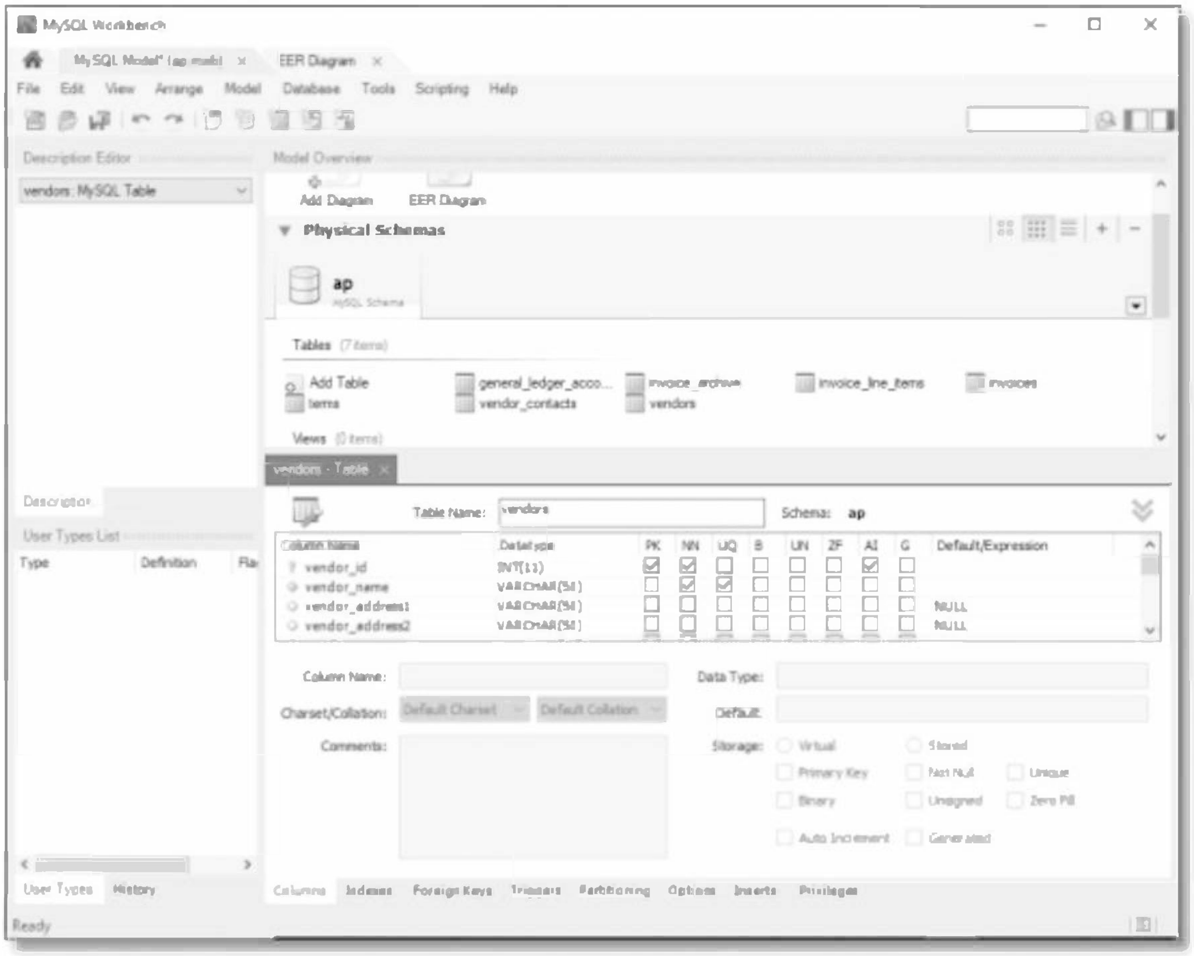
Since you typically begin designing a database by creating the tables of the database, this figure focuses on how to work with tables. However, you can use similar skills to work with other database objects that are stored in the model, such as views and stored programs.

Since it's usually easier to work with a visual representation of the model, you can open a diagram that corresponds to the model. As you'll see in the next figure, this can make it easier to see the relationships between tables. When you work with a diagram, some changes that you make affect the corresponding model. As a result, you can think of working with a diagram as a more visual way of working with the model.

When you create or open a model, the diagram for the model is displayed by default. If you close the tab for the diagram, however, you can open it again by double-clicking on the name of the diagram. In this figure, for example, the model for the AP database contains a diagram named EER Diagram. For small databases, you may only need a single diagram like this. However, for larger databases, you may need to create multiple diagrams that provide ways to view different parts of the database. To create a new diagram for the model, you can double-click the Add Diagram icon. Then, the diagram is given a name such as EER Diagram 1, EER Diagram 2, and so on.

When you're done creating your model, you can create a MySQL database creation script from the diagram. To do that, you can select File→Export→Forward Engineer SQL CREATE Script. Then, you can implement your design by using MySQL Workbench to run the script. This creates the database that corresponds to the model.

## The EER model for the AP database




## Description

- An EER model is a representation of the entities, or objects, of the database including the tables, views, and stored programs.
- To edit a table, double-click on it. Then, use the tabs that appear across the bottom of the window to modify the table's columns, indexes, and foreign keys.
- To add a new table, double-click on the Add Table icon. Then, use the tab that appears to define the table.
- To delete a table, right-click on it and select Delete.
- The skills for working with tables also apply to other database objects such as views and stored programs.
- The EER model typically includes at least one diagram named EER Diagram.
- To open a diagram, double-click on the name of the diagram.
- To create a new diagram, double-click on the Add Diagram icon or select Model→Add Diagram.
- To export a database creation script from the model, select File→Export→Forward Engineer SQL CREATE Script.

Figure 10-15 How to work with an EER model

## How to work with an EER diagram

When you open an EER diagram, it's displayed in a tab as shown in figure 10-16. Here, you can see the diagram that's associated with the model for the AP database. This diagram shows the definitions of the columns in the tables as well as the relationships between the tables. For example, it shows that there's a one-to-many relationship between the Vendors and Invoices tables.

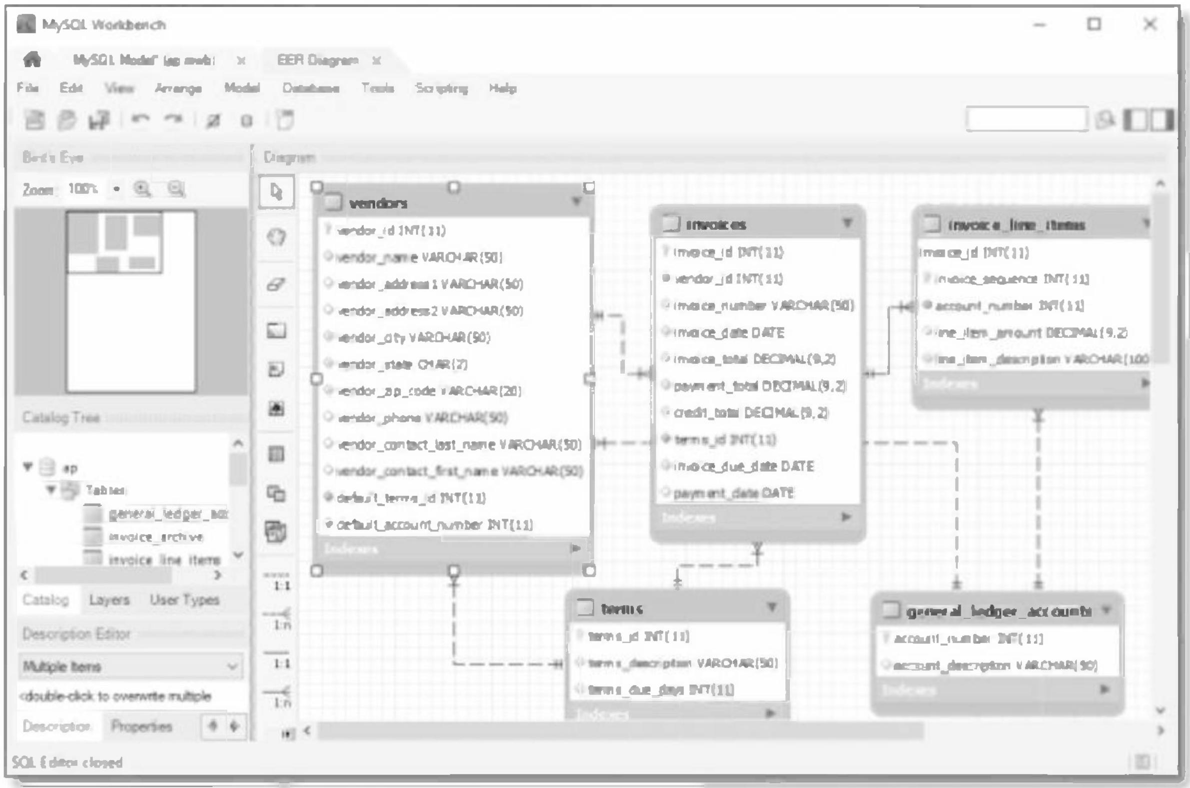
To edit a table, you can double-click on it. This displays a tab for the table that works the same as the one you saw in the last figure. As you learned in that figure, you can use this tab to make changes to the columns, indexes, and foreign keys.

To add a table that exists in the model to the diagram, you can drag the table from the Catalog Tree pane onto the diagram. Or, if you want to create a new table, you can click the Place a New Table button in the vertical toolbar to the left of the diagram and then click on the diagram. This adds a new table to the diagram and to the model.

Since a diagram provides a visual representation of the relationships between tables, you often use it to define those relationships. To do that, you can use the six relationship buttons at the bottom of the toolbar. The first five buttons generate foreign keys for the table, so you can use these buttons when the column for a foreign key doesn't exist yet. You can use the last relationship button if the foreign key column already exists in your diagram. For example, to create a relationship between the Vendors and Invoices tables, I clicked on the last button (the Place a Relationship Using Existing Columns button). Then, I clicked on the vendor_id column in the Invoices table to identify the foreign key, and I clicked on the vendor_id column in the Vendors table to identify the primary key.

In the next chapter, you'll learn more about the SQL statements that are generated by a tool like this. This will help you understand how to use MySQL Workbench, and it will allow you to edit the SQL statements that are generated by your database design tools.

## The EER diagram for the AP database




## Description

- An EER diagram is a visual representation of an EER model. As a result, when you modify the tables in the diagram, you also modify the model and vice versa.
- To add a table that already exists in the model to the diagram, drag the table from the Catalog Tree window onto the diagram.
- To add a new table to the diagram, click the Place a New Table button in the vertical toolbar at the left edge of the diagram. Then, click on the diagram where you want to add the table.
- To display the model for a table, double-click on the table. Then, a tab is displayed for the table, and you can use the techniques you learned in the previous figure to edit the table.
- To define the relationship between two tables, click one of the relationship buttons in the vertical toolbar. Then, click on the column in each table that defines the relationship.
- To edit or delete a relationship, right-click on the relationship icon and select the appropriate item.
- To remove a table from the diagram but keep it in the model, right-click on the table and select Remove Figure.
- To remove a table from the diagram and delete it from the model, right-click on the table and select Delete.

Figure 10-16 How to work with an EER diagram

# Perspective

Database design is a complicated subject. Because of that, it's impossible to teach you everything you need to know in a single chapter. With the skills you've learned in this chapter, though, you should now be able to design simple databases of your own. More importantly, you should be able to evaluate the design of any database that you work with. That way, you can be sure that the queries you code will be as efficient and as effective as possible.

## Terms

data structure
entity
attribute
instance
entity-relationship (ER) modeling
CASE (computer-aided software engineering)
linking table
connecting table
associate table
referential integrity
declarative referential integrity (DRI)
foreign key constraint
orphaned row
normalization
data redundancy
unnormalized data structure
normalized data structure
normal forms
index
table scan
composite index
Boyce-Codd normal form
transitive dependency
multivalued dependency
domain-key normal form
derived data
denormalization
entity-relationship (ER) model
enhanced entity-relationship (EER) model
EER diagram

## Exercises

1. Use MySQL Workbench to create an EER diagram for a database that stores information about products.

   Each product must have a product name, description, and price.

   Each product must belong to one category.

   Each category must have a category name and description.

   Each category can include multiple products.

2. Use MySQL Workbench to create an EER diagram for a database that stores information about customers.

   Each customer must have an email address, first name, and last name.

   Each customer can have two or more addresses.

   Each customer can have a default billing address and a default shipping address.

   Each address must have a street address, city, state, postal code, and country.

   Each country name should be stored in one place only. In other words, you shouldn't store the name of the country, which may be many characters, in the address.

3. Use MySQL Workbench to create an EER diagram for a database that tracks the memberships for an association and for the groups within the association.

   Each member must have an email address, first name, and last name.

   Each member can belong to any number of groups.

   Each group must have a name.

   Each group can have any number of members.

# 11

# How to create databases, tables, and indexes

Now that you've learned how to design a database, you're ready to learn how to implement your design. To do that, you use the set of SQL statements that are known as the data definition language (DDL). In this chapter, you'll learn how to use both DDL statements and MySQL Workbench to create databases, tables, and indexes. In addition, you'll learn how to change the character set, collation, and storage engine.

# How to work with databases

Before you can begin creating the tables of a database, you must create the database itself. Then, if multiple databases are running on the server, you'll need to select the database before you begin working with it. Of course, if you later decide that you no longer need a database, you can drop it, which causes the database and all of its tables and data to be deleted.

If you're working on a large database project, you probably won't need to code DDL statements like these because that will be handled by a database design specialist or a database administrator (DBA). For small projects, though, a SQL programmer may have to serve as the DBA too. And even when working with large projects, a SQL programmer often needs to use DDL statements to create smaller tables for testing.

## How to create and drop a database

Figure 11-1 starts by presenting the CREATE DATABASE statement. The first example in this figure uses the CREATE DATABASE statement to create a database named AP. If a database already exists with that name, however, this statement generates an error and doesn't execute.

When writing scripts, it's often helpful to check whether a database exists before creating it. To do that, you can add the IF NOT EXISTS keywords to the CREATE DATABASE statement as shown in the second example. That way, if the database exists, the statement generates a warning instead of an error. This allows a script to continue executing instead of being stopped.

The syntax of the DROP DATABASE statement is also shown in this figure. The third example uses this statement to delete the database named AP that was created in the first two examples. This permanently deletes everything in the entire database, so use it with caution!

The fourth example is similar, but it includes the IF EXISTS keywords. That way, if the database doesn't exist, the statement generates a warning instead of an error. This allows a script to continue executing instead of being stopped.

## How to select a database

Figure 11-1 also shows how to select a database using the USE statement. The example shown here uses this statement to select the database that was created by the CREATE DATABASE statement in the first example. Although the USE statement isn't a standard SQL statement, it's a MySQL extension that's commonly used when working with MySQL databases.

## How to use the CREATE DATABASE statement

### Syntax

```
CREATE DATABASE [IF NOT EXISTS] db_name
```

### Create a database named AP

```
CREATE DATABASE ap
```

### Create a database named AP only if it doesn't exist

```
CREATE DATABASE IF NOT EXISTS ap
```

## How to use the DROP DATABASE statement

### Syntax

```
DROP DATABASE [IF EXISTS] db_name
```

### Drop a database named AP

```
DROP DATABASE ap
```

### Drop a database named AP only if it exists

```
DROP DATABASE IF EXISTS ap
```

## How to use the USE statement

### Syntax

```
USE db_name
```

### Select a database named AP

```
USE ap
```

## Description

- The CREATE DATABASE statement creates a database with the specified name on the server.
- The DROP DATABASE statement deletes the database with the specified name from the server. This deletes all of the tables and data that are stored in the database.
- The USE statement selects the specified database and makes it the current database.

Figure 11-1 How to create, drop, and select a database

# How to work with tables

This topic shows how to code the DDL statements that work with the tables of a database. Because the syntax for these statements is complex, this chapter doesn't present complete syntax diagrams for these statements. Instead, the diagrams present only the commonly used clauses. If you're interested in the complete syntax of any statement, though, you can refer to the MySQL Reference Manual.

## How to create a table

Figure 11-2 presents a simplified syntax for the CREATE TABLE statement. By default, this statement creates a new table in the current database. If that's not what you want, you can qualify the table name with the database name. For example, you can qualify the Vendors table with the EX database like this:

```
CREATE TABLE ex.vendors
```

Before I continue, you should realize that if you run the statements shown in this figure against the AP database, the statements will fail. That's because the AP database already contains tables named Vendors and Invoices. As a result, if you want to test these statements, you can run them against the EX database or create a new database as shown in the previous figure. Then, the Vendors and Invoices tables will be created in that database.

In its simplest form, the CREATE TABLE statement consists of the name of the new table followed by the names and data types of its columns. This is illustrated by the first example in this figure. However, in most cases, you'll code one or more *attributes* for each column as illustrated by the second example. For instance, to indicate that a column doesn't accept null values, you can code the NOT NULL attribute. If you omit this attribute, the column allows null values.

To indicate that each row in a column must contain a unique value, you can code the UNIQUE attribute. Since two null values aren't considered to be the same, a unique column can contain multiple null values. However, it's common to use the NOT NULL and UNIQUE attributes to define a column that can't contain null values and where each value in the column must be unique.

To generate unique numbers in sequence, you use the AUTO_INCREMENT attribute. This attribute can only be specified for one column in a table, and that column must be defined as either the primary key or a unique key. When you define a column with the AUTO_INCREMENT attribute, MySQL automatically generates the next number in sequence for the column if you don't specify a value. By default, MySQL starts numbering with 1, but you can start with a value other than 1 by coding an option like this at the table level:

```
AUTO_INCREMENT = 3
```

Finally, to specify a default value for a column, you can use the DEFAULT attribute. This value is used if another value isn't specified when a row is added to the database. The default value you specify must correspond to the data type for the column. For example, the default value for the payment_total column

## The syntax of the CREATE TABLE statement

```
CREATE TABLE [IF NOT EXISTS] [db_name.]table_name
(
  column_name_1 data_type [column_attributes]
  [, column_name_2 data_type [column_attributes]]...
  [, table_level_constraints]
)
```

## Common column attributes

| Attribute | Description |
|---|---|
| `NOT NULL` | Indicates that the column doesn't accept null values. If omitted, the column can accept null values. |
| `UNIQUE` | Specifies that each value stored in the column must be unique. |
| `DEFAULT default_value` | Specifies a default value for the column as a literal or as an expression. |
| `AUTO_INCREMENT` | Identifies a column whose value is automatically incremented by MySQL when a new row is added. An auto increment column must be defined with one of the integer types. |

## A statement that creates a table without column attributes

```
CREATE TABLE vendors
(
  vendor_id      INT,
  vendor_name    VARCHAR(50)
)
```

## A statement that creates a table with column attributes

```
CREATE TABLE vendors
(
  vendor_id      INT            NOT NULL    UNIQUE AUTO_INCREMENT,
  vendor_name    VARCHAR(50)    NOT NULL    UNIQUE
)
```

## Another statement that creates a table with column attributes

```
CREATE TABLE invoices
(
  invoice_id        INT              NOT NULL     UNIQUE,
  vendor_id         INT              NOT NULL,
  invoice_number    VARCHAR(50)      NOT NULL,
  invoice_date      DATE,
  invoice_total     DECIMAL(9,2)     NOT NULL,
  payment_total     DECIMAL(9,2)                  DEFAULT 0
)
```

## Description

- To test the code in this figure and in the figures that follow, you can use the EX database.
- The CREATE TABLE statement creates a table based on the column names, data types, and *attributes* that you specify. In addition, it allows you to specify some attributes and constraints at the table level as described later in this chapter.

Figure 11-2 How to create a table

is set to a value of zero. With MySQL 8.0.13 and later, you can also specify a default value as an expression. For example, you could specify a default value for the invoice_date column as the CURRENT_DATE function.

Although it's not illustrated here, you can also code the IF NOT EXISTS keywords on the CREATE TABLE statement. These keywords work the same way they do for the CREATE DATABASE statement, and they're most useful when you're writing scripts. Without them, the statement generates an error if the table already exists. With them, the statement generates a warning instead of an error. This allows a script to continue executing instead of being stopped.

## How to code a primary key constraint

The NOT NULL and UNIQUE keywords you just learned about are examples of *constraints*. A constraint restricts the type of data that can be stored in a column. For example, the NOT NULL keyword prevents null values from being stored in a column, and the UNIQUE keyword only allows unique values.

Figure 11-3 shows how to code another type of constraint that's known as a *primary key constraint*. The easiest way to define a primary key is to code the PRIMARY KEY keywords after the data type for the column as shown in the first example. When you identify a column as the primary key, two of the column's attributes are changed automatically. First, the column is forced to be NOT NULL. Second, the column is forced to contain a unique value for each row. In addition, an index is automatically created based on the column.

When you define a constraint in a column definition as shown in the first example, it's called a *column-level constraint*. However, you can also define a constraint at the table level using the CONSTRAINT keyword. When you code a *table-level constraint*, you can provide a name for the constraint to make it easier to refer to later on. In the second example in this figure, for instance, the first constraint provides a name of vendors_pk for the primary key of the Vendors table. Note how the constraint names used in this example begin with a table name or a column name. In addition, they use a two-letter suffix to identify the type of constraint.

Although you can't name them at the column level, the vendors_pk and vendor_name_uq constraints work the same regardless of whether they are coded at the column level or the table level. As a result, where you code these constraints is largely a matter of personal preference. I prefer to code the primary key and unique key constraints at the column level as shown in the first example. However, when MySQL Workbench generates code from an EER model, it usually codes these constraints at the table level as shown in the second example.

In addition to allowing you to name a primary key, a table-level constraint provides another capability that isn't available from column-level constraints: it can refer to multiple columns in the table. As a result, if you need to refer to multiple columns, you must use a table-level constraint. For example, to create the composite primary key for the Invoice_Line_Items table, I coded the constraint at the table level as shown in the third example.

### The syntax of a column-level primary key constraint

```
column_name data_type PRIMARY KEY column_attributes
```

### The syntax of a table-level primary key constraint

```
[CONSTRAINT [constraint_name]]
PRIMARY KEY (column_name_1[, column_name_2]...)
```

### A table with column-level constraints

```
CREATE TABLE vendors
(
  vendor_id       INT             PRIMARY KEY    AUTO_INCREMENT,
  vendor_name     VARCHAR(50)     NOT NULL       UNIQUE
)
```

### A table with table-level constraints

```
CREATE TABLE vendors
(
  vendor_id       INT             AUTO_INCREMENT,
  vendor_name     VARCHAR(50)     NOT NULL,
  CONSTRAINT vendors_pk PRIMARY KEY (vendor_id),
  CONSTRAINT vendor_name_uq UNIQUE (vendor_name)
)
```

### A table with a two-column primary key constraint

```
CREATE TABLE invoice_line_items
(
  invoice_id              INT             NOT NULL,
  invoice_sequence        INT             NOT NULL,
  line_item_description   VARCHAR(100)    NOT NULL,
  CONSTRAINT line_items_pk PRIMARY KEY (invoice_id, invoice_sequence)
)
```

### Description

- *Constraints* are used to enforce the integrity of the data in a table by defining rules about the values that can be stored in the columns of the table.
- You code a *column-level constraint* as part of the definition of the column it constrains. You code a *table-level constraint* as if it is a separate column definition, and you name the columns it constrains within that definition.
- A *not null constraint* prevents null values from being stored in the column. A *unique constraint* requires that each row has a unique value in the column but allows null values to be stored in the column.
- A *primary key constraint* requires that each row has a unique value for the column or columns for the primary key, and it does not allow null values.

Figure 11-3 How to code a primary key constraint

When you code a constraint at the table level, you must code a comma at the end of the preceding column definition. If you don't, you will get an error when you try to run the statement.

## How to code a foreign key constraint

Figure 11-4 shows how to code a *foreign key constraint*, which is also known as a *reference constraint*. This type of constraint is used to define the relationships between tables and to enforce referential integrity.

To create a foreign key constraint at the column level, you code the REFERENCES keyword followed by the name of the related table and the name of the related column in parentheses. In this figure, for instance, the first example creates a table with a vendor_id column that includes a REFERENCES clause that identifies the vendor_id column in the Vendors table as the related column.

The second example shows how to code the same foreign key constraint shown in the first example at the table level. When you use this syntax, you can include the CONSTRAINT keyword followed by a name, followed by the FOREIGN KEY keywords. Although this requires a little more code, it allows you to provide a name for the foreign key, which is a good programming practice. It also lets you reference a foreign key that consists of multiple columns.

The third example in this figure shows what happens when you try to insert a row into the Invoices table with a vendor_id value that isn't matched by the vendor_id column in the Vendors table. Because of the foreign key constraint, the system enforces referential integrity by refusing to do the operation. It also displays an error message that indicates the constraint that was violated.

Similarly, if you try to delete a row from the Vendors table that has related rows in the Invoices table, the delete operation will fail and the system will display an error message. Since this prevents rows in the Invoices table from being orphaned, this is usually what you want.

In some cases, though, you may want to automatically delete the related rows in the Invoices table when a row in the Vendors table is deleted. To do that, you can code the ON DELETE clause on the foreign key constraint as illustrated by the fourth example. Here, this clause is coded with the CASCADE option. Then, when you delete a row from the primary key table, the delete is *cascaded* to the related rows in the foreign key table. If, for example, you delete a row from the Vendors table, all related rows in the Invoices table will also be deleted. Because a *cascading delete* makes it easier to delete data that you didn't intend to delete, you should use it with caution.

You can also code the SET NULL option on the ON DELETE clause. Then, when you delete a row from the primary key table, the values in the foreign key column of the foreign key table are set to null. Since this creates rows in the foreign key table that aren't related to the primary key table, you'll rarely want to use this option.

### The syntax of a column-level foreign key constraint

```
[CONSTRAINT] REFERENCES table_name (column_name)
  [ON DELETE {CASCADE|SET NULL}]
```

### The syntax of a table-level foreign key constraint

```
[CONSTRAINT constraint_name]
  FOREIGN KEY (column_name_1[, column_name_2]...)
  REFERENCES table_name (column_name_1[, column_name_2]...)
  [ON DELETE {CASCADE|SET NULL}]
```

### A table with a column-level foreign key constraint

```
CREATE TABLE invoices
(
  invoice_id       INT            PRIMARY KEY,
  vendor_id        INT            REFERENCES vendors (vendor_id),
  invoice_number   VARCHAR(50)    NOT NULL    UNIQUE
)
```

### A table with a table-level foreign key constraint

```
CREATE TABLE invoices
(
  invoice_id       INT            PRIMARY KEY,
  vendor_id        INT            NOT NULL,
  invoice_number   VARCHAR(50)    NOT NULL        UNIQUE,
  CONSTRAINT invoices_fk_vendors
    FOREIGN KEY (vendor_id) REFERENCES vendors (vendor_id)
)
```

### An INSERT statement that fails because a related row doesn't exist

```
INSERT INTO invoices
VALUES (1, 1, '1')
```

#### The response from the system

```
Error Code: 1452. Cannot add or update a child row: a foreign key con-
straint fails ('ex'.'invoices', CONSTRAINT 'invoices_fk_vendors' FOREIGN
KEY ('vendor_id') REFERENCES 'vendors' ('vendor_id'))
```

### A constraint that uses the ON DELETE clause

```
CONSTRAINT invoices_fk_vendors
  FOREIGN KEY (vendor_id) REFERENCES vendors (vendor_id)
  ON DELETE CASCADE
```

### Description

- A *foreign key constraint* requires values in one table to match values in another table. This defines the relationship between two tables and enforces referential integrity.
- To define a relationship that consists of two or more columns, you must define the constraint at the table level.
- Not all MySQL storage engines support foreign key constraints.

Figure 11-4 How to code a foreign key constraint

## How to alter the columns of a table

After you create tables, you may need to change the columns of a table. For example, you may need to add, modify, or drop a column. To do that, you can use the ALTER TABLE statement shown in figure 11-5.

The first example in this figure shows how to add a new column to a table. To do that, you code the column definition the same way you do when you create a new table. To start, you specify the column name. Then, you code the data type and column attributes.

The second example shows how to drop an existing column. Note that MySQL prevents you from dropping some columns. For example, you can't drop a column if it's the primary key column.

The third example shows how to modify the length of the data type for an existing column. In this case, a column that was defined as VARCHAR(50) is changed to VARCHAR(100). Since the new data type is bigger than the old data type, you can be sure that the existing data will still fit.

Notice in this example that the definition for the vendor_name column includes the NOT NULL attribute that was included on the original column definition. If you don't include an existing attribute for a column when you modify the column, that attribute is dropped from the column definition. The exceptions are attributes that define indexes, including the PRIMARY KEY and UNIQUE attributes. Because of that, you shouldn't code these attributes when modifying an existing column.

The fourth example shows how to change the data type to a different data type. In this case, a column that was defined as VARCHAR(100) is changed to CHAR(100). Since these data types both store the same type of characters, you know that no data will be lost.

The fifth example shows how to change the default value for a column. In this case, a default value of "New Vendor" is assigned to the vendor_name column.

The sixth example shows how to change the name of a column. Here, the name of the vendor_name column is changed to v_name. Note that if you need to change both the name and definition of a column, you can do that more easily using the CHANGE clause of the ALTER TABLE statement. For more information on this clause, see the MySQL Reference Manual.

In the first six statements, MySQL can alter the table without losing any data. As a result, these statements execute successfully and alter the table. However, if the change will result in a loss of data, it's not allowed. For example, the seventh statement attempts to change the length of the column whose name was changed to v_name by the sixth example to a length that's too small for existing data that's stored in this column. As a result, MySQL doesn't modify the column, and the system returns an error message like the one shown in this figure.

### The syntax for modifying the columns of a table

```
ALTER TABLE [db_name.]table_name
{
ADD           column_name data_type [column_attributes] |
DROP COLUMN   column_name |
MODIFY        column_name data_type [column_attributes] |
RENAME COLUMN old_column_name TO new_column_name
}
```

### A statement that adds a new column

```
ALTER TABLE vendors
ADD last_transaction_date DATE
```

### A statement that drops a column

```
ALTER TABLE vendors
DROP COLUMN last_transaction_date
```

### A statement that changes the length of a column

```
ALTER TABLE vendors
MODIFY vendor_name VARCHAR(100) NOT NULL
```

### A statement that changes the data type of a column

```
ALTER TABLE vendors
MODIFY vendor_name CHAR(100) NOT NULL
```

### A statement that changes the default value of a column

```
ALTER TABLE vendors
MODIFY vendor_name VARCHAR(100) NOT NULL DEFAULT 'New Vendor'
```

### A statement that changes the name of a column

```
ALTER TABLE vendors
RENAME COLUMN vendor_name TO v_name
```

### A statement that fails because it would cause data to be lost

```
ALTER TABLE vendors
MODIFY v_name VARCHAR(10) NOT NULL
```

#### The response from the system

```
Error Code: 1265. Data truncated for column 'v_name' at row 1
```

### Description

- You can use the ALTER TABLE statement to add, drop, or modify the columns of an existing table.
- MySQL won't allow you to change a column if that change would cause data to be lost.

### Warning

- You should never alter a table or other database object in a production database without first consulting the DBA.

Figure 11-5 How to alter the columns of a table

## How to alter the constraints of a table

You may also need to change the constraints of a table after you create it. For example, you may need to add or drop a constraint. To do that, you can use the ALTER TABLE statement as shown in figure 11-6.

The first example shows how to add a primary key to a table. To do that, you code the ADD PRIMARY KEY keywords followed by the names of the key columns in parentheses.

The second example shows how to add a foreign key to a table. This example uses the FOREIGN KEY keywords to identify the vendor_id column as the foreign key, and it uses the REFERENCES clause to identify the vendor_id column in the Vendors table as the related column. In addition, this example includes the optional CONSTRAINT keyword to provide a name for the foreign key, which is a good programming practice because it makes it easier to refer to the key later.

The third example uses the DROP PRIMARY KEY keywords to delete the primary key for the Vendors table. Depending on how this table and the other tables in the database are defined, MySQL may not allow you to drop the primary key for a table. That's true if the primary key is an auto increment column or if it's referred to by foreign keys. Since most primary keys are referred to by at least one foreign key, you can't typically delete a primary key without first deleting or modifying related rows in other tables.

The last example uses the DROP FOREIGN KEY keywords to drop the invoices_fk_vendors foreign key from the Invoices table. Because a table can contain more than one foreign key, you must know the name of the key you want to drop. If you don't know its name, you can use MySQL Workbench to look it up as shown later in this chapter.

### The syntax for modifying the constraints of a table

```
ALTER TABLE [dbname.]table_name
{
ADD  PRIMARY KEY constraint_definition |
ADD  [CONSTRAINT constraint_name] FOREIGN KEY constraint_definition |
DROP PRIMARY KEY |
DROP FOREIGN KEY constraint_name
}
```

### A statement that adds a primary key constraint

```
ALTER TABLE vendors
ADD PRIMARY KEY (vendor_id)
```

### A statement that adds a foreign key constraint

```
ALTER TABLE invoices
ADD CONSTRAINT invoices_fk_vendors
  FOREIGN KEY (vendor_id) REFERENCES vendors (vendor_id)
```

### A statement that drops a primary key constraint

```
ALTER TABLE vendors
DROP PRIMARY KEY
```

### A statement that drops a foreign key constraint

```
ALTER TABLE invoices
DROP FOREIGN KEY invoices_fk_vendors
```

### Description

- You can use the ALTER TABLE statement to add or drop the constraints of an existing table.
- To drop a foreign key constraint, you must know its name. If you don't know its name, you can use MySQL Workbench to look up the name as shown later in this chapter.

Figure 11-6 How to alter the constraints of a table

## How to rename, truncate, and drop a table

Figure 11-7 shows how to use the RENAME TABLE, TRUNCATE TABLE, and DROP TABLE statements. When you use these statements, use them cautiously, especially when you're working on a production database.

To start, you can use the RENAME TABLE statement to rename an existing table. This is useful if you want to change the name of a table without modifying its column definitions or the data that's stored in the table. In this figure, for instance, the first example changes the name of the Vendors table to Vendor. If you rename a table, you should probably update the names of any constraints that use the name of the table. To do that, you have to drop the constraint and then add it back.

You can use the TRUNCATE TABLE statement to delete all of the data from a table without deleting the column definitions for the table. In this figure, for instance, the second example deletes all rows from the newly renamed Vendor table.

You can use the DROP TABLE statement to delete all of the data from a table and also delete the definition of the table, including the constraints for the table. In this figure, for instance, the third and fourth examples drop the Vendor table. However, the fourth example explicitly specifies that it is dropping the Vendor table that's stored in the EX database, not the Vendor table in another database such as the AP database.

When you issue a DROP TABLE statement, MySQL checks to see if other tables depend on the table you're trying to delete. If they do, MySQL won't allow the deletion. For instance, you can't delete the Vendors table from the AP database because a foreign key constraint in the Invoices table refers to the Vendors table. If you try to delete the Vendors table, the system will return an error message like the one shown in the fifth example. In that case, you must drop the Invoices table before you can drop the Vendors table.

When writing scripts, it's often helpful to check whether a table exists before dropping it. To do that, you can add the IF EXISTS keywords to the DROP TABLE statement as shown in the sixth example. That way, if the table doesn't exist, the statement generates a warning instead of an error. This allows a script to continue executing instead of being stopped.

When you drop a table, any indexes or triggers that have been defined for the table are also dropped. You'll learn how to create indexes for a table in just a moment. You'll learn how to create triggers for a table in chapter 16.

### A statement that renames a table

```
RENAME TABLE vendors TO vendor
```

### A statement that deletes all data from a table

```
TRUNCATE TABLE vendor
```

### A statement that deletes a table from the current database

```
DROP TABLE vendor
```

### A statement that qualifies the table to be deleted

```
DROP TABLE ex.vendor
```

### A statement that returns an error due to a foreign key reference

```
DROP TABLE vendors
```

#### The response from the system

```
Error Code: 3730. Cannot drop table 'vendors' referenced by a foreign key
constraint 'invoices_fk_vendors' on table 'invoices'
```

### A statement that deletes a table only if it exists

```
DROP TABLE IF EXISTS vendor
```

### Description

- You can use the RENAME TABLE statement to change the name of an existing table.
- You can use the TRUNCATE TABLE statement to delete all data from a table without deleting the definition for the table.
- You can use the DROP TABLE statement to delete a table from the current database.
- To rename, truncate, or drop a table from another database, you must qualify the table name with the database name.
- You can't truncate or drop a table if a foreign key constraint in another table refers to that table.
- When you drop a table, all of its data, constraints, and indexes are deleted.

### Warning

- You shouldn't use these statements on a production database without first consulting the DBA.

Figure 11-7 How to rename, truncate, and drop a table

# How to work with indexes

An *index* speeds up joins and searches by providing a way for a database management system to go directly to a row rather than having to search through all the rows until it finds the one you want. By default, MySQL creates indexes for the primary keys, foreign keys, and unique columns of a table. Usually, that's what you want. In addition, you may want to create indexes for other columns that are used frequently in search conditions or joins. However, you'll want to avoid creating indexes on columns that are updated frequently since this slows down insert, update, and delete operations.

## How to create an index

Figure 11-8 presents the basic syntax of the CREATE INDEX statement, which creates an index based on one or more columns of a table. To create an index, you name the table and columns that the index will be based on in the ON clause. For each column, you can specify the ASC or DESC keyword to indicate whether you want the index sorted in ascending or descending sequence. If you don't specify a sort order, ASC is the default. In addition, you can use the UNIQUE keyword to specify that an index contains only unique values.

You may be interested to know that with releases of MySQL before 8.0, indexes weren't actually stored in descending sequence if you included the DESC keyword. Instead, when the index was used to access the table, the index was scanned in reverse sequence, which resulted in poor performance. With MySQL 8.0 and later, though, a descending index is actually stored in descending sequence. That way, when the index is used to access the table, the index can be scanned in forward sequence, which results in improved performance.

In the examples in this figure, the names follow a standard naming convention. To start, the index name specifies the name of the table, followed by the name of the column or columns, followed by a suffix of IX. This naming convention makes it easy to see which columns of which tables have been indexed. However, if the table or column names are lengthy, you can abbreviate their names in the name of the index.

## How to drop an index

The last example in figure 11-8 shows how to use the DROP INDEX statement to drop an index. You may want to drop an index if you suspect that it isn't speeding up your joins and searches and that it may be slowing down your insert, update, and delete operations.

### The syntax of the CREATE INDEX statement

```
CREATE [UNIQUE] INDEX index_name
  ON [dbname.]table_name (column_name_1 [ASC|DESC][,
                                   column_name_2 [ASC|DESC]]...)
```

### A statement that creates an index based on a single column

```
CREATE INDEX invoices_invoice_date_ix
  ON invoices (invoice_date)
```

### A statement that creates an index based on two columns

```
CREATE INDEX invoices_vendor_id_invoice_number_ix
  ON invoices (vendor_id, invoice_number)
```

### A statement that creates a unique index

```
CREATE UNIQUE INDEX vendors_vendor_phone_ix
  ON vendors (vendor_phone)
```

### A statement that creates an index that's sorted in descending order

```
CREATE INDEX invoices_invoice_total_ix
  ON invoices (invoice_total DESC)
```

### A statement that drops an index

```
DROP INDEX vendors_vendor_phone_ix ON vendors
```

### Description

- MySQL automatically creates an *index* for primary key, foreign key, and unique constraints.
- You can use the CREATE INDEX statement to create other indexes for a table. An index can improve performance when MySQL searches for rows in the table.
- You can use the DROP INDEX statement to drop an index from a table.

Figure 11-8 How to create and drop an index

# A script that creates a database

Figure 11-9 presents the DDL statements that are used to create the AP database that's used throughout this book. In this figure, these statements are coded as part of a script.

As you learned in earlier chapters, a *script* is a file that contains one or more SQL statements. Scripts are often used to create the objects for a database as shown in this figure. When you code a script, you code a semicolon at the end of each SQL statement.

The DROP DATABASE IF EXISTS statement that begins this script drops the entire database if it already exists, including all of its tables. This suppresses any error messages that would be displayed if you attempted to drop a database that didn't exist. Then, the CREATE DATABASE statement creates the AP database.

The USE statement selects the AP database. As a result, the rest of the statements in the script are executed against the AP database.

The CREATE TABLE statements create the five main tables of the AP database. For each statement, I coded the primary key column (or columns) first. Although this isn't required, it's a good programming practice. After the primary key, I coded the remaining columns in a logical order. That way, if you use a SELECT * statement to retrieve all of the columns, they're returned in a logical order.

When you create tables, you must create the tables that don't have foreign keys first. That way, the other tables can define foreign keys that refer to them. In this figure, for example, I created the General_Ledger_Accounts and Terms tables first since they don't have foreign keys. Then, I coded the Vendors table, which has foreign keys that refer to these tables. And so on. Conversely, when you drop tables, you must start by dropping the last table that was created. Then, you can work back to the first table that was created. Otherwise, the foreign keys might not allow you to delete the tables.

## The SQL script that creates the AP database Page 1

```
-- create the database
DROP DATABASE IF EXISTS ap;
CREATE DATABASE ap;

-- select the database
USE ap;

-- create the tables
CREATE TABLE general_ledger_accounts
(
  account_number          INT            PRIMARY KEY,
  account_description     VARCHAR(50)    UNIQUE
);

CREATE TABLE terms
(
  terms_id                INT            PRIMARY KEY    AUTO_INCREMENT,
  terms_description       VARCHAR(50)    NOT NULL,
  terms_due_days          INT            NOT NULL
);

CREATE TABLE vendors
(
  vendor_id                    INT            PRIMARY KEY    AUTO_INCREMENT,
  vendor_name                  VARCHAR(50)    NOT NULL       UNIQUE,
  vendor_address1              VARCHAR(50),
  vendor_address2              VARCHAR(50),
  vendor_city                  VARCHAR(50)    NOT NULL,
  vendor_state                 CHAR(2)        NOT NULL,
  vendor_zip_code              VARCHAR(20)    NOT NULL,
  vendor_phone                 VARCHAR(50),
  vendor_contact_last_name     VARCHAR(50),
  vendor_contact_first_name    VARCHAR(50),
  default_terms_id             INT            NOT NULL,
  default_account_number       INT            NOT NULL,
  CONSTRAINT vendors_fk_terms
    FOREIGN KEY (default_terms_id)
    REFERENCES terms (terms_id),
  CONSTRAINT vendors_fk_accounts
    FOREIGN KEY (default_account_number)
    REFERENCES general_ledger_accounts (account_number)
);
```

Figure 11-9 The script used to create the AP database (part 1 of 2)

For most of the columns in these tables, I coded a NOT NULL constraint or a DEFAULT attribute. In general, I only allow a column to accept null values when I want to allow for unknown values. If, for example, a vendor doesn't supply an address, the address is unknown. In that case, you can store a null value in the vendor_address1 and vendor_address2 columns.

Another option is to store an empty string for these columns. To do that, I could have defined the vendor address columns like this:

```
vendor_address1     VARCHAR(50)     DEFAULT '',
vendor_address2     VARCHAR(50)     DEFAULT '',
```

In this case, empty strings would be stored for these columns unless other values were assigned to them.

In practice, a null value is a more intuitive representation of an unknown value than a default value is. Conversely, it makes sense to use a default value like an empty string to indicate that a value is known but the column is empty. For example, an empty string might indicate that a vendor hasn't provided its street address. Although how you use nulls and empty strings is largely a matter of personal preference, it does affect the way you query a table.

When a primary key consisted of a single column, I coded the PRIMARY KEY constraint at the column level. Similarly, I coded the UNIQUE constraint at the column level. As a result, I didn't provide names for these constraints. However, whenever I coded a primary key or foreign key constraint at the table level, I followed a convention that begins with the name of the table or an abbreviated name for the table.

As you know, when MySQL creates a table, it automatically creates indexes for the primary key, foreign keys, and unique columns. MySQL uses the name "PRIMARY" for the name of the index for a table's primary key. It uses the name of the column for the name of the index for a unique key. And it uses the name of the foreign key for the name of the index for a foreign key column. For the Invoices table, for example, MySQL automatically creates an index named "PRIMARY" for the invoice_id column, it creates an index named invoices_fk_vendors for the vendor_id column, and it creates an index named invoices_fk_terms for the terms_id column.

In addition to the indexes that are created automatically, I used a CREATE INDEX statement to create an index for the invoice_date column in the Invoices table. Since this column is frequently used to search for rows in this table, this index should improve performance of the database. To name this index, I followed the naming conventions presented earlier in this chapter. As a result, when you view the name of an index, you can easily identify the table and column that's being indexed.

## The SQL script that creates the AP database Page 2

```
CREATE TABLE invoices
(
  invoice_id          INT            PRIMARY KEY    AUTO_INCREMENT,
  vendor_id           INT            NOT NULL,
  invoice_number      VARCHAR(50)    NOT NULL,
  invoice_date        DATE           NOT NULL,
  invoice_total       DECIMAL(9,2)   NOT NULL,
  payment_total       DECIMAL(9,2)   NOT NULL       DEFAULT 0,
  credit_total        DECIMAL(9,2)   NOT NULL       DEFAULT 0,
  terms_id            INT            NOT NULL,
  invoice_due_date    DATE           NOT NULL,
  payment_date        DATE,
  CONSTRAINT invoices_fk_vendors
    FOREIGN KEY (vendor_id)
    REFERENCES vendors (vendor_id),
  CONSTRAINT invoices_fk_terms
    FOREIGN KEY (terms_id)
    REFERENCES terms (terms_id)
);

CREATE TABLE invoice_line_items
(
  invoice_id              INT            NOT NULL,
  invoice_sequence        INT            NOT NULL,
  account_number          INT            NOT NULL,
  line_item_amount        DECIMAL(9,2)   NOT NULL,
  line_item_description   VARCHAR(100)   NOT NULL,
  CONSTRAINT line_items_pk
    PRIMARY KEY (invoice_id, invoice_sequence),
  CONSTRAINT line_items_fk_invoices
    FOREIGN KEY (invoice_id)
    REFERENCES invoices (invoice_id),
  CONSTRAINT line_items_fk_acounts
    FOREIGN KEY (account_number)
    REFERENCES general_ledger_accounts (account_number)
);

-- create an index
CREATE INDEX invoices_invoice_date_ix
  ON invoices (invoice_date DESC);
```

Figure 11-9 The script used to create the AP database (part 2 of 2)

# How to use MySQL Workbench

Since you often use a script to create tables and other database objects, it's important to understand the DDL skills presented in this chapter. Once you understand these skills, it's easy to learn how to use a graphical user interface such as MySQL Workbench to work with database objects such as tables and indexes. For example, it's often useful to view these database objects before writing SELECT, INSERT, UPDATE, or DELETE statements that use them.

## How to work with the columns of a table

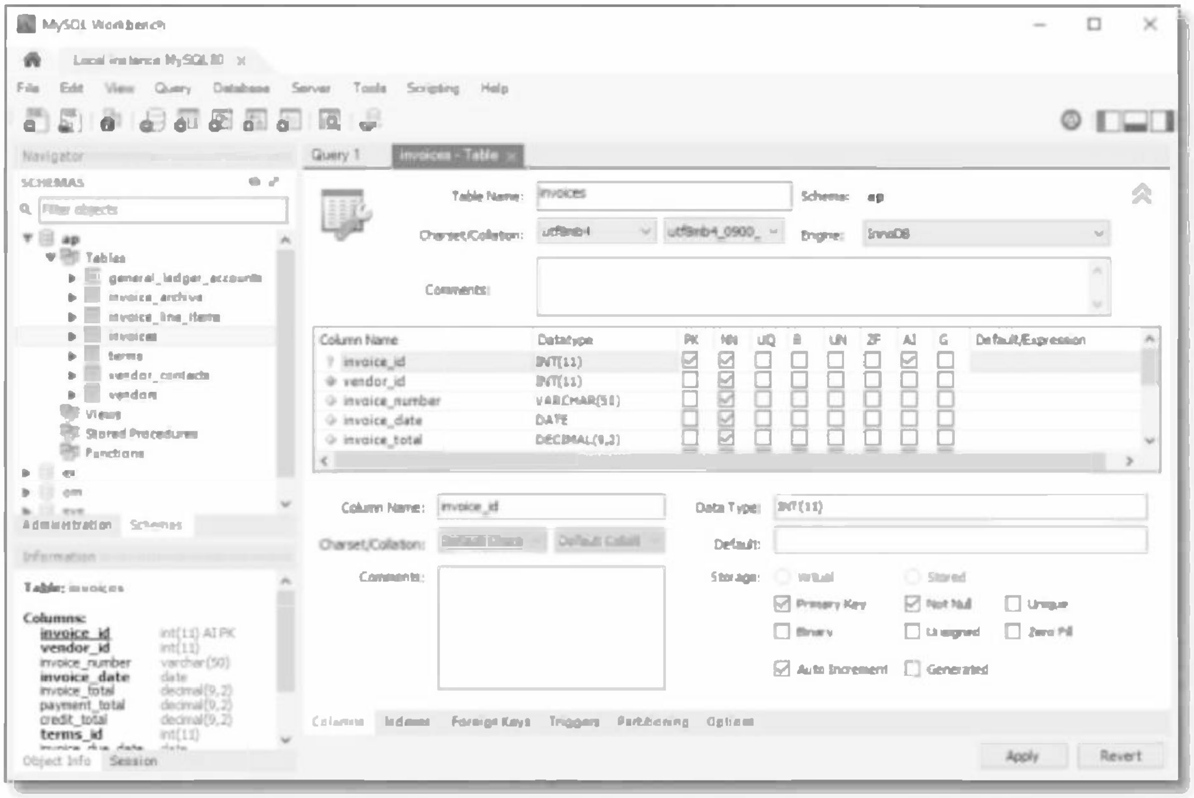
Figure 11-10 shows how to work with the column definitions of a table. To start, you can view the column definitions for a table by right-clicking on the table in the Navigator window and selecting Alter Table to display the table in the main window. Then, click on the Columns tab at the bottom of the window.

For example, this figure shows the columns for the Invoices table. Here, you can see the name, data type, and other attributes of each column. For instance, you can see that the invoice_id column is the primary key column and an auto increment column. The payment_total and credit_total columns specify a default value of 0.00. And the payment_date column allows null values and its default value is NULL.

If you need to add a new column, you can double-click below the last name in the Column Name column. Then, you can type in a name for the new column, and you can specify its attributes to the right of the column name.

You can also work with a new or existing column using the controls below the list of columns. In this figure, for example, I've selected the invoice_id column, so the information for that column is displayed below the column list. This is useful if you aren't familiar with the abbreviations that are used for the check boxes in the column list, since these attributes are clearly identified by the check boxes below the list. You can also use the Charset and Collation drop-down lists to change the character set and collation for some columns. You'll learn more about that later in this chapter.

## The column definitions for the Invoices table




## Description

- To view the columns for a table, right-click on the table in the Navigator window, select the Alter Table item, and click on the Columns tab.
- To rename a column, double-click on the column name and enter the new name.
- To change the data type for a column, click on the data type in the Datatype column. Then, select a data type from the drop-down list that's displayed.
- To change the default value for a column, enter a new default value in the Default column.
- To change other attributes of the column, check or uncheck the attribute check boxes to the right of the column.
- To drop a column, right-click on the column name and select Delete Selected.
- To move a column up or down, right-click on the column name and select Move Up or Move Down. You can also use the Up and Down keys on the keyboard.
- To add a new column, double-click in the Column Name column below the last column and type in a new name. Then, specify the attributes for the new column.
- To apply the changes to the table, click the Apply button. To reverse the changes, click the Revert button.

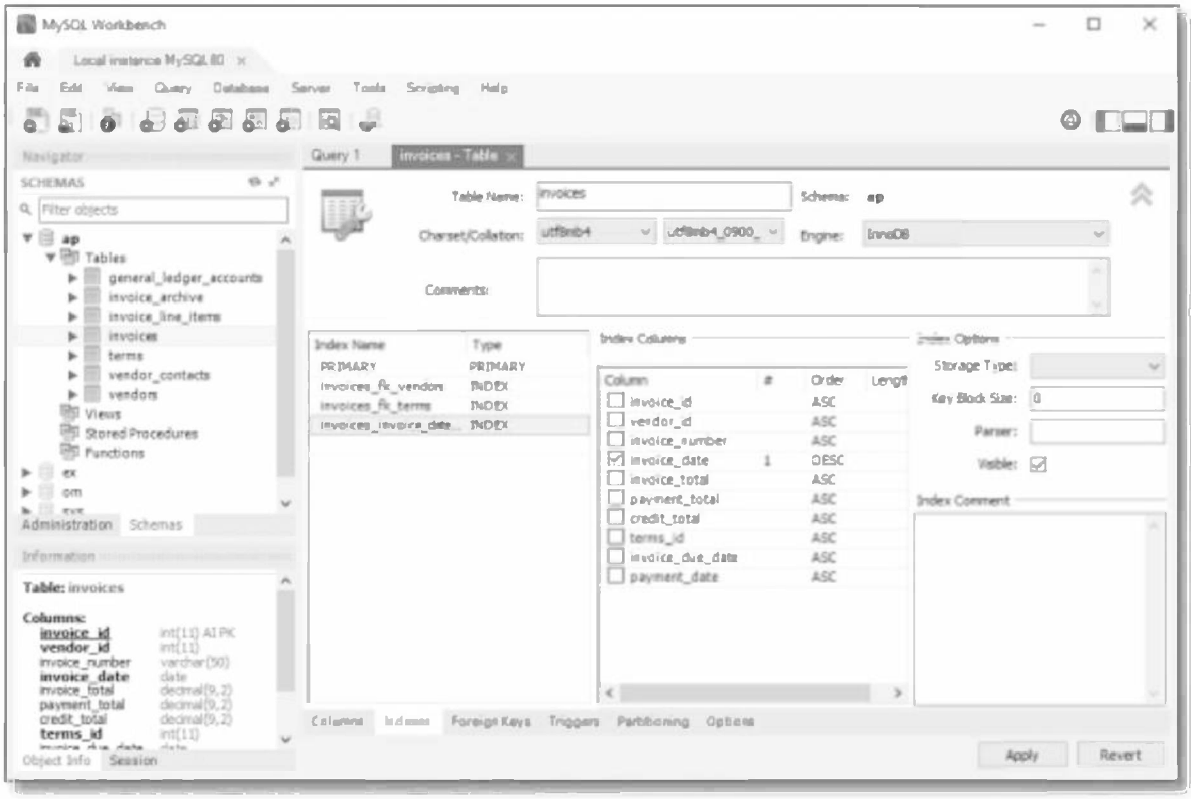
Figure 11-10 How to work with the columns of a table

## How to work with the indexes of a table

Although MySQL Workbench provides several ways to work with indexes, one of the easiest is to right-click on the table in the Navigator window and select the Alter Table command to display the table definition. Then, you can click on the Indexes tab to display the indexes of the table. For example, figure 11-11 shows the indexes for the Invoices table.

You can use the Indexes tab to perform a variety of operations, including adding, renaming, and dropping indexes. In most cases, you'll use this tab to add indexes to a table. To do that, you start by double-clicking below the last index name and entering the name of the new index. Then, you can select the type of index you want to create, the column or columns you want to index, and the order for each column.

### The indexes for the Invoices table




## Description

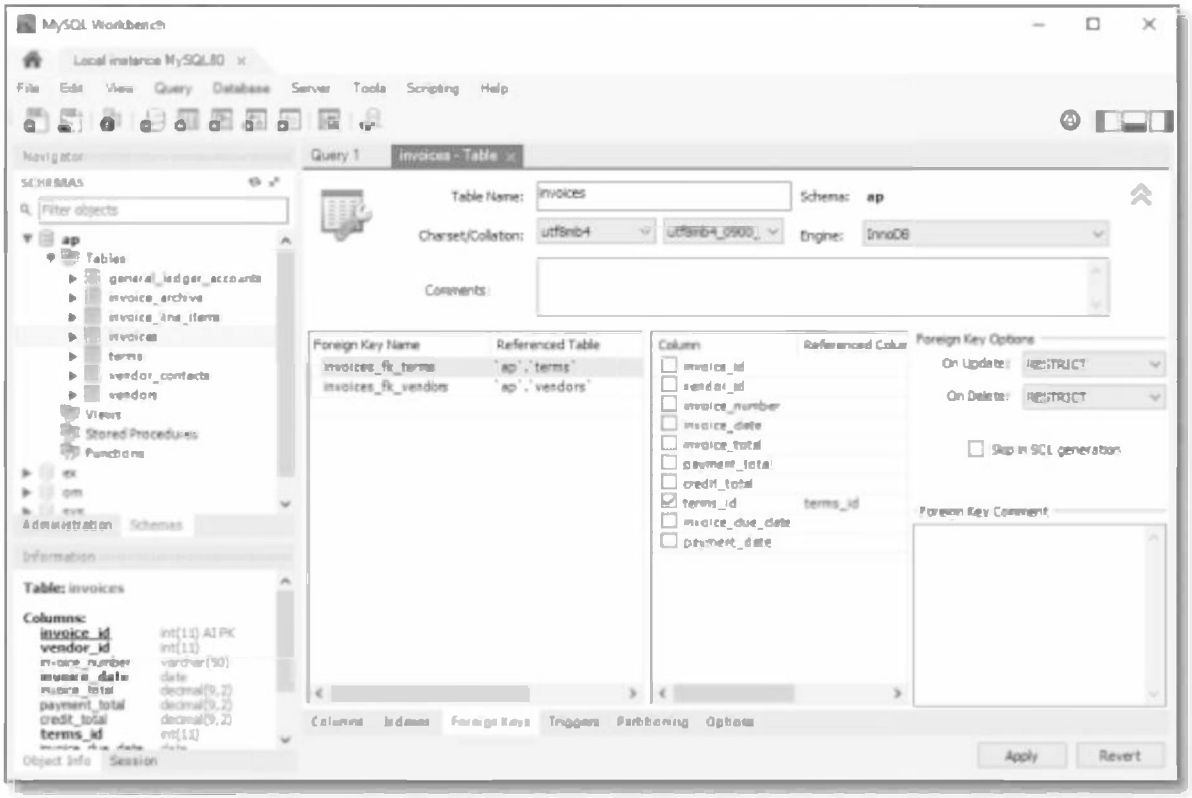
- To view the indexes for a table, right-click on the table in the Navigator window, select Alter Table, and click on the Indexes tab.
- To rename an index, double-click on the name and enter the new name.
- To change the type of an index, click on the Type column. Then, select a type from the drop-down list that appears.
- To change the column that's indexed, select the index and then select its column in the list of columns that appears. You can also change the sort order of the index by clicking in the Order column and then selecting ASC or DESC from the drop-down list that appears.
- To drop an index, right-click on the index name and select Delete Selected.
- To add a new index, double-click below the last index name and type in a new name. Then, specify the type, column, and order for the index.
- To apply the changes to the table, click the Apply button. To reverse the changes, click the Revert button.

Figure 11-11 How to work with the indexes of a table

## How to work with the foreign keys of a table

To work with the foreign keys of a table, you use the Foreign Keys tab. For example, figure 11-12 shows the foreign keys for the Invoices table, and the foreign key named invoices_fk_terms is selected. Here, MySQL Workbench shows the table that's referenced by the foreign key, the foreign key column, and the column that's referenced by the foreign key. If you need to, you can change any of the information that defines the foreign key as described in this figure. You can also add new foreign keys, and you can drop existing keys.

## The foreign keys for the Invoices table




## Description

- To view the foreign keys for a table, right-click on the table in the Navigator window, select Alter Table, and click on the Foreign Keys tab.
- To rename a foreign key, double-click on the name and enter the new name.
- To change the referenced table, click on the table name in the Referenced Table column and select a table from the drop-down list that appears.
- To change the column or referenced column for a foreign key, select the foreign key and then select the column or referenced column in the list that appears.
- To drop a foreign key, right-click on its name and select Delete Selected.
- To add a new foreign key, double-click below the last foreign key name and type in a new name. Then, specify the referenced table, foreign key column, and referenced column.
- To apply the changes to the table, click the Apply button. To reverse the changes, click the Revert button.

Figure 11-12 How to work with the foreign keys of a table

# How to work with character sets and collations

So far, this book has assumed that you're working with the default character set and collation for MySQL. In this topic, you'll learn more about characters sets and collations and why you might want to use a character set or collation that's different from the default. Then, you'll learn how to specify the character set and collation for a database, a table, or even a column.

## An introduction to character sets and collations

When a column is defined with a string type such as CHAR or VARCHAR, MySQL stores a numeric value for each character. Then, it uses a *character set* to map the numeric values to the characters of the string.

Figure 11-13 begins by presenting three character sets that are commonly used by MySQL. To start, it presents the default character set for MySQL 5.5 and earlier: the latin1 character set. This character set uses one byte per character to provide for most characters in Western European languages. However, if you need to store other characters, you can use the utf8mb3 or utf8mb4 character set.

The utf8mb3 character set is the default for MySQL 5.6 and 5.7, and the utf8mb4 character set is the default for MySQL 8.0 and later. Currently, MySQL refers to the utf8mb3 character set with the alias utf8. However, the utf8mb3 character set is deprecated and will be removed in a future release of MySQL. When that happens, utf8 will become an alias for the utf8mb4 character set. Because of that, you should explicitly specify utf8mb4 if that's the character set you want to use.

The advantage of the utf8mb4 character set is that it provides for all characters specified by the Unicode character set. This includes most characters from most languages worldwide. As a result, it's appropriate when you're going to be working with a global application that needs to be able to store characters from multiple languages. You can also use it to store characters like emojis, which are becoming more and more common.

The disadvantage of the utf8mb4 character set is that it can use up to four bytes per character. This forces MySQL to reserve four bytes per character for each character in the CHAR type. As a result, this can increase data storage requirements for a database that makes extensive use of the CHAR type. Fortunately, this typically isn't an issue. If it is, you can fix the issue by using the VARCHAR type instead of the CHAR type.

Every character set has a corresponding *collation* that determines how the characters within the set are sorted. For example, the latin1 character set uses the collation named latin1_swedish_ci by default, since MySQL was developed in Sweden. Here, the beginning of the name shows that it corresponds to the latin1 character set. In addition, the *ci* at the end shows that it is *case-insensitive*. This means that MySQL sorts uppercase letters such as *A* and lowercase letters such as *a* at the same level, which is usually what you want.

### Three commonly used character sets

| Name | Description |
|---|---|
| latin1 | The latin1 character set uses one byte per character to provide for most characters in Western European languages. |
| utf8mb3 | The utf8mb3 character set uses one to three bytes per character to provide for all characters specified by the Unicode character set. This character set provides for most characters in most of the world's languages. |
| utf8mb4 | The utf8mb4 character set uses one to four bytes per character to provide for all characters specified by the Unicode character set, plus additional characters like emojis. |

### Four collations for the latin1 character set

| Name | Description |
|---|---|
| latin1_swedish_ci | The default collation for the latin1 character set. |
| latin1_general_ci | A general purpose, case-insensitive collation. |
| latin1_general_cs | A general purpose, case-sensitive collation. |
| latin1_bin | The binary collation for this character set. |

### Four collations for the utf8mb3 character set

| Name | Description |
|---|---|
| utf8_general_ci | The default collation for the utf8mb3 (utf8) character set. |
| utf8_unicode_ci | A case-insensitive collation that provides for more correct sorting. |
| utf8_spanish_ci | A case-insensitive collation for the Spanish language. |
| utf8_bin | The binary collation for this character set. |

### Three collations for the utf8mb4 character set

| Name | Description |
|---|---|
| utf8mb4_0900_ai_ci | The default collation for the utf8mb4 character set. |
| utf8mb4_0900_as_cs | An accent-sensitive, case-sensitive collation. |
| utf8mb4_bin | The binary collation for this character set. |

### Description

- The *character set* that's used by a database, table, or column determines which characters can be stored and how many bytes are used to store the characters.
- Every character set has a corresponding *collation* that determines how the characters within the set are sorted.
- If the name of a collation ends with *ci*, the collation is *case-insensitive*. If the name of a collation ends with *cs*, the collation is *case-sensitive*.
- If the name of a collation includes *ai*, the collation is *accent-insensitive*. If the name of a collation includes *as*, the collation is *accent-sensitive*.
- If the name of a collation ends with *bin*, the collation is *binary*, which means that the characters are sorted according to the binary numbers that correspond to each character.

Figure 11-13 An introduction to character sets and collations

If MySQL isn't sorting characters the way you want, you can use another character set and collation. If you're using utf8mb4, for example, you can use the utf8mb4_0900_as_cs collation instead of the default of utf8mb4_0900_ai_ci.

In general, if you want to use a case-sensitive sort, you can use a collation with a name that ends with *cs*. Or, you can use a collation with a name that ends with *bin*, which stands for *binary*. This sorts characters by their numeric values instead of by their character values. Finally, if you want to use an accent-sensitive sort, you can use a collation that includes *as*.

## How to view character sets and collations

Figure 11-14 starts by showing how to view all character sets that are available on your MySQL server. To do that, you use the SHOW CHARSET statement as shown in the first example. As the results of this statement show, the SHOW CHARSET statement displays information about each character set in addition to its name.

You can also use the SHOW CHARSET statement to view information about a single character set. To do that, you can use a LIKE clause to identify the character set as shown in the second example.

This figure also shows how to use the SHOW COLLATION statement to view information about collations. For instance, the third example in this figure shows how to view information about all the collations that are available on the current server. In the result set that's returned by this statement, you can see some of the collations for the utf8mb4 character set.

If you only want to view the collations for a specific character set, you can use a LIKE clause with the % wildcard character. In this figure, for example, the second SHOW COLLATION statement shows the collations for the utf8mb4 character set.

The next four examples in this figure show how to use the SHOW VARIABLES statement to view the default character set and collation for your current server or database. In these examples, the LIKE clause is used to specify the name of a variable. For example, to view the default character set for a server, you use the character_set_server variable.

You can also view the character set and collation for all the tables in a database. To do that, you can query the table named Tables in the database named Information_Schema as shown in the last example. Here, the SELECT statement returns the table name and table collation for each table in the AP database. Since the name of the collation also identifies the character set, this indicates the character set for each table.

## How to view all available character sets for a server

```
SHOW CHARSET
```

| Charset | Description | Default collation | Maxlen |
|---|---|---|---|
| utf16 | UTF-16 Unicode | utf16_general_ci | 4 |
| utf16le | UTF-16LE Unicode | utf16le_general_ci | 4 |
| utf32 | UTF-32 Unicode | utf32_general_ci | 4 |
| utf8 | UTF-8 Unicode | utf8_general_ci | 3 |
| utf8mb4 | UTF-8 Unicode | utf8mb4_0900_ai_ci | 4 |

## How to view a specific character set

```
SHOW CHARSET LIKE 'utf8mb4'
```

## How to view all available collations for a server

```
SHOW COLLATION
```

| Collation | Charset | Id | Default | Compiled | Sortlen | Pad_attribute |
|---|---|---|---|---|---|---|
| utf8mb4_0900_ai_ci | utf8mb4 | 255 | Yes | Yes | 0 | NO PAD |
| utf8mb4_0900_as_ci | utf8mb4 | 305 | | Yes | 0 | NO PAD |
| utf8mb4_0900_as_cs | utf8mb4 | 278 | | Yes | 0 | NO PAD |
| utf8mb4_bin | utf8mb4 | 46 | | Yes | 1 | PAD SPACE |
| utf8mb4_croatian_ci | utf8mb4 | 245 | | Yes | 8 | PAD SPACE |
| utf8mb4_cs_0900_ai_ci | utf8mb4 | 266 | | Yes | 0 | NO PAD |
| utf8mb4_cs_0900_as_cs | utf8mb4 | 289 | | Yes | 0 | NO PAD |
| utf8mb4_czech_ci | utf8mb4 | 234 | | Yes | 8 | PAD SPACE |
| utf8mb4_danish_ci | utf8mb4 | 235 | | Yes | 8 | PAD SPACE |

## How to view all available collations for a specific character set

```
SHOW COLLATION LIKE 'utf8mb4%'
```

## How to view the default character set for a server

```
SHOW VARIABLES LIKE 'character_set_server'
```

## How to view the default collation for a server

```
SHOW VARIABLES LIKE 'collation_server'
```

## How to view the default character set for a database

```
SHOW VARIABLES LIKE 'character_set_database'
```

## How to view the default collation for a database

```
SHOW VARIABLES LIKE 'collation_database'
```

## How to view the character set and collation for all the tables in a database

```
SELECT table_name, table_collation
FROM information_schema.tables
WHERE table_schema = 'ap'
```

| TABLE_NAME | TABLE_COLLATION |
|---|---|
| invoice_line_items | utf8mb4_0900_ai_ci |
| invoices | utf8mb4_0900_ai_ci |
| terms | utf8mb4_0900_ai_ci |

Figure 11-14 How to view character sets and collations

## How to specify a character set and a collation

Figure 11-15 shows how to specify a character set and a collation at three levels: database, table, and column. In most cases, you want to specify the character set and collation at the database level as shown in the first group of examples. Then, all the columns in all of the tables that store string data are defined with that character set and collation. If necessary, though, you can also set the character set and collation at the table or column level as shown by the second and third groups of examples.

To specify a character set or collation, you can use the CHARSET or COLLATE clauses. For a new database or table, you can add these clauses to the CREATE statement for the database or table. For an existing database or table, you can add these clauses to the ALTER statement for the database or table.

Most of the examples in this figure use both the CHARSET and COLLATE clauses. This clearly shows the character set and collation that are being specified. In most cases, though, you only need to use one clause or the other. That's because every character set has a default collation, and every collation has a corresponding character set. As a result, if you omit the COLLATE clause, MySQL uses the default collation for the specified character set. And, if you omit the CHARSET clause, MySQL uses the character set that corresponds to the specified collation. If you want to use a collation other than the default for a character set, then, you can do that by coding the COLLATE clause without the CHARSET clause.

You can also use MySQL Workbench to change the character set and collation for a table or column. To do that, you use the Columns tab that you saw in figure 11-10. To change the character set and collation for a table, you use the Charset and Collation drop-down lists at the top of this tab. To change the character set and collation for a column, you select the column and then use the Charset and Collation drop-down lists below the list of columns.

### The clauses used to specify a character set and collation

```
[CHARSET character_set] [COLLATE collation]
```

### How to specify a character set and collation at the database level

#### For a new database

```
CREATE DATABASE ar CHARSET latin1 COLLATE latin1_general_ci
```

#### For an existing database

```
ALTER DATABASE ar CHARSET utf8mb4 COLLATE utf8mb4_0900_ai_ci
```

#### For an existing database using the CHARSET clause only

```
ALTER DATABASE ar CHARSET utf8mb4
```

#### For an existing database using the COLLATE clause only

```
ALTER DATABASE ar COLLATE utf8mb4_0900_ai_ci
```

### How to specify a character set and collation at the table level

#### For a new table

```
CREATE TABLE employees
(
  emp_id      INT            PRIMARY KEY,
  emp_name    VARCHAR(25)
)
CHARSET latin1 COLLATE latin1_general_ci
```

#### For an existing table

```
ALTER TABLE employees
CHARSET utf8mb4 COLLATE utf8mb4_0900_ai_ci
```

### How to specify a character set and collation at the column level

#### For a column in a new table

```
CREATE TABLE employees
(
  emp_id      INT            PRIMARY KEY,
  emp_name    VARCHAR(25)    CHARSET latin1 COLLATE latin1_general_ci
)
```

#### For a column in an existing table

```
ALTER TABLE employees
MODIFY emp_name VARCHAR(25) CHARSET utf8mb4 COLLATE utf8mb4_0900_ai_ci
```

### Description

- You can use the CHARSET and COLLATE clauses to set the character set and collation at the database, table, or column level.
- If you omit the CHARSET clause, MySQL uses the character set that corresponds to the specified collation.
- If you omit the COLLATE clause, MySQL uses the default collation for the specified character set.
- The CHARACTER SET keywords are a synonym for the CHARSET keyword.

Figure 11-15 How to specify a character set and a collation

# How to work with storage engines

A *storage engine* determines how MySQL stores data and which database features are available to you. Unlike many other databases, MySQL provides several different storage engines that you can use, and each of these engines provides slightly different features.

## An introduction to storage engines

Figure 11-16 begins by presenting two storage engines: InnoDB and MyISAM. The InnoDB engine is the default engine for MySQL 5.5 and later. As a result, if you installed the software as described in appendix A or B of this book, you have been using the InnoDB engine so far. This engine supports foreign keys as described earlier in this chapter. In addition, it supports transactions, save points, and row-level locking, which are described in chapter 14.

Prior to MySQL 5.5, the MyISAM engine was the default storage engine. As a result, if you ever work on an older MySQL database, there's a good chance its tables use the MyISAM engine. This engine supports some features that weren't supported by InnoDB tables until later releases of MySQL, including full-text searches and spatial data types. However, the MyISAM engine doesn't support foreign keys for maintaining referential integrity. Although you can still code foreign key constraints to show the relationships between tables, MySQL doesn't enforce these relationships.

Although this book doesn't cover the full-text search feature, you should know that this feature uses a special type of index that makes it easier and faster to search string data using natural language search strings.

## How to view storage engines

Figure 11-16 also shows how to view information about storage engines. To start, it shows how to use the SHOW ENGINES statement to view all available storage engines for the current server. In this figure, for example, the result set shows that the InnoDB storage engine is the default storage engine for the server. In addition, it shows that several other storage engines are available to the server.

If you want to quickly view the default storage engine for the server, you can use the SHOW VARIABLES statement shown in this figure. This statement returns a single row that includes the name of the default storage engine.

If you want to view the storage engine that's used for all the tables in a database, you can use a SELECT statement to query the tables in the Information_Schema database as shown in the last example. Here, the SELECT statement displays the table name and storage engine for the tables in the AP database. You can also display this information for all tables on the server by removing the WHERE clause from this SELECT statement.

## Two storage engines provided by MySQL

| Name | Description |
|---|---|
| InnoDB | The default storage engine for MySQL 5.5 and later. This engine supports foreign keys, transactions, save points, and row-level locking. |
| MyISAM | The default storage engine prior to MySQL 5.5. |

## How to view all storage engines for a server

```
SHOW ENGINES
```

| Engine | Support | Comment | Transactions | XA | Savepoints |
|---|---|---|---|---|---|
| MEMORY | YES | Hash based, stored in memory, useful for temp... | NO | NO | NO |
| MRG_MYISAM | YES | Collection of identical MyISAM tables | NO | NO | NO |
| CSV | YES | CSV storage engine | NO | NO | NO |
| FEDERATED | NO | Federated MySQL storage engine | NULL | NULL | NULL |
| PERFORMANCE_SCHEMA | YES | Performance Schema | NO | NO | NO |
| MyISAM | YES | MyISAM storage engine | NO | NO | NO |
| InnoDB | DEFAULT | Supports transactions, row-level locking, and fo... | YES | YES | YES |
| ndbinfo | NO | MySQL Cluster system information storage engine | NULL | NULL | NULL |
| BLACKHOLE | YES | /dev/null storage engine (anything you write to ... | NO | NO | NO |
| ARCHIVE | YES | Archive storage engine | NO | NO | NO |
| ndbcluster | NO | Clustered, fault-tolerant tables | NULL | NULL | NULL |

## How to view the default storage engine for a server

```
SHOW VARIABLES LIKE 'default_storage_engine'
```

## How to view the storage engine for all the tables in a database

```
SELECT table_name, engine
FROM information_schema.tables
WHERE table_schema = 'ap'
```

| TABLE_NAME | ENGINE |
|---|---|
| invoice_line_items | InnoDB |
| invoices | InnoDB |
| terms | InnoDB |

## Description

- The *storage engine* determines how MySQL stores data and which database features are available to you.
- You can use multiple storage engines on the same server and within the same database.

Figure 11-16 How to view storage engines

## How to specify a storage engine

If you don't specify a storage engine when you create your tables, MySQL uses the default storage engine for the server. However, if the default storage engine doesn't provide the features that you want, you can use the ENGINE clause to change the storage engine for the tables that you create. To create a table that uses the MyISAM engine, for example, you can code a CREATE TABLE statement that uses the ENGINE clause as shown in the first example of figure 11-17.

You can also use the ENGINE clause on the ALTER TABLE statement to change the storage engine that an existing table uses as shown in the second example. You might want to do that for older tables that use the MyISAM storage engine so you can take advantage of the foreign key features provided by the InnoDB storage engine. When you change the storage engine for an existing table, you should know that it can take MySQL a significant amount of time to rebuild the table. In addition, the table can't be accessed while this is happening. As a result, you shouldn't attempt to change the storage engine on a production database unless you are ready to stop all applications from accessing the database while MySQL rebuilds the table.

You can also change the storage engine for a table from MySQL Workbench. To do that, you use the Columns tab shown in figure 11-10. Then, you use the Engine drop-down list to choose a storage engine.

If you find that you are often using a storage engine that's different than the default engine for your server, you can change the default storage engine for the current session. To do that, you can code a SET SESSION statement to set the default_storage_engine variable for the current session. Since that only changes the storage engine for the current session, you may want to change the storage engine permanently. To do that, though, you need to modify the configuration file for the server as shown in chapter 17.

### The clause used to specify a storage engine

```
ENGINE = engine_name
```

### How to specify a storage engine for a table

#### For a new table

```
CREATE TABLE product_descriptions
(
  product_id              INT             PRIMARY KEY,
  product_description     VARCHAR(200)
)
ENGINE = MyISAM
```

#### For an existing table

```
ALTER TABLE product_descriptions ENGINE = InnoDB
```

### How to set the default storage engine for the current session

```
SET SESSION default_storage_engine = InnoDB
```

### Description

- To specify a storage engine for a table, you can use the ENGINE clause.
- To change the default storage engine for the current session, you can use the SET SESSION statement to set the storage_engine variable for the current session.
- To permanently change the default storage engine for a server, you can modify the configuration file for the server. For more information about how to do this, see chapter 17.

Figure 11-17 How to specify a storage engine

# Perspective

Now that you've completed this chapter, you should be able to create and modify the tables of a database by coding DDL statements. In addition, you should be able to use MySQL Workbench's graphical interface to work with the tables of a database.

Before you move on, though, take a moment to consider the advantages and disadvantages of using MySQL Workbench to work with database objects. The advantage, of course, is that MySQL Workbench provides a graphical user interface that makes it easy to view and work with database objects. The disadvantage is that no record is kept of any changes that you make to the database. For example, if you add a column to a table, that change isn't stored anywhere for future use.

In contrast, if you use a script to add a column to a table, that change is stored for future use. This makes it easy to recreate the database if you ever need to do that. That's why it's common to use scripts to make any changes to the structure of a database. On the other hand, MySQL Workbench is an excellent tool for quickly viewing the objects of a database or for quickly creating temporary tables or other objects that won't need to be recreated later.

## Terms

attribute
constraint
column-level constraint
table-level constraint
not null constraint
unique constraint
primary key constraint
foreign key constraint
reference constraint
cascading delete
index
script
character set
collation
case-insensitive collation
case-sensitive collation
accent-insensitive collation
accent-sensitive collation
binary collation
storage engine

## Exercises

1. Write a script that adds an index to the AP database for the zip code field in the Vendors table.
2. Write a script that contains the CREATE TABLE statements needed to implement the following design in the EX database:


   These tables provide for members of an association, and each member can be registered in one or more committees within the association.

   The member_id and committee_id columns are the primary keys of the Members and Committees tables, and these columns are foreign keys in the Members_Committees table.

   Include any constraints or default values that you think are necessary.

   Include statements to drop the tables if they already exist.
3. Write INSERT statements that add rows to the tables that are created in exercise 2. Use any data that you like.

   Add two rows to the Members table for the first two member IDs.

   Add two rows to the Committees table for the first two committee IDs.

   Add three rows to the Members_Committees table: one row for member 1 and committee 2; one for member 2 and committee 1; and one for member 2 and committee 2.

   Write a SELECT statement that joins the three tables and retrieves the committee name, member last name, and member first name. Sort the results by the committee name, member last name, and member first name.
4. Write an ALTER TABLE statement that adds two new columns to the Members table created in exercise 2.

   Add one column for annual dues that provides for three digits to the left of the decimal point and two to the right. This column should have a default value of 52.50.

   Add one column for the payment date.
5. Write an ALTER TABLE statement that modifies the Committees table created in exercise 2 so the committee name in each row has to be unique. Then, use an INSERT statement to attempt to insert a duplicate name. This statement should fail due to the unique constraint.

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# How to create views

As you've seen throughout this book, SELECT queries can be complicated, particularly if they use multiple joins, subqueries, or complex functions. Because of that, you may want to save the queries you use regularly. One way to do that is to store the statement in a script. Another way is to create a view.

Unlike scripts, which are stored in files, views are stored as part of the database. As a result, they can be used by both SQL programmers and applications that have access to the database. This provides some advantages over querying tables directly.

# An introduction to views

Before you learn the details for working with views, it's helpful to get a general idea of how views work. In addition, it's helpful to consider some of the benefits of views so you can determine whether you want to use them.

## How views work

A *view* is a SELECT statement that's stored in the database as a database object. To create a view, you use a CREATE VIEW statement like the one shown in figure 12-1. This statement creates a view named Vendors_Min that retrieves the vendor_name, vendor_state, and vendor_phone columns from the Vendors table.

You can think of a view as a virtual table that consists only of the rows and columns specified in its CREATE VIEW statement. The table or tables that are listed in the FROM clause are called the *base tables* for the view. Since the view refers back to the base tables, it doesn't store any data itself, and it always reflects the most current data in the base tables.

To use a view, you refer to it from another SQL statement. In this figure, for example, the SELECT statement uses the Vendors_Min view in the FROM clause instead of a table. As a result, this SELECT statement extracts its result set from the virtual table that the view represents. In this case, all the rows for vendors in California are retrieved from the view.

When you create a view like the one in this figure, the view is updatable. As a result, it's possible to use the view in an INSERT, UPDATE, or DELETE statement. In this figure, for example, the UPDATE statement uses the Vendors_Min view to update the vendor_phone column in the Vendors table for the specified vendor.

To drop a view, you can use the DROP VIEW statement as shown in this figure. This works similarly to the DROP statements for tables and indexes that you learned about in the previous chapter.

Because a view is stored as an object in a database, it can be used by anyone who has appropriate privileges. That may include users who have access to the database through applications that provide for ad hoc queries and report generation. In addition, that may include custom applications that are written specifically to work with the data in the database. In fact, views are often designed to be used with these types of applications.

## A CREATE VIEW statement for a view named Vendors_Min

```
CREATE VIEW vendors_min AS
  SELECT vendor_name, vendor_state, vendor_phone
  FROM vendors
```

### The virtual table that's represented by the view

| vendor_name | vendor_state | vendor_phone |
|---|---|---|
| US Postal Service | WI | (800) 555-1205 |
| National Information Data Ctr | DC | (301) 555-8950 |
| Register of Copyrights | DC | NULL |
| Jobtrak | CA | (800) 555-8725 |
| Newbrige Book Clubs | NJ | (800) 555-9980 |

```
(122 rows)
```

## A SELECT statement that uses the Vendors_Min view

```
SELECT * FROM vendors_min
WHERE vendor_state = 'CA'
ORDER BY vendor_name
```

### The result set that's returned by the SELECT statement

| vendor_name | vendor_state | vendor_phone |
|---|---|---|
| Abbey Office Furnishings | CA | (559) 555-8300 |
| American Express | CA | (800) 555-3344 |
| ASC Signs | CA | NULL |
| Aztek Label | CA | (714) 555-9000 |
| Bertelsmann Industry Svcs. Inc | CA | (805) 555-0584 |
| BFI Industries | CA | (559) 555-1551 |

```
(75 rows)
```

## An UPDATE statement that uses a view to update the base table

```
UPDATE vendors_min
SET vendor_phone = '(800) 555-3941'
WHERE vendor_name = 'Register of Copyrights'
```

## A statement that drops a view

```
DROP VIEW vendors_min
```

## Description

- A *view* consists of a SELECT statement that's stored as an object in the database. The tables referenced in the SELECT statement are called the *base tables* for the view.
- When you create a view, you can refer to the view anywhere you would normally use a table in a SELECT, INSERT, UPDATE, or DELETE statement.
- Although a view behaves like a virtual table, it doesn't store any data. Instead, a view always refers back to its base tables.
- A view can also be referred to as a *viewed table* because it provides a view to the underlying base tables.

Figure 12-1 How views work

## Benefits of using views

Figure 12-2 describes some of the advantages of using views. To start, you can use views to limit the exposure of the tables in your database to external users and applications. To illustrate, suppose a view refers to a table that you've decided to divide into two tables. To accommodate this change, you simply modify the view. In other words, you don't have to modify any statements that refer to the view. That means that users who query the database using the view don't have to be aware of the change in the database structure, and application programs that use the view don't have to be modified.

You can also use views to restrict access to the data in a database. To do that, you create a view that includes just the columns and rows you want a user or an application to have access to. Then, you let the user or application access the data only through the views. For example, let's assume you have an Employees table that has a salary column that contains information about each employee's salary. In this case, you can create a view that doesn't include the salary column for the users who need to view and maintain this table, but who shouldn't be able to view salaries. Then, you can create another view that includes the salary column for the users who need to view and maintain salary information.

In addition, you can use views to hide the complexity of a SELECT statement. For example, if you have a long and unwieldy SELECT statement that joins multiple tables, you can create a view for that statement. This makes it easier for you and other database users to work with this data.

Finally, when you create a view, you can allow data in the base table to be updated through the view. To do that, you use INSERT, UPDATE, or DELETE statements to work with the view.

## Some of the benefits provided by views

| Benefit | Description |
|---|---|
| Design independence | Views can limit the exposure of tables to external users and applications. As a result, if the design of the tables changes, you can modify the view as necessary so users who query the view don't need to be aware of the change, and applications that use the view don't need to be modified. |
| Data security | Views can restrict access to the data in a table by using the SELECT clause to include only selected columns of a table or by using the WHERE clause to include only selected rows in a table. |
| Simplified queries | Views can be used to hide the complexity of retrieval operations. Then, the data can be retrieved using simple SELECT statements that specify a view in the FROM clause. |
| Updatability | With certain restrictions, views can be used to update, insert, and delete data from a base table. |

## Description

- You can create a view based on almost any SELECT statement. That means that you can code views that join tables, summarize data, and use subqueries and functions.

Figure 12-2 Benefits of using views

# How to work with views

Now that you have a general understanding of how views work and of the benefits that they provide, you're ready to learn the details for working with them.

## How to create a view

Figure 12-3 presents the CREATE VIEW statement that you use to create a view. In its simplest form, you code the CREATE VIEW keywords, followed by the name of the view, followed by the AS keyword and the SELECT statement that defines the view. In this figure, for instance, the first statement creates a view named Vendors_Phone_List. This view includes four columns from the Vendors table for all vendors with invoices.

If you execute the first CREATE VIEW statement and a view with that name doesn't already exist in the current database, MySQL adds the view and displays a message to indicate that the statement was successful. However, if a view with this name already exists, MySQL doesn't add the view and displays a message that indicates that the name is already in use. In that case, you need to specify a new name for the view, or you need to drop the view that's already using that name.

When you code a CREATE VIEW statement, you can specify that you want to automatically drop a view that has the same name as the view that you're creating. To do that, you can specify the OR REPLACE keywords after the CREATE keyword as shown in all of the examples in this figure except for the first.

The SELECT statement for a view can use most of the features of a normal SELECT statement. In this figure, for instance, the second example creates a view that joins data from two tables. Similarly, the third statement creates a view that uses a LIMIT clause.

By default, the columns in a view are given the same names as the columns in the base tables. If a view contains a calculated column, however, you'll want to name that column just as you do in other SELECT statements. In addition, you'll need to rename columns from different tables that have the same name. To do that, you can code the column names in the CREATE VIEW clause as shown in the fourth example. Or, you can use the AS clause in the SELECT statement as shown in the fifth example.

Note that if you use the technique shown in the fourth example, you have to assign names to all of the columns. By contrast, if you use the technique shown in the fifth example, you only have to assign names to the columns you need to rename. As a result, you'll typically want to use the technique presented in the fifth example.

## The syntax of the CREATE VIEW statement

```
CREATE [OR REPLACE] VIEW view_name
  [(column_alias_1[, column_alias_2]...)]
AS
  select_statement
  [WITH CHECK OPTION]
```

## A view of vendors that have invoices

```
CREATE VIEW vendors_phone_list AS
  SELECT vendor_name, vendor_contact_last_name,
         vendor_contact_first_name, vendor_phone
  FROM vendors
  WHERE vendor_id IN (SELECT DISTINCT vendor_id FROM invoices)
```

## A view that uses a join

```
CREATE OR REPLACE VIEW vendor_invoices AS
  SELECT vendor_name, invoice_number, invoice_date, invoice_total
  FROM vendors
    JOIN invoices ON vendors.vendor_id = invoices.vendor_id
```

## A view that uses a LIMIT clause

```
CREATE OR REPLACE VIEW top5_invoice_totals AS
  SELECT vendor_id, invoice_total
  FROM invoices
  ORDER BY invoice_total DESC
  LIMIT 5
```

## A view that names all of its columns in the CREATE VIEW clause

```
CREATE OR REPLACE VIEW invoices_outstanding
  (invoice_number, invoice_date, invoice_total, balance_due)
AS
  SELECT invoice_number, invoice_date, invoice_total,
         invoice_total - payment_total - credit_total
  FROM invoices
  WHERE invoice_total - payment_total - credit_total > 0
```

## A view that names just the calculated column in its SELECT clause

```
CREATE OR REPLACE VIEW invoices_outstanding AS
  SELECT invoice_number, invoice_date, invoice_total,
         invoice_total - payment_total - credit_total AS balance_due
  FROM invoices
  WHERE invoice_total - payment_total - credit_total > 0
```

Figure 12-3 How to create a view (part 1 of 2)

The example in part 2 of figure 12-3 creates a view that summarizes the rows in the Invoices table by vendor. This shows that a view can use aggregate functions and the GROUP BY clause to summarize data. In this case, the rows are grouped by vendor name, and a count of the invoices and the invoice total are calculated for each vendor.

When you create a view, the SELECT statement you code within the definition of the view can refer to another view instead of a base table. In other words, views can be *nested*. In theory, *nested views* can make it easier to present data to your users. In practice, using nested views can make the dependencies between tables and views confusing, which can make your code difficult to maintain. As a result, if you use nested views, you should use them carefully.

### A view that summarizes invoices by vendor

```
CREATE OR REPLACE VIEW invoice_summary AS
  SELECT vendor_name,
    COUNT(*) AS invoice_count,
    SUM(invoice_total) AS invoice_total_sum
  FROM vendors
    JOIN invoices ON vendors.vendor_id = invoices.vendor_id
  GROUP BY vendor_name
```

### Description

- You use the CREATE VIEW statement to create a view.
- If you include the OR REPLACE keywords, the CREATE VIEW statement will replace any existing view that has the same name. Otherwise, you must specify a name that doesn't already exist for the view.
- If you name the columns of a view in the CREATE VIEW clause, you have to name all of the columns. By contrast, if you name the columns in the SELECT clause, you can name just the columns you need to rename.
- You can create a view that's based on another view rather than on a table. This is known as a *nested view*.

Figure 12-3 How to create a view (part 2 of 2)

## How to create an updatable view

Once you create a view, you can refer to it in a SELECT statement. In addition, you may be able to refer to it in INSERT, UPDATE, and DELETE statements to modify the data that's stored in an underlying table. To do that, the view must be updatable. Figure 12-4 lists the requirements for creating *updatable views*.

The first two requirements have to do with what you can code in the select list of the SELECT statement that defines the view. In particular, the select list can't include the DISTINCT keyword or aggregate functions. In addition, the SELECT statement can't include a GROUP BY or HAVING clause, and you can't join two SELECT statements using a union operation.

The CREATE VIEW statement in this figure creates a view that's updatable. As a result, you can refer to it in an INSERT, UPDATE, or DELETE statement. For example, you can use the first UPDATE statement shown in this figure to update the credit_total column in the Invoices base table. Note that to execute this statement in MySQL Workbench, you will need to turn safe update mode off as described in chapter 5, since the WHERE clause doesn't refer to a primary or foreign key.

However, you can't update any calculated columns that are used by the view. For example, you can't use the second UPDATE statement shown in this figure to update the balance_due column that's calculated from the other columns in the view.

In addition, when you update data through a view, you can only update the data in a single base table at a time, even if the view refers to two or more tables. In this figure, for instance, the view includes data from two base tables: Vendors and Invoices. Because of that, you can code an UPDATE statement that updates the data in the Vendors table or the data in the Invoices table, but not in both tables at once. For example, the first UPDATE statement only refers to columns in the Invoices table, so it's able to update data in that table.

### Requirements for creating updatable views

- The select list can't include a DISTINCT clause.
- The select list can't include aggregate functions.
- The SELECT statement can't include a GROUP BY or HAVING clause.
- The view can't include the UNION operator.

### A CREATE VIEW statement that creates an updatable view

```
CREATE OR REPLACE VIEW balance_due_view AS
  SELECT vendor_name, invoice_number,
         invoice_total, payment_total, credit_total,
         invoice_total - payment_total - credit_total AS balance_due
  FROM vendors JOIN invoices ON vendors.vendor_id = invoices.vendor_id
  WHERE invoice_total - payment_total - credit_total > 0
```

### An UPDATE statement that uses the view to update data

```
UPDATE balance_due_view
SET credit_total = 300
WHERE invoice_number = '9982771'
```

#### The response from the system

```
(1 row affected)
```

### An UPDATE statement that attempts to use the view to update a calculated column

```
UPDATE balance_due_view
SET balance_due = 0
WHERE invoice_number = '9982771'
```

#### The response from the system

```
Error Code: 1348. Column 'balance_due' is not updatable
```

### Description

- An *updatable view* is a view that can be used in an INSERT, UPDATE, or DELETE statement to update the data in the base table. If a view isn't updatable, it's called a *read-only view*.
- The requirements for coding updatable views are more restrictive than for coding read-only views. That's because MySQL must be able to unambiguously determine which base tables and columns are affected.

### Note

- If you try running these UPDATE statements and get an error that says "You are using safe update mode…", you can turn off safe update mode. To do that, select Edit→Preferences, select the SQL Editor node, uncheck "Safe Updates", and restart MySQL Workbench.

Figure 12-4 How to create an updatable view

## How to use the WITH CHECK OPTION clause

Figure 12-5 shows an example of an updatable view that uses the WITH CHECK OPTION clause to prevent an update if it causes the row to be excluded from the view. To start, the CREATE VIEW statement creates an updatable view named Vendor_Payment that joins data from the Vendors and Invoices tables and retrieves all invoices that have a balance due that's greater than or equal to zero.

Then, the first UPDATE statement uses this view to modify the payment_date and payment_total columns for a specific invoice. This works because this UPDATE statement doesn't exclude the row from the view.

However, the second UPDATE statement causes the balance due to become less than zero. As a result, this statement fails due to the WITH CHECK OPTION clause, and an error is displayed. Since this can prevent users from storing invalid data in a database, this clause can be useful in some situations.

## An updatable view that has a WITH CHECK OPTION clause

```
CREATE OR REPLACE VIEW vendor_payment AS
  SELECT vendor_name, invoice_number, invoice_date, payment_date,
         invoice_total, credit_total, payment_total
  FROM vendors JOIN invoices ON vendors.vendor_id = invoices.vendor_id
  WHERE invoice_total - payment_total - credit_total >= 0
WITH CHECK OPTION
```

## A SELECT statement that displays a row from the view

```
SELECT * FROM vendor_payment
WHERE invoice_number = 'P-0608'
```

### The result set

| vendor_name | invoice_number | invoice_date | payment_date | invoice_total | credit_total | payment_total |
|---|---|---|---|---|---|---|
| Malloy Lithographing Inc | P-0608 | 2022-07-23 | NULL | 20551.18 | 1200.00 | 0.00 |

## An UPDATE statement that updates the view

```
UPDATE vendor_payment
SET payment_total = 400.00,
    payment_date = '2022-08-01'
WHERE invoice_number = 'P-0608'
```

### The response from the system

```
(1 row affected)
```

### The same row data after the update

| vendor_name | invoice_number | invoice_date | payment_date | invoice_total | credit_total | payment_total |
|---|---|---|---|---|---|---|
| Malloy Lithographing Inc | P-0608 | 2022-07-23 | 2022-08-01 | 20551.18 | 1200.00 | 400.00 |

## An UPDATE statement that attempts to update the view

```
UPDATE vendor_payment
SET payment_total = 30000.00,
    payment_date = '2022-08-01'
WHERE invoice_number = 'P-0608';
```

### The response from the system

```
Error Code: 1369. CHECK OPTION failed 'ap.vendor_payment'
```

## Description

- If you don't include a WITH CHECK OPTION clause when you create a view, a change you make through the view can cause the modified rows to no longer be included in the view.
- If you specify a WITH CHECK OPTION clause when you create a view, an error will occur if you try to modify a row in such a way that it would no longer be included in the view.

Figure 12-5 How to use the WITH CHECK OPTION clause

## How to insert or delete rows through a view

In the previous figures, you learned how to use a view to update data in the underlying tables. Now, figure 12-6 shows how to use a view to insert or delete data in an underlying table. In general, this works the same as it does when you work directly with a table. However, due to table constraints, using a view to insert or delete rows often results in errors like the ones shown in this figure. As a result, it's generally more common to work directly with base tables when inserting or deleting rows.

At the top of this figure, you can see a CREATE VIEW statement for a view named ibm_invoices. This view retrieves columns and rows from the Invoices table for the vendor named IBM, which has a vendor_id of 34. Then, the INSERT statement that follows attempts to insert a row into the Invoices table through this view.

This insert operation fails, though, because the view and the INSERT statement don't include all of the required columns for the Invoices table. In this case, a value is required for other columns in the Invoices table, including the vendor_id and invoice_due_date columns. As a result, to use a view to insert rows, you must design a view that includes all required columns for the underlying table.

In addition, an INSERT statement that uses a view can insert rows into only one table at a time. That's true even if the view is based on two or more tables and all of the required columns for those tables are included in the view. In that case, you could use separate INSERT statements to insert rows into each table through the view.

This figure also shows how to delete rows through a view. To do that, you use a DELETE statement like the ones shown here. To start, the first DELETE statement attempts to delete an invoice from the Invoices table through the ibm_invoices view. However, this DELETE statement fails because the Invoice_Line_Items table contains rows related to the invoice. This causes an error message like the one in this figure to be displayed. To get this DELETE statement to work, you must first delete the related line items for the invoice. This is illustrated by the last two DELETE statements in this figure.

### A statement that creates an updatable view

```
CREATE OR REPLACE VIEW ibm_invoices AS
  SELECT invoice_number, invoice_date, invoice_total
  FROM invoices
  WHERE vendor_id = 34
```

### The contents of the view

| invoice_number | invoice_date | invoice_total |
|---|---|---|
| QP58872 | 2022-05-07 | 116.54 |
| Q545443 | 2022-06-09 | 1083.58 |

### An INSERT statement that fails

```
INSERT INTO ibm_invoices
  (invoice_number, invoice_date, invoice_total)
VALUES
  ('RA23988', '2022-07-31', 417.34)
```

#### The response from the system

```
Error Code: 1423. Field of view 'ap.ibm_invoices' underlying table doesn't
have a default value
```

### A DELETE statement that fails

```
DELETE FROM ibm_invoices
WHERE invoice_number = 'Q545443'
```

#### The response from the system

```
Error Code: 1451. Cannot delete or update a parent row: a foreign key
constraint fails ('ap'.'invoice_line_items', CONSTRAINT
'line_items_fk_invoices' FOREIGN KEY ('invoice_id') REFERENCES 'invoices'
('invoice_id'))
```

### Two DELETE statements that succeed

```
DELETE FROM invoice_line_items
WHERE invoice_id = (SELECT invoice_id FROM invoices
                    WHERE invoice_number = 'Q545443');

DELETE FROM ibm_invoices
WHERE invoice_number = 'Q545443';
```

#### The response from the system

```
(1 row affected)
```

### Description

- You can use the INSERT statement to insert rows into a base table through a view only if the view includes all of the columns required by the base table.
- If the view names more than one base table, an INSERT statement can insert data into only one of those tables.
- You can use the DELETE statement to delete rows from a base table through a view. For this to work, the view must be based on a single table.

Figure 12-6 How to insert or delete rows through a view

## How to alter or drop a view

Although MySQL supports an ALTER VIEW statement, it's usually easier to alter a view by using the CREATE OR REPLACE VIEW statement to replace the existing view with a new one. In figure 12-7, for instance, the first example uses a CREATE VIEW statement to create a view named vendors_sw that retrieves rows from the Vendors table for vendors located in four states. Then, the second example uses the CREATE OR REPLACE VIEW statement to modify this view so it includes vendors in two additional states.

To drop a view, you use the DROP VIEW statement to name the view you want to drop. In this figure, for instance, the third example drops the view named vendors_sw. Like the other statements for dropping database objects, this statement permanently deletes the view. As a result, you should be careful when you use it.

When writing scripts, it's often helpful to check whether a view exists before dropping it. To do that, you can add the IF EXISTS keywords to the DROP VIEW statement as shown in the fourth example. That way, if the view doesn't exist, the statement generates a warning instead of an error. This allows a script to continue executing instead of being stopped.

### A statement that creates a view

```
CREATE VIEW vendors_sw AS
SELECT *
FROM vendors
WHERE vendor_state IN ('CA','AZ','NV','NM')
```

### A statement that replaces the view with a new view

```
CREATE OR REPLACE VIEW vendors_sw AS
SELECT *
FROM vendors
WHERE vendor_state IN ('CA','AZ','NV','NM','UT','CO')
```

### A statement that drops the view

```
DROP VIEW vendors_sw
```

### A statement that drops the view only if it exists

```
DROP VIEW IF EXISTS vendors_sw
```

### Description

- To alter a view, you can use the CREATE OR REPLACE VIEW statement to replace the existing view with a new one.
- You can also use the ALTER VIEW statement to alter a view, but if the view doesn't exist, an error will occur. The syntax of the ALTER VIEW statement is the same as the syntax of the CREATE OR REPLACE VIEW statement.
- To delete a view from the database, you can use the DROP VIEW statement.

Figure 12-7 How to alter or drop a view

# Perspective

In this chapter, you learned how to create and use views. As you've seen, views provide a powerful and flexible way to predefine the data that can be retrieved from a database. By using them, you can restrict the access to a database while providing a consistent and simplified way for end users and application programs to access that data.

## Terms

view
base table
viewed table
nested view
updatable view
read-only view

## Exercises

1. Create a view named open_items that shows the invoices that haven't been paid.

   This view should return four columns from the Vendors and Invoices tables:

   vendor_name, invoice_number, invoice_total, and balance_due (invoice_total - payment_total - credit_total)

   A row should only be returned when the balance due is greater than zero, and the rows should be in sequence by vendor_name.

2. Write a SELECT statement that returns all of the columns in the open_items view that you created in exercise 1, with one row for each invoice that has a balance due of $1000 or more.

3. Create a view named open_items_summary that returns one summary row for each vendor that has invoices that haven't been paid.

   Each row should include vendor_name, open_item_count (the number of invoices with a balance due), and open_item_total (the total of the balance due amounts).

   The rows should be sorted by the open item totals in descending sequence.

4. Write a SELECT statement that returns just the first 5 rows from the open_items_summary view that you created in exercise 3.

5. Create an updatable view named vendor_address that returns the vendor_id column and all of the address columns for each vendor.

6. Write an UPDATE statement that changes the address for the row with a vendor ID of 4 so the suite number (Ste 260) is stored in the vendor_address2 column instead of the vendor_address1 column.

# Section 4

## Stored program development

This section presents the essential skills for using MySQL to create stored programs. These are the skills that will take your SQL capabilities to the next level. In chapter 13, you'll learn the language basics for writing procedural code within stored programs. In chapter 14, you'll learn how to manage transactions and locking from within stored programs. In chapter 15, you'll learn how to create two types of stored programs: stored procedures and functions. And in chapter 16, you'll learn how to create two more types of stored programs: triggers and events.

# 13

# Language skills for writing stored programs

This chapter presents the basic language skills that you need to write stored programs. With the skills presented in this chapter, you'll be able to code stored programs that provide functionality similar to procedural programming languages like Python, PHP, Java, C++, C#, and Visual Basic.

If you have experience with another procedural language, you shouldn't have any trouble with the skills presented in this chapter. However, you should know that the programming power of MySQL is limited when compared to other languages. That's because MySQL is designed specifically to work with MySQL databases rather than as a general-purpose programming language. For its intended use, however, MySQL is both powerful and flexible.

# An introduction to stored programs

MySQL provides for using standard SQL to write *stored programs*. Stored programs can include procedural code that controls the flow of execution.

## Four types of stored programs

Figure 13-1 presents the four types of stored programs that you can create in MySQL. A *stored procedure* can be called from an application that has access to the database. For example, a PHP application can call a stored procedure and pass parameters to it. A *stored function* can be called from a SQL statement, just like the functions provided by MySQL. However, you can customize stored functions so they perform tasks that are specific to your database. Stored procedures and stored functions are similar in many ways and are also known as *stored routines*.

Triggers and events don't need to be called. Instead, they execute automatically when something happens. A *trigger* executes when an INSERT, UPDATE, or DELETE statement is run against a specific table. And an *event* executes at a scheduled time.

## A script that creates and calls a stored procedure

The script shown in figure 13-1 creates a stored procedure named test that doesn't accept any parameters. Then, it calls this procedure to execute the statements that are stored within it. This provides a way for you to experiment with the procedural language features that are available from MySQL. That's why this script is used throughout this chapter.

This script begins with the USE statement, which selects the AP database. Then, the DROP PROCEDURE IF EXISTS command drops the procedure named test if it already exists. This suppresses any error messages that would be displayed if you attempted to drop a procedure that didn't exist.

The DELIMITER statement changes the delimiter that identifies the end of a statement from the default of the semicolon (;) to two slashes (//). This is necessary because the semicolon is used within the CREATE PROCEDURE statement, and you want MySQL Server to treat the entire stored procedure definition as a single statement. So changing the delimiter to two front slashes (//) allows you to identify the end of the CREATE PROCEDURE statement. It's also common to see two dollar signs ($$) or two semicolons (;;) used as the delimiter.

The CREATE PROCEDURE statement creates the procedure. To indicate that this procedure doesn't accept any parameters, this code includes an empty set of parentheses after the procedure's name.

The code within the CREATE PROCEDURE statement is defined by a *block of code* that begins with the BEGIN keyword and ends with the END keyword. Within this block of code, the DECLARE statement defines a variable named sum_balance_due_var of the DECIMAL type. This data type corresponds to the

## Four types of stored programs

| Type | Description |
|---|---|
| Stored procedure | Can be called from an application that has access to the database. |
| Stored function | Can be called from a SQL statement just like the functions provided by MySQL. |
| Trigger | Is executed in response to an INSERT, UPDATE, or DELETE statement on a specified table. |
| Event | Is executed at a scheduled time. |

## A script that creates and calls a stored procedure named test

```
USE ap;

DROP PROCEDURE IF EXISTS test;

-- Change statement delimiter from semicolon to double front slash
DELIMITER //

CREATE PROCEDURE test()
BEGIN
  DECLARE sum_balance_due_var DECIMAL(9, 2);

  SELECT SUM(invoice_total - payment_total - credit_total)
  INTO sum_balance_due_var
  FROM invoices
  WHERE vendor_id = 95;

  IF sum_balance_due_var > 0 THEN
    SELECT CONCAT('Balance due: $', sum_balance_due_var) AS message;
  ELSE
    SELECT 'Balance paid in full' AS message;
  END IF;
END//

-- Change statement delimiter from double front slash to semicolon
DELIMITER ;

CALL test();
```

## The response from the system

| message |
|---|
| Balance paid in full |

## Description

- A *stored program* consists of one or more SQL statements stored in the database for later use.
- Within a stored program, you can write procedural code that controls the flow of execution. That includes if/else constructs, loops, and error-handling code.

Figure 13-1 An introduction to stored programs data types that are used for the invoice_total, payment_total, and credit_total columns of the Invoices table. Then, a SELECT statement sets the value that's stored in this variable. To do that, the SELECT statement returns a single value and includes an INTO clause that specifies the name of the variable. As a result, the SELECT statement selects the value into the variable.

After the first SELECT statement, the script uses an IF statement to test the value of the variable. If the variable is greater than zero, the statement in the THEN clause uses a SELECT statement to return a result set that indicates the balance that is due. Otherwise, the statement in the ELSE clause uses a SELECT statement to return a result set that indicates that the balance is paid in full.

After the stored procedure has been created, this script uses the DELIMTER statement to change the delimiter back to the default delimiter of a semicolon (;). Then, it uses a CALL statement to call the stored procedure. This executes the code stored within the procedure. You'll learn more about how the CALL statement works in chapter 15.

For now, don't worry if you don't understand the coding details for this script. Instead, focus on the general ideas. Later in this chapter, you'll learn the details that you need to use the procedural language that's provided by MySQL. Then, in chapter 15, you'll learn more about the details of creating stored procedures.

## A summary of statements for coding stored programs

Figure 13-2 begins by summarizing the SQL statements for controlling the flow of execution within stored programs. These statements can be used to add functionality that's similar to the functionality provided by procedural languages.

After the SQL statements for writing procedural code, this figure presents three statements that are commonly used within stored procedures. You saw all three of these statements in the script in the previous figure. When working with stored programs, though, you should know that you can use the SELECT statement to return a result set to the calling program. This is often used to display messages that can help the programmer develop and debug a stored program.

In addition, you can use the SELECT statement with an INTO clause to retrieve data from the database and store it in one or more variables. You saw an example of this in the previous figure, and you'll learn more about how this works as you progress through this chapter.

### SQL statements for controlling the flow of execution

| Keywords | Description |
|---|---|
| `IF...ELSEIF...ELSE` | Controls the flow of execution based on a condition. |
| `CASE...WHEN...ELSE` | Controls the flow of execution based on a condition. |
| `WHILE...DO` | Repeats statements while a condition is true. |
| `REPEAT...UNTIL` | Repeats statements while a condition is true. |
| `LOOP` | Repeats statements until a condition is true. |
| `DECLARE CURSOR FOR` | Defines a result set that can be processed by a loop. |
| `DECLARE...HANDLER` | Defines a handler that's executed when a stored program encounters an error. |

### SQL statements used within stored programs

| Statement | Description |
|---|---|
| `DELIMITER` | Changes the default delimiter so the entire stored program is treated as a single statement. |
| `BEGIN...END` | Defines a statement block. |
| `SELECT` | Returns a result set to the calling program. Or, retrieves data from the database and stores it so it can be processed by the stored program. |

### Description

- MySQL provides statements that can be used within scripts to add functionality similar to that provided by procedural programming languages.

Figure 13-2 A summary of statements for coding stored programs

# How to write procedural code

Now that you have a general idea of how stored programs work, you're ready to learn the details for writing procedural code that's used within stored programs.

## How to display data

As you develop stored programs, you often need to display messages as shown in figure 13-3. This can help you make sure that the stored program is executing correctly, and it can help you debug your programs. To display a message, you can use a SELECT statement. In this figure, for example, the stored procedure uses a SELECT statement to return a result set that contains a single row with a column named message that contains a string that says, "This is a test."

You can also code SELECT statements that display more complex messages. In the next figure, for example, you'll see a stored procedure that uses a SELECT statement that returns a result set with multiple values. Then, the SELECT statement stores those values in variables so the variables can be formatted and displayed.

This figure only shows the DELIMITER statement and the CREATE PROCEDURE statement that are necessary to create the stored procedure. Before you execute these statements, you may need to select the appropriate database and drop any procedure with the same name using the USE and DROP PROCEDURE IF EXISTS statements. And after you execute these statements, you have to use the CALL statement to execute the stored procedure.

### A stored procedure that displays a message

```
DELIMITER //

CREATE PROCEDURE test()
BEGIN
  SELECT 'This is a test.' AS message;
END//
```

### The response from the system when the procedure is called


### Description

- To display a message from a stored program, you can use the SELECT statement to return a result set.

Figure 13-3 How to display data

## How to declare and set variables

A *variable* stores a value that can change as the procedure executes. Figure 13-4 shows how to declare and set variables.

To declare a variable, you code the DECLARE keyword followed by the variable name and data type. In this figure, for example, the stored procedure begins by declaring five variables. The data type for each variable corresponds to the data type that's used for a column that's related to the variable. For example, the first two variables are declared with the DECIMAL type. This is the same data type that's used by the invoice_total column of the Invoices table. The third variable also uses this data type, but with 4 decimal places instead of 2. The last two variables use the INT type, which matches the data type for the invoice_id and vendor_id columns. When specifying the data type for a variable, you can use any of the data types that you can use when you specify the data type for a column.

Once you declare a variable, you can assign a value to it using the SET statement. To assign a literal value or the result of an expression, you can code the assignment operator (=) followed by the literal value or the expression. In the script in this figure, for example, the first SET statement uses the assignment operator to assign a value of 95 to the variable named vendor_id_var. The second SET statement uses the assignment operator to assign the result of a calculation to the variable named percent_difference.

You can also use the DEFAULT keyword to assign a default value to a variable when you declare it. Then, the default value is used if another value isn't assigned to the variable. For this to work, the default value must be a literal value, not an expression. To declare and assign a value to the vendor_id_var variable, for example, you could code a statement like this:

```
DECLARE vendor_id_var INT DEFAULT 95;
```

If you want to assign a value that's returned by a SELECT statement to a variable, you can add an INTO clause to a SELECT statement. In the script in this figure, for example, the first SELECT statement uses the INTO clause to assign the three values that are returned by the SELECT statement to the three corresponding variables that are specified by the INTO clause. For this to work, the SELECT statement must return one value for each of the variables that are specified in the INTO clause. In addition, the data types for the columns must be compatible with the data types for the variables.

To review, the script in this figure uses five variables to calculate the percent difference between the minimum and maximum invoices for a particular vendor. To do that, this script uses the assignment operator to assign a value to two of the variables. In addition, it uses the INTO clause of a SELECT statement to assign values to the other three variables. Finally, a SELECT statement displays the values of four of the variables.

In this figure, the script uses the equal sign (=) as the assignment operator. However, MySQL also allows you to use a colon plus the equal sign (:=) as the assignment operator. So, if you are reviewing another programmer's code, you might see this operator.

### The syntax for declaring a variable

```
DECLARE variable_name data_type [DEFAULT literal_value];
```

### The syntax for setting a variable to a literal value or an expression

```
SET variable_name = {literal_value|expression};
```

### The syntax for setting a variable to a selected value

```
SELECT column_1[, column_2]...
INTO variable_name_1[, variable_name_2]...
```

### A stored procedure that uses variables

```
DELIMITER //

CREATE PROCEDURE test()
BEGIN
  DECLARE max_invoice_total  DECIMAL(9,2);
  DECLARE min_invoice_total  DECIMAL(9,2);
  DECLARE percent_difference DECIMAL(9,4);
  DECLARE count_invoice_id   INT;
  DECLARE vendor_id_var      INT;

  SET vendor_id_var = 95;

  SELECT MAX(invoice_total), MIN(invoice_total), COUNT(invoice_id)
  INTO max_invoice_total, min_invoice_total, count_invoice_id
  FROM invoices WHERE vendor_id = vendor_id_var;

  SET percent_difference = (max_invoice_total - min_invoice_total) /
                            min_invoice_total * 100;

  SELECT CONCAT('$', max_invoice_total) AS 'Maximum invoice',
         CONCAT('$', min_invoice_total) AS 'Minimum invoice',
         CONCAT('%', ROUND(percent_difference, 2)) AS 'Percent difference',
         count_invoice_id AS 'Number of invoices';
END//
```

### The response from the system when the procedure is called

| | Maximum invoice | Minimum invoice | Percent difference | Number of invoices |
|---|---|---|---|---|
| ▸ | $46.21 | $16.33 | %182.98 | 6 |

### Description

- A *variable* stores a value that can change as a stored program executes.
- A variable must have a name that's different from the names of any columns used in any SELECT statement within the stored program. To distinguish a variable from a column, you can add a suffix like "_var" to the variable name.

Figure 13-4 How to declare and set variables

## How to code IF statements

Figure 13-5 shows how to use an IF statement to execute one or more statements based on a value that's returned by a *Boolean expression*. A Boolean expression is an expression that returns a true value or a false value.

The script in this figure uses an IF statement to test the value of a variable. This variable contains the oldest invoice due date in the Invoices table. If this due date is less than the current date, the Boolean expression evaluates to true, and the statement in the IF clause shows that outstanding invoices are overdue. If the value is equal to the current date, the statement in the ELSEIF clause indicates that outstanding invoices are due today. If neither of these conditions is true, the oldest due date must be greater than the current date. As a result, the script indicates that no invoices are overdue.

In this figure, the IF statement only contains one ELSEIF clause. However, you can add as many ELSEIF clauses as you need. As a result, you can code dozens of these clauses if you need them. But if you don't need an ELSEIF clause, you don't have to code one. For example, it's common to code an IF statement without an ELSEIF clause like this:

```
IF first_invoice_due_date < NOW() THEN
  SELECT 'Outstanding invoices are overdue!';
ELSE
  SELECT 'No invoices are overdue.';
END IF;
```

Similarly, the ELSE clause is also optional. As a result, it's common to code an IF statement like this:

```
IF first_invoice_due_date < NOW() THEN
  SELECT 'Outstanding invoices are overdue!';
END IF;
```

You can also *nest* one IF statement within another like this:

```
IF first_invoice_due_date <= NOW() THEN
  SELECT 'Outstanding invoices are overdue!';
  IF first_invoice_due_date = NOW() THEN
    SELECT 'TODAY!';
  END IF;
END IF;
```

In this case, the outer IF statement is executed when the oldest invoice due date is less than or equal to the current date. However, the nested IF statement is only executed when the oldest invoice due date is equal to the current date. In other words, if the current date equals the oldest invoice due date, this code returns two result sets instead of one. As you'll see later in this chapter, you can also nest an IF statement within other types of statements such as loops.

## The syntax of the IF statement

```
IF boolean_expression THEN
  statement_1;
  [statement_2;]...
[ELSEIF boolean_expression THEN
  statement_1;
  [statement_2;]...]...
[ELSE
  statement_1;
  [statement_2;]...]
END IF;
```

## A stored procedure that uses an IF statement

```
DELIMITER //

CREATE PROCEDURE test()
BEGIN
  DECLARE first_invoice_due_date DATE;

  SELECT MIN(invoice_due_date)
  INTO first_invoice_due_date
  FROM invoices
  WHERE invoice_total - payment_total - credit_total > 0;

  IF first_invoice_due_date < NOW() THEN
    SELECT 'Outstanding invoices are overdue!';
  ELSEIF first_invoice_due_date = NOW() THEN
    SELECT 'Outstanding invoices are due today!';
  ELSE
    SELECT 'No invoices are overdue.';
  END IF;
END//
```

## The response from the system when the procedure is called


## Description

- You can use an *IF statement* to execute one or more statements depending on one or more Boolean expressions. A *Boolean expression* is an expression that evaluates to true or false.
- You can *nest* an IF statement within another IF statement or within other SQL statements, such as the statements for coding loops.
- You can code parentheses around the Boolean expressions in an IF statement like this:

```
IF (first_invoice_due_date < NOW()) THEN ...
```

## How to code CASE statements

In chapter 9, you learned how to code a CASE expression within a SELECT statement. A CASE expression like that usually runs faster than a CASE statement that's coded within a stored program. As a result, if you can use a CASE expression to solve the task at hand, you should. However, you may sometimes need to use a CASE statement as shown in figure 13-6.

The script in this figure shows how to use a *simple CASE statement* to execute one or more statements depending on a value that's returned by an expression. To do that, you begin by coding the CASE keyword followed by an expression that returns a value. In this script, the variable that's coded after the CASE statement returns an integer value that indicates the payment terms for an invoice.

After the CASE clause, you can code one or more WHEN clauses that contain the statement or statements that are executed for each of the values that may be returned. In this example, the CASE statement includes three WHEN clauses for the values of 1, 2, and 3. Each of these clauses displays an appropriate message.

After the WHEN clauses, you can code an optional ELSE clause that's executed if the value that's returned doesn't match the values coded in any of the WHEN clauses. This works much like the ELSE clause that's available from the IF statement. Note that if none of the WHEN clause values match the expression and no ELSE clause is coded, the CASE statement will return a "Case not found" error.

Although this figure doesn't show an example of it, you can also use a *searched CASE statement* to execute one or more statements depending on one or more Boolean expressions. This works similarly to an IF statement. For example, you can use a searched CASE statement to replace the IF statement in the previous figure like this:

```
CASE
  WHEN first_invoice_due_date < NOW() THEN
    SELECT ('Outstanding invoices are overdue!');
  WHEN first_invoice_due_date = NOW() THEN
    SELECT ('Outstanding invoices are due today!');
  ELSE
    SELECT ('No invoices are overdue.');
END CASE;
```

Conversely, you can easily rewrite the simple CASE statement shown in this figure as an IF statement.

So, when should you use an IF statement and when should you use a CASE statement? Although this is largely a matter of personal preference, you usually should try to use the statement that yields the code that's easiest to read and understand.

## The syntax of the simple CASE statement

```
CASE expression
  WHEN expression_value_1 THEN
    statement_1;
    [statement_2;]...
  [WHEN expression_value_2 THEN
    statement_1;
    [statement_2;]...]...
  [ELSE
    statement_1;
    [statement_2;]...]
END CASE;
```

## A stored procedure that uses a simple CASE statement

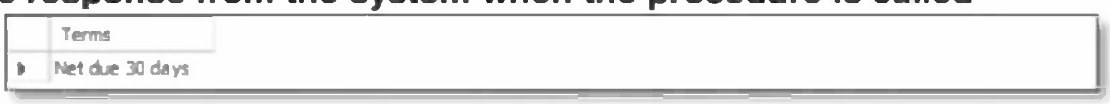
```
DELIMITER //

CREATE PROCEDURE test()
BEGIN
  DECLARE terms_id_var INT;

  SELECT terms_id INTO terms_id_var
  FROM invoices WHERE invoice_id = 4;

  CASE terms_id_var
    WHEN 1 THEN
      SELECT 'Net due 10 days' AS Terms;
    WHEN 2 THEN
      SELECT 'Net due 20 days' AS Terms;
    WHEN 3 THEN
      SELECT 'Net due 30 days' AS Terms;
    ELSE
      SELECT 'Net due more than 30 days' AS Terms;
  END CASE;
END//
```

## The response from the system when the procedure is called




## The syntax of a searched CASE statement

```
CASE
  WHEN boolean_expression THEN
    statement_1;
    [statement_2;]...
  [WHEN boolean_expression THEN
    statement_1;
    [statement_2;]...]...
  [ELSE
    statement_1;
    [statement_2;]...]
END CASE;
```

## Description

- You can use a *simple CASE statement* or a *searched CASE statement* to execute one or more statements depending on a value that's returned by an expression.

Figure 13-6 How to code CASE statements

## How to code loops

Figure 13-7 shows how to use a *loop* to repeat a statement or several statements while a condition is true. This figure starts by showing how to use a *WHILE loop* to continue executing while a counter variable is within the specified range. In the example, the stored procedure begins by declaring a counter variable named i that has a default value of 1. Then, it declares a string variable named s that can store up to 400 characters and has a default value of an empty string.

The WHILE statement begins by declaring that the loop should continue while the counter variable is less than four. Since the second SET statement increases the value of the counter variable by 1 each time through the loop, the loop is executed three times (when the counter is equal to 1, 2, and 3). As a result, the first SET statement is executed three times. This statement appends some string literals and the value of the counter variable to the string variable.

After the loop finishes executing, the SELECT statement displays the string variable. This variable provides a string representation of the three values of the counter variable. Although this example doesn't accomplish anything useful, it clearly shows how a WHILE loop works and presents a technique that can be useful for debugging.

The next two examples show how to use different types of loops to get the same result as the first example. Because they work similarly to the WHILE loop, the syntax for these loops isn't shown.

The second example shows how to use a *REPEAT loop*. In this example, the REPEAT loop continues to execute until a counter variable named i equals 4. This works similarly to the WHILE loop, except that the Boolean expression is coded at the end of the loop. As a result, a REPEAT loop always executes at least once. Because of that, you should use a REPEAT loop if you want to execute the code at least once, and you should use a WHILE loop if you don't want the code to execute at all in some cases.

The syntax of the WHILE loop indicates that you can code a label at the beginning and end of the loop to name the loop. This applies to the other types of loops as well. In most cases, though, you'll only use labels if you nest loops within other loops. However, you must also use a label if you code the LEAVE or ITERATE statement within a simple loop, as shown in the third example.

To code a *simple loop*, you use the LOOP statement. Ironically, a simple loop is the most complex to code. In addition to coding a label, you typically use an IF statement to determine when the loop should end. Then, within the IF statement, you can use the LEAVE statement to jump to the end of the loop. On this statement, you name the loop you want to leave. Although you can also name the loop following the END LOOP keywords, that's not required. Because of the extra code that's required for a simple loop, you'll typically use a WHILE or REPEAT loop instead.

In the rare case that you need to jump to the beginning of a loop, you can use an ITERATE statement. This statement works like the LEAVE statement, except that it jumps to the beginning of a loop instead of to the end of a loop.

## The syntax of the WHILE loop

```
[label :] WHILE boolean_expression DO
  statement_1;
  [statement_2;]...
END WHILE [label];
```

## A stored procedure that uses a WHILE loop

```
DELIMITER //

CREATE PROCEDURE test()
BEGIN
  DECLARE i INT DEFAULT 1;
  DECLARE s VARCHAR(400) DEFAULT '';

  WHILE i < 4 DO
    SET s = CONCAT(s, 'i=', i, ' | ');
    SET i = i + 1;
  END WHILE;

  SELECT s AS message;

END//
```

## The output for this code


## A REPEAT loop

```
REPEAT
  SET s = CONCAT(s, 'i=', i, ' | ');
  SET i = i + 1;
UNTIL i = 4
END REPEAT;
```

## A simple loop with a label

```
testLoop : LOOP
  SET s = CONCAT(s, 'i=', i, ' | ');
  SET i = i + 1;

  IF i = 4 THEN
     LEAVE testLoop;
  END IF;
END LOOP testLoop;
```

## Description

- To execute a SQL statement repeatedly, you can use a *loop*. MySQL provides for three types of loops: a *WHILE loop*, a *REPEAT loop*, and a *simple loop*.
- You can use the LEAVE statement to go to the end of a loop.
- You can use the ITERATE statement to go to the beginning of a loop.
- You can name a loop using a *label*. This is most helpful for identifying loops in nested loops.

Figure 13-7 How to code loops

## How to use a cursor

By default, SQL statements work with an entire result set rather than individual rows. However, you may sometimes need to work with the data in a result set one row at a time. To do that, you can use a *cursor* as described in figure 13-8.

In this figure, the stored procedure begins by declaring four variables. Note that the third variable is declared with the BOOL type and is assigned a default value of FALSE. As you learned in chapter 8, this works because the FALSE keyword is an alias for 0. Although many programmers use 0 to represent a false value and 1 to represent a true value, this chapter uses the FALSE and TRUE keywords instead because they make the code easier to read.

Next, this code declares a variable of the CURSOR type named invoices_cursor. Within this declaration, this code uses a SELECT statement to define the result set for this cursor. This result set contains two columns from the invoices table and all of the rows that have a balance due.

After declaring the cursor, this code declares an error handler that's executed when no more rows are found in the result set for the cursor. This error handler sets the variable named row_not_found to a value of TRUE. Because the WHILE loop that follows executes only while the row_not_found variable is equal to FALSE, this causes the WHILE loop to stop executing.

After declaring the error handler, this code uses the OPEN statement to open the cursor. Then, it uses a WHILE loop to loop through each row in the cursor. This WHILE loop continues until the row_not_found variable is set to TRUE by the error handler.

Within the WHILE loop, the FETCH statement gets the column values from the next row and stores them in the variables that were declared earlier. Then, an IF statement checks whether the value of the invoice_total column for the current row is greater than 1000. If it is, an UPDATE statement adds 10% of the invoice_total column to the credit_total column for the row, and a SET statement increments the count of the number of rows that have been updated.

After the WHILE loop, this code closes the cursor. Finally, it uses a SELECT statement to display a count of the number of rows that have been updated.

Before you use a cursor to work with individual rows in a result set, you should consider other solutions. That's because standard database access is faster and uses fewer server resources than cursor-based access. For example, you can accomplish the same update as the stored procedure in this figure with this UPDATE statement:

```
UPDATE invoices
SET credit_total = credit_total + (invoice_total * .1)
WHERE invoice_total - payment_total - credit_total > 0
AND invoice_total > 1000
```

## The syntax

### Declare a cursor

```
DECLARE cursor_name CURSOR FOR select_statement;
```

### Declare an error handler for when no rows are found in the cursor

```
DECLARE CONTINUE HANDLER FOR NOT FOUND handler_statement;
```

### Open the cursor

```
OPEN cursor_name;
```

### Get column values from the row and store them in a series of variables

```
FETCH cursor_name INTO variable1[, variable2][, variable3]...;
```

### Close the cursor

```
CLOSE cursor_name;
```

## A stored procedure that uses a cursor

```
DELIMITER //

CREATE PROCEDURE test()
BEGIN
  DECLARE invoice_id_var    INT;
  DECLARE invoice_total_var DECIMAL(9,2);
  DECLARE row_not_found     BOOL DEFAULT FALSE;
  DECLARE update_count      INT DEFAULT 0;

  DECLARE invoices_cursor CURSOR FOR
    SELECT invoice_id, invoice_total  FROM invoices
    WHERE invoice_total - payment_total - credit_total > 0;

  DECLARE CONTINUE HANDLER FOR NOT FOUND
    SET row_not_found = TRUE;

  OPEN invoices_cursor;

  WHILE row_not_found = FALSE DO
    FETCH invoices_cursor INTO invoice_id_var, invoice_total_var;

    IF invoice_total_var > 1000 THEN
      UPDATE invoices
      SET credit_total = credit_total + (invoice_total * .1)
      WHERE invoice_id = invoice_id_var;
      SET update_count = update_count + 1;
    END IF;
  END WHILE;

  CLOSE invoices_cursor;

  SELECT CONCAT(update_count, ' row(s) updated.');
END//
```

## The response from the system when the procedure is called

| CONCAT(update_count, ' row(s) updated.') |
|---|
| 2 row(s) updated. |

Figure 13-8 How to use a cursor

## How to declare a condition handler

Before you declare a condition handler, you need to be familiar with the MySQL error codes and named conditions that are defined by MySQL. Figure 13-9 begins by listing five of the thousands of MySQL error codes. These error codes should give you an idea of the types of errors MySQL provides for.

Each of these error codes corresponds to a SQLSTATE code that's part of the ANSI standard. However, the MySQL codes are typically more useful since they're more specific. For example, the last four MySQL error codes all correspond to a SQLSTATE code of 23000.

In general, you only need to handle these errors when you encounter them during testing. However, if you're interested in viewing a list of all the error codes, you'll find them in the MySQL Reference Manual.

The second table in this figure lists the three built-in named conditions MySQL provides. To start, it provides the NOT FOUND condition that was used in the stored procedure in figure 13-8. This condition corresponds to MySQL error code 1329 and SQLSTATE code 02000.

In addition, MySQL provides the SQLEXCEPTION and SQLWARNING conditions. The SQLEXCEPTION condition provides a way for you to handle all errors, even ones that you did not encounter during testing. The SQLWARNING condition works like the SQLEXCEPTION condition, but it allows you to catch warnings and errors instead of just errors.

This figure also shows how to use the DECLARE…HANDLER statement to handle the errors that may occur in your stored programs. In MySQL, this is referred to as a *condition handler*. In other languages, this is referred to as an *error handler* or *exception handler*.

The three examples in this figure show how to declare condition handlers for a MySQL error code, a SQLSTATE code, and a named condition. All three of these condition handlers use the CONTINUE keyword, which causes the stored program to continue executing at the statement after the statement that caused the error to occur. If that's not what you want, you can use the EXIT keyword to continue execution after the current block of code. You'll see an example of that in the next figure.

In most cases, you can use the MySQL error codes and the built-in named conditions to handle the exceptions that you encounter. In some cases, though, you may want to create your own named conditions. Although this doesn't provide any new capabilities, it can sometimes improve the readability of your code. For more information about creating your own named conditions, you can search the MySQL Reference Manual for information about the DECLARE… CONDITION statement.

### Commonly used MySQL error codes

| Error code | SQLSTATE code | Description |
|---|---|---|
| 1329 | 02000 | Occurs when a program attempts to fetch data from a row that doesn't exist. |
| 1062 | 23000 | Occurs when a program attempts to store duplicate values in a column that has a unique constraint. |
| 1048 | 23000 | Occurs when a program attempts to insert a NULL value into a column that doesn't accept NULL values. |
| 1216 | 23000 | Occurs when a program attempts to add or update a child row but can't because of a foreign key constraint. |
| 1217 | 23000 | Occurs when a program attempts to delete or update a parent row but can't because of a foreign key constraint. |

### Built-in named conditions

| Named condition | Description |
|---|---|
| NOT FOUND | Occurs when a program attempts to use a FETCH statement or a SELECT statement to retrieve data and no data is found. |
| SQLEXCEPTION | Occurs when any error condition other than the NOT FOUND condition occurs. |
| SQLWARNING | Occurs when any error condition other than the NOT FOUND condition occurs or when any warning messages occur. |

### The syntax for declaring a condition handler

```
DECLARE {CONTINUE|EXIT} HANDLER
  FOR {mysql_error_code|SQLSTATE sqlstate_code|named_condition}
  handler_actions;
```

### How to declare a condition handler for a MySQL error code

```
DECLARE CONTINUE HANDLER FOR 1329
  SET row_not_found = TRUE
```

### How to declare a condition handler for a SQLSTATE code

```
DECLARE CONTINUE HANDLER FOR SQLSTATE '02000'
  SET row_not_found = TRUE
```

### How to declare a condition handler for a named condition

```
DECLARE CONTINUE HANDLER FOR NOT FOUND
  SET row_not_found = TRUE
```

### Description

- You can use the DECLARE…HANDLER statement to declare a handler for errors that may occur. In MySQL, this is referred to as a *condition handler*.
- To continue execution when an error occurs, use the CONTINUE keyword. To exit the current block of code when an error occurs, use the EXIT keyword.
- For a complete list of the MySQL error codes and their corresponding SQLSTATE codes, you can search the MySQL Reference Manual for "Server error codes".

Figure 13-9 How to declare a condition handler

## How to use a condition handler

Now that you know how to declare a condition handler, figure 13-10 shows how to use a condition handler. To help you understand the difference between a stored program that handles errors and one that doesn't, the first stored procedure shows what happens when an error occurs and the procedure doesn't handle errors. Here, the INSERT statement attempts to insert a duplicate value ("Cash") into a column (account_description) that has been defined with a unique constraint. Because the error condition this causes isn't handled, MySQL displays an error message like the one that's shown. This message identifies the error code (1062), and it displays a description of the error that helps you identify the cause of the error.

Although an error message like this can be helpful as you develop a stored procedure, it isn't helpful to the end user of an application. As a result, you often want to handle exceptions before you put your stored programs into production. Since the most specific way to handle an error is to use a MySQL error code, you usually want to declare a condition handler for the error code that's occurring. Then, you can handle this error by executing the appropriate code. Often, that just means displaying a more user-friendly message. However, you can also perform other error-handling tasks such as writing information about the error to a log table or rolling back a transaction.

The second stored procedure handles the error that occurs. To do that, it begins by declaring a variable named duplicate_entry_for_key of the BOOL type and setting its default value to FALSE. Then, it declares a handler for error code 1062. This handler uses the CONTINUE keyword to allow the procedure to continue executing when the error is encountered. However, it also uses a SET statement to set the value of the duplicate_entry_for_key variable to TRUE. As a result, the IF statement can test the value of this variable and handle the error when it occurs. In this figure, this code just handles the error by displaying a message that indicates that the row was not inserted because of a duplicate key.

To test this procedure, you can change the values in the INSERT statement. If you run the statement as shown in this figure, for example, the error with code 1062 occurs and the stored procedure returns the result set shown in this figure. However, if you enter valid values, this procedure returns a result set that indicates that one row was inserted.

## A stored procedure that doesn't handle errors

```
DELIMITER //

CREATE PROCEDURE test()
BEGIN
  INSERT INTO general_ledger_accounts VALUES (130, 'Cash');

  SELECT '1 row was inserted.';
END//
```

### The response from the system

```
Error Code: 1062. Duplicate entry 'Cash' for key 'account_description'
```

## A stored procedure that uses a CONTINUE handler to handle an error

```
DELIMITER //

CREATE PROCEDURE test()
BEGIN
  DECLARE duplicate_entry_for_key BOOL DEFAULT FALSE;

  DECLARE CONTINUE HANDLER FOR 1062
    SET duplicate_entry_for_key = TRUE;

  INSERT INTO general_ledger_accounts VALUES (130, 'Cash');

  IF duplicate_entry_for_key = TRUE THEN
    SELECT 'Row was not inserted - duplicate key encountered.' AS message;
  ELSE
    SELECT '1 row was inserted.' AS message;
  END IF;
END//
```

### The response from the system

| message |
|---|
| Row was not inserted - duplicate key encountered. |

Figure 13-10 How to use a condition handler (part 1 of 2)

The first stored procedure in part 2 shows how to exit the current block of code as soon as an error occurs. To start, this stored procedure begins by declaring a variable named duplicate_entry_for_key just like the stored procedure in part 1. Then, it uses the BEGIN and END keywords to nest a block of code within the block of code for the procedure. Within the nested block of code, the first statement declares a condition handler for the MySQL error with a code of 1062. This handler uses the EXIT keyword to indicate that it should exit the block of code when this error occurs. Then, the second statement executes the INSERT statement that may cause the error. If no error occurs, the third statement in the block displays a message that indicates that the row was inserted.

If an error occurs, however, the duplicate_entry_for_key variable is set to TRUE. In addition, code execution exits the block of code and jumps to the IF statement that's coded after the block. This statement displays a message that indicates that the row was not inserted because of a duplicate key.

So, when should you use a CONTINUE handler and when should you use an EXIT handler? If you want to allow MySQL to attempt to execute statements in a block of code even after it encounters an error, you should use a CONTINUE handler. On the other hand, if allowing MySQL to continue to execute statements in the block causes problems, you should use an EXIT handler.

The last stored procedure in this figure shows how to use a named condition to handle the error that occurs when a row can't be inserted. In this case, the stored procedure uses the SQLEXCEPTION condition. When this condition occurs, the stored procedure displays a message that indicates that the row was not inserted because of a SQL exception.

When handling the SQLEXCEPTION condition, many programmers make the mistake of displaying a generic message like this: "An unexpected error occurred." Although this message is user-friendly, it doesn't provide any information that can help a programmer find and fix the error. As a result, it's often better not to handle this exception at all. In that case, the stored procedure displays an error as shown in the first example in part 1 of this figure.

## A stored procedure that uses an EXIT handler to handle an error

```
DELIMITER //

CREATE PROCEDURE test()
BEGIN
  DECLARE duplicate_entry_for_key BOOL DEFAULT FALSE;
  BEGIN
    DECLARE EXIT HANDLER FOR 1062
      SET duplicate_entry_for_key = TRUE;

    INSERT INTO general_ledger_accounts VALUES (130, 'Cash');

    SELECT '1 row was inserted.' AS message;
  END;

  IF duplicate_entry_for_key = TRUE THEN
    SELECT 'Row was not inserted - duplicate key encountered.' AS message;
  END IF;
END//
```

### The response from the system

| message |
|---|
| Row was not inserted - duplicate key encountered. |

## A stored procedure that uses a named condition to handle all errors

```
DELIMITER //

CREATE PROCEDURE test()
BEGIN
  DECLARE sql_error BOOL DEFAULT FALSE;
  BEGIN
    DECLARE EXIT HANDLER FOR SQLEXCEPTION
      SET sql_error = TRUE;

    INSERT INTO general_ledger_accounts VALUES (130, 'Cash');

    SELECT '1 row was inserted.' AS message;
  END;

  IF sql_error = TRUE THEN
    SELECT 'Row was not inserted - SQL exception encountered.' AS message;
  END IF;
END//
```

### The response from the system

| message |
|---|
| Row was not inserted - SQL exception encountered. |

## Description

- If you want MySQL to exit the current block of code as soon as it encounters an error, use an EXIT handler.

Figure 13-10 How to use a condition handler (part 2 of 2)

## How to use multiple condition handlers

When coding a stored program, it's common to declare multiple condition handlers as shown in figure 13-11. If you do that, the most specific error handlers are executed first, and the least specific error handlers are executed last.

The stored procedure in this figure begins by declaring three variables that are used to indicate whether an error condition has occurred. Here, all three variables are set to a default value of FALSE.

After declaring these three variables, this stored procedure defines a block of code. Within this block, the first three statements declare three condition handlers that correspond to the three variables. These handlers all exit the block of code if the specified error occurs. Of these handlers, the first two are specific to MySQL error codes 1062 and 1048, but the third is a general handler that catches any other errors that may occur.

After the block of code, an IF statement examines the variables that are set by the condition handlers. Then, it executes the appropriate code. For the first two variables, this code displays a user-friendly message that's appropriate for the corresponding MySQL error code. For the third variable, this code displays information about the unanticipated error that occurred. In other words, if MySQL error code 1062 or 1048 occurs, this code displays a user-friendly error that includes information about the error that's useful to the programmer. Otherwise, it displays a user-friendly error message that includes information that's less useful to the programmer.

If you run the stored procedure shown in this figure, it returns a result set like the one that's shown. In this case, the row wasn't inserted because the first column contained an illegal NULL value. To test for other errors, you can change the values in the INSERT statement. For example, if you enter a third column with a value of 'xx', the stored procedure executes the condition handler for the SQLEXCEPTION condition.

## A stored procedure that uses multiple condition handlers

```
DELIMITER //

CREATE PROCEDURE test()
BEGIN
  DECLARE duplicate_entry_for_key BOOL DEFAULT FALSE;
  DECLARE column_cannot_be_null   BOOL DEFAULT FALSE;
  DECLARE sql_exception           BOOL DEFAULT FALSE;

  BEGIN
    DECLARE EXIT HANDLER FOR 1062
      SET duplicate_entry_for_key = TRUE;
    DECLARE EXIT HANDLER FOR 1048
      SET column_cannot_be_null = TRUE;
    DECLARE EXIT HANDLER FOR SQLEXCEPTION
      SET sql_exception = TRUE;

    INSERT INTO general_ledger_accounts VALUES (NULL, 'Test');

    SELECT '1 row was inserted.' AS message;
  END;

  IF duplicate_entry_for_key = TRUE THEN
    SELECT 'Row was not inserted - duplicate key encountered.' AS message;
  ELSEIF column_cannot_be_null = TRUE THEN
    SELECT 'Row was not inserted - column cannot be null.' AS message;
  ELSEIF sql_exception = TRUE THEN
    SELECT 'Row was not inserted - SQL exception encountered.' AS message;
  END IF;
END//
```

### The response from the system

| message |
| --- |
| Row was not inserted - column cannot be null. |

## Description

- You can declare multiple condition handlers for a single stored program. If you do that, the most specific error handlers are executed first and the least specific error handlers are executed last.
- The MySQL error codes and the NOT FOUND condition identify specific errors. The SQLSTATE codes identify less specific ANSI-standard errors. And the SQLEXCEPTION and SQLWARNING conditions identify general errors.

Figure 13-11 How to use multiple condition handlers

# Perspective

In this chapter, you were introduced to stored programs, and you learned how to use MySQL to write procedural code. In the next three chapters, you'll learn more about writing stored programs. In chapter 14, you'll learn how to manage transactions and locking. In chapter 15, you'll learn how to code stored procedures and functions. And in chapter 16, you'll learn how to code triggers and events.

## Terms

stored program
stored procedure
stored function
stored routine
trigger
event
block of code
variable
IF statement
Boolean expression
nested statement
simple CASE statement
searched CASE statement
loop
WHILE loop
REPEAT loop
label
simple LOOP
cursor
condition handler
error handler
exception handler
named condition

## Exercises

Each of the scripts that you create in the following exercises should use the same general structure as the script presented in figure 13-1.

1. Write a script that creates and calls a stored procedure named test. This stored procedure should declare a variable and set it to the count of all rows in the Invoices table that have a balance due that's greater than or equal to $5,000. Then, the stored procedure should display a result set that displays the variable in a message like this:

   ```
   3 invoices exceed $5,000.
   ```

2. Write a script that creates and calls a stored procedure named test. This stored procedure should use two variables to store (1) the count of all of the invoices in the Invoices table that have a balance due and (2) the sum of the balances due for all of those invoices. If that total balance due is greater than or equal to $30,000, the stored procedure should display a result set that displays the values of both variables. Otherwise, the procedure should display a result set that displays a message like this:

   ```
   Total balance due is less than $30,000.
   ```

3. Write a script that creates and calls a stored procedure named test. This procedure should calculate the factorial for the number 10. (To calculate a factorial, you multiply an integer by every positive integer less than itself.) Then, it should display a string that includes the factorial like this:

```
The factorial of 10 is: 3,628,800.
```

4. Write a script that creates and calls a stored procedure named test. This procedure should create a cursor for a result set that consists of the vendor_name, invoice_number, and balance_due columns for each invoice with a balance due that's greater than or equal to $5,000. The rows in this result set should be sorted in descending sequence by balance due. Then, the procedure should display a string variable that includes the balance due, invoice number, and vendor name for each invoice so it looks something like this:

   ```
   16896.06|P-0608|Malloy Lithographing Inc//9878.45|0-2436|Malloy
   Lithographing Inc//
   ```

   Here, each column is separated by a pipe character (|) and each row is separated by two front slashes (//).

5. Write a script that creates and calls a stored procedure named test. This procedure should attempt to update the invoice_due_date column so it's equal to NULL for the invoice with an invoice ID of 1. If the update is successful, the procedure should display this message:

   ```
   1 row was updated.
   ```

   If the update is unsuccessful, the procedure should display this message:

   ```
   Row was not updated - column cannot be null.
   ```

6. Write a script that creates and calls a stored procedure named test. This procedure should identify all of the prime numbers less than 100. (A prime number is an integer that can't be divided by another integer other than 1 and itself.) Then, it should display a string variable that includes the prime numbers like this:

   ```
   2 | 3 | 5 | 7 | 11 | 13 | 17 | 19 | 23 | 29 | 31 |...
   ```

   *Hint: To get this to work, you will need to nest one loop within another loop. In addition, you will need to code an IF statement within the inner loop.*

7. Enhance your script for exercise 4 so it shows the invoice data in three groups based on the balance due amount with these headings:

   ```
   $20,000 or More
   $10,000 to $20,000
   $5,000 to $10,000
   ```

   When you're done, the string variable that's returned should be in this format:

   ```
   $20,000 or More: $10,000 to $20,000: 16896.06|P-0608|Malloy
   Lithographing Inc//$5,000 to $10,000: 9878.45|0-2436|Malloy
   Lithographing Inc//
   ```

   To accomplish this, you can loop through the cursor three times by opening and closing the cursor for each loop. *Hint: For each group of invoices, you can code a separate block of code that contains an EXIT handler for the NOT FOUND condition.*

# 14

# How to use transactions and locking

If you've been working with MySQL on your own computer, you've been the only user of your database. In the real world, though, a database may be used by thousands of users at the same time. Then, what happens when two users try to update the same data at the same time? In this chapter, you'll learn how MySQL handles this situation. But first, you'll learn how to combine multiple SQL statements into a single logical unit of work known as a transaction.

# How to work with transactions

A *transaction* is a group of SQL statements that you combine into a single logical unit of work. By combining SQL statements like this, you can prevent certain kinds of database errors.

Before you begin using MySQL to work with transactions, you should realize that some storage engines don't support transactions. In particular, the MyISAM storage engine doesn't support transactions. As a result, the skills presented in this topic only apply to storage engines such as InnoDB that support transactions.

## How to commit and rollback transactions

By default, a MySQL session uses autocommit mode, which automatically commits INSERT, UPDATE, and DELETE statements immediately after you execute them. So far in this book, we have assumed that you have been using autocommit mode. If that's not what you want, though, you can use transactions to control when changes are committed.

Since transactions are often coded within stored procedures, figure 14-1 presents a stored procedure named test that contains three INSERT statements that are coded as a transaction. To start, this stored procedure declares a variable named sql_error and sets it to FALSE to indicate that no SQL error has occurred. Then, the second DECLARE statement creates a condition handler that sets the sql_error variable to TRUE if a SQL error occurs.

The START TRANSACTION statement identifies the start of the transaction, which temporarily turns off autocommit mode. Then, the first INSERT statement adds a new invoice to the Invoices table. Next, two more INSERT statements add the line items for the invoice to the Invoice_Line_Items table.

After the INSERT statements, an IF statement uses the sql_error variable to check whether an error occurred when executing any of the INSERT statements. If a SQL error did not occur, this code uses the COMMIT statement to *commit* the changes to the database, which makes the changes permanent. Otherwise, the ROLLBACK statement *rolls back* the changes, which cancels them.

To understand why this is necessary, suppose that each of these INSERT statements is committed to the database immediately after it's executed. Then, what will happen if the third INSERT statement fails? In that case, the Invoices and Invoice_Line_Items tables won't match. Specifically, the sum of the line_item_amount columns in the Invoice_Line_Items table won't be equal to the invoice_total column in the Invoices table. In other words, the integrity of the data won't be maintained.

Similarly, consider the example of a transfer between a checking and a savings account in a banking system. In that case, one update reduces the balance in the checking account and another update increases the balance in the savings account. Then, if one of these updates fails, the customer either gains or loses the amount of the transaction. But again, treating the two updates as a single transaction solves this problem. Usually, that's what you want.

## A stored procedure that runs three INSERT statements as a transaction

```
DELIMITER //

CREATE PROCEDURE test()
BEGIN
  DECLARE sql_error BOOL DEFAULT FALSE;

  DECLARE CONTINUE HANDLER FOR SQLEXCEPTION
    SET sql_error = TRUE;

  START TRANSACTION;

  INSERT INTO invoices
  VALUES (115, 34, 'ZXA-080', '2023-01-18',
          14092.59, 0, 0, 3, '2023-04-18', NULL);

  INSERT INTO invoice_line_items
  VALUES (115, 1, 160, 4447.23, 'HW upgrade');

  INSERT INTO invoice_line_items
  VALUES (115, 2, 167, 9645.36, 'OS upgrade');

  IF sql_error = FALSE THEN
    COMMIT;
    SELECT 'The transaction was committed.';
  ELSE
    ROLLBACK;
    SELECT 'The transaction was rolled back.';
  END IF;
END//
```

## When to use transactions

- When you code two or more INSERT, UPDATE, or DELETE statements that affect related data.
- When you move rows from one table to another table by using INSERT and DELETE statements.
- Whenever the failure of an INSERT, UPDATE, or DELETE statement would violate data integrity.

## Description

- By default, MySQL runs in autocommit mode, which automatically commits changes to the database immediately after each INSERT, UPDATE, or DELETE statement is executed. If that's not what you want, you can group statements into a logical unit of work called a *transaction*.
- To start a transaction, code the START TRANSACTION statement. This turns off autocommit mode until the statements in the transaction are committed or rolled back. To *commit* the changes, code a COMMIT statement. To *roll back* the changes, use a ROLLBACK statement.
- MySQL automatically commits changes after a DDL statement such as a CREATE TABLE statement. As a result, you shouldn't code a DDL statement within a transaction unless you want to commit the changes and end the transaction.

Figure 14-1 How to commit and roll back transactions

## How to work with save points

The script in figure 14-2 shows how to use the SAVEPOINT statement to identify one or more *save points* within a transaction. Here, a SAVEPOINT statement is used to identify a save point before each of the three INSERT statements that are included in the script. As a result, the script includes three save points.

This script also shows how to use the ROLLBACK TO SAVEPOINT statement to roll back all or part of a transaction. Here, the three ROLLBACK TO SAVEPOINT statements rollback the transaction to each of the three save points. The first statement rolls back to the point before the second line item was inserted. The second statement rolls back to the point before the first line item was inserted. And the third statement rolls back to the point before the invoice was inserted.

At this point, the script calls the COMMIT statement to commit any changes that have been made. However, the three ROLLBACK TO SAVEPOINT statements have rolled back all three INSERT statements, so this doesn't commit any changes to the database. To verify this, you can use a SELECT statement to view the rows in the Invoices and Invoice_Line_Items tables that have an invoice_id of 115.

In general, save points are used when a transaction contains so many statements that rolling back the entire transaction would be inefficient. In that case, an application can roll back to the last save point before an error occurred. Then, the appropriate processing can be done from there. For most applications, though, you won't need to use save points.

In most cases, a transaction and its save points are coded within a stored procedure as shown in figure 14-1. In this figure, though, the transaction and its statements are coded in a script. Although this isn't a realistic example, it does show how save points work. In addition, this example shows that you can use the statements for working with transactions within a script, which is sometimes helpful when working with database creation scripts like the ones described in chapter 11.

### A script that uses save points

```
USE ap;

START TRANSACTION;

SAVEPOINT before_invoice;

INSERT INTO invoices
VALUES (115, 34, 'ZXA-080', '2023-01-18',
        14092.59, 0, 0, 3, '2023-04-18', NULL);

SAVEPOINT before_line_item1;

INSERT INTO invoice_line_items
VALUES (115, 1, 160, 4447.23, 'HW upgrade');

SAVEPOINT before_line_item2;

INSERT INTO invoice_line_items
VALUES (115, 2, 167, 9645.36,'OS upgrade');

ROLLBACK TO SAVEPOINT before_line_item2;

ROLLBACK TO SAVEPOINT before_line_item1;

ROLLBACK TO SAVEPOINT before_invoice;

COMMIT;
```

### Description

- When you use *save points*, you can roll back a transaction to the beginning of the transaction or to a particular save point.
- You can use the SAVEPOINT statement to create a save point with the specified name.
- You can use the ROLLBACK TO SAVEPOINT statement to roll back a transaction to the specified save point.
- Save points are useful when a single transaction contains so many SQL statements that rolling back the entire transaction would be inefficient.

Figure 14-2 How to work with save points

# How to work with concurrency and locking

When two or more users have access to the same database, it's possible for them to be working with the same data at the same time. This is called *concurrency*. Although concurrency isn't a problem when two users retrieve the same data at the same time, it can become a problem when one user updates data that other users are also viewing or updating. In the topics that follow, you'll learn how to prevent concurrency problems.

## How concurrency and locking are related

Figure 14-3 presents two transactions that show how MySQL handles concurrency by default. To start, transaction A submits an UPDATE statement that adds a value of 100 to the value that's stored in the credit_total column of the invoice that has an invoice_id value of 6. Because transaction A hasn't yet committed this change to the database, it retains a *lock* on this row. This is known as *locking*.

At this point, if you run the SELECT statement in transaction B, the result set doesn't include the updated value in the credit_total column. In other words, the SELECT statement only reads changes that have been committed.

In addition, the UPDATE statement in transaction B won't be able to update the row due to the lock that transaction A has on the row. As a result, it will have to wait for transaction A to finish before it updates the row.

Once transaction A commits the change made by the UPDATE statement, the SELECT statement in transaction B will show the updated value in the credit_total column if you run it again. In addition, when transaction A commits the update, it releases its lock on the row. Then, the UPDATE statement in transaction B finishes executing if it has been waiting. Or, if you execute the UPDATE statement in transaction B again, it will execute immediately.

To experiment with concurrency, you need to simulate multiple users by opening multiple connections and using them to execute SQL statements. For example, when you're using MySQL Workbench, you can use the Home tab to open two connections. (You can even open both connections for the same user.) Then, you can use the first connection to execute transaction A and the second connection to execute transaction B. To do that, you can run one statement at a time by placing the cursor in each statement and using the Execute Current Statement button (Ctrl+Enter). This allows you to slow down the execution of each script. Otherwise, if you use the Execute SQL Script button (Ctrl+Shift+Enter), the script runs so quickly that you won't be able to get both scripts to access the same row at the same time.

This example shows that MySQL's default locking behavior prevents most concurrency problems. However, if you find that the default locking behavior is insufficient, you may need to override it. You'll learn how to do that in a moment. But first, you need to understand the four concurrency problems that locks can prevent.

### Two transactions that retrieve and then modify the data in the same row

#### Transaction A

```
-- Execute each statement one at a time.
-- Alternate with Transaction B as described.

START TRANSACTION;

UPDATE invoices SET credit_total = credit_total + 100 WHERE invoice_id = 6;

-- the SELECT statement in Transaction B won't show the updated data
-- the UPDATE statement in Transaction B will wait for transaction A to finish

COMMIT;

-- the SELECT statement in Transaction B will display the updated data
-- the UPDATE statement in Transaction B will execute immediately
```

#### Transaction B

```
-- Use a second connection to execute these statements!
-- Otherwise, they won't work as described.

START TRANSACTION;

SELECT invoice_id, credit_total FROM invoices WHERE invoice_id = 6;

UPDATE invoices SET credit_total = credit_total + 200 WHERE invoice_id = 6;

COMMIT;
```

### Description

- *Concurrency* is the ability of a system to support two or more transactions working with the same data at the same time.
- By default, MySQL prevents most concurrency problems by using *locks*. A lock delays the execution of another transaction if it conflicts with a transaction that is already running.
- Concurrency is a problem only when the data is being modified. When two or more transactions read the same data, the transactions don't affect each other.

Figure 14-3 How concurrency and locking are related

## The four concurrency problems that locks can prevent

Figure 14-4 describes the four most common concurrency problems. To start, a *lost update* is the problem that you learned about in the previous figure. It occurs when two transactions select the same row and then update the row based on the values originally selected. Since each transaction is unaware of the other, the later update overwrites the earlier update.

Lost updates might not adversely affect a database. That depends on the nature of the data. In fact, for many systems, when lost updates occur, they can be corrected by resubmitting the query that caused the problem. However, for some databases, lost updates can cause serious problems with data integrity.

Like lost updates, the other three concurrency problems might not adversely affect a database. However, for some databases, these problems can cause serious problems with data integrity.

If your database has a relatively small number of users, the likelihood of concurrency problems is low. However, for a large system, you should expect concurrency problems to occur.

Although locks can prevent the problems listed in this figure, MySQL's default locking behavior doesn't prevent *phantom reads*. If this level of locking isn't acceptable, you can change the default locking behavior by setting the transaction isolation level as shown in the next figure.

## The four types of concurrency problems

| Problem | Description |
|---|---|
| Lost updates | Occur when two transactions select the same row and then update the row based on the values originally selected. Since each transaction is unaware of the other, the later update overwrites the earlier update. |
| Dirty reads | Occur when a transaction selects data that hasn't been committed by another transaction. For example, transaction A changes a row. Transaction B then selects the changed row before transaction A commits the change. If transaction A then rolls back the change, transaction B has selected data that doesn't exist in the database. |
| Nonrepeatable reads | Occur when two SELECT statements that try to get the same data get different values because another transaction has updated the data in the time between the two statements. For example, transaction A selects a row. Transaction B then updates the row. When transaction A selects the same row again, the data is different. |
| Phantom reads | Occur when you perform an update or delete on a set of rows at the same time that another transaction is performing an insert or delete that affects one or more rows in that same set of rows. For example, transaction A updates the payment total for each invoice that has a balance due, but transaction B inserts a new, unpaid, invoice while transaction A is still running. After transaction A finishes, there is still an invoice with a balance due. |

## Description

- In a large system with many users, you should expect for these kinds of problems to occur. In general, you don't need to take any action except to anticipate the problem. In many cases, if the SQL statement is resubmitted, the problem goes away.
- On some systems, if two transactions overwrite each other, the validity of the database is compromised and resubmitting one of the transactions won't eliminate the problem. If you're working on such a system, you must anticipate these concurrency problems and account for them in your code.
- You should consider these locking problems as you write your code. If one of these problems could affect the data integrity of your system, you can change the default locking behavior by setting the transaction isolation level as shown in the next figure.

Figure 14-4 The four concurrency problems that locks can prevent

## How to set the transaction isolation level

The simplest way to prevent concurrency problems is to change the default locking behavior. To do that, you use the SET TRANSACTION ISOLATION LEVEL statement shown in figure 14-5 to set the *transaction isolation level*. By default, this statement sets the isolation level for the next new transaction in the current session. If you want to set the isolation level for all the transactions in a session, though, you can include the SESSION keyword. And if you want to set the isolation level for all sessions, you can include the GLOBAL keyword. The examples in this figure illustrate how this works.

This figure also lists the four transaction isolation levels that MySQL provides and shows which concurrency problems they prevent or allow. For example, if you use the SERIALIZABLE option, all four concurrency problems will be prevented.

When you set the isolation level to SERIALIZABLE, each transaction is completely isolated from every other transaction and concurrency is severely restricted. The server does this by locking each resource, preventing other transactions from accessing it. Since each transaction must wait for the previous transaction to commit, the transactions are executed serially, one after another.

Since the SERIALIZABLE level eliminates all concurrency problems, you may think that this is always the best option. However, this option requires more overhead to manage all of the locks, so the access time for each transaction is increased. For some systems, this may cause significant performance problems. As a result, you typically want to use the SERIALIZABLE isolation level only for situations in which phantom reads aren't acceptable.

The lowest isolation level is READ UNCOMMITTED, which allows all four of the concurrency problems to occur. It does this by performing SELECT queries without setting any locks and without honoring any existing locks. Since this means that your SELECT statements will always execute immediately, this setting provides the best performance. Since other transactions can retrieve and modify the same data, however, this setting can't prevent concurrency problems.

The READ COMMITTED isolation level prevents transactions from seeing data that has been changed by other transactions but not committed. This prevents dirty reads, but allows for other types of concurrency problems.

The default isolation level for MySQL is REPEATABLE READ. With this level, rows read by a transaction will be read consistently within the same transaction. To accomplish that, the server places locks on all the data used by the transaction that prevent other users from updating the data.

The REPEATABLE READ level allows more concurrency than the SERIALIZABLE level but less than the READ COMMITTED level. As you might expect, then, it results in faster performance than SERIALIZABLE and permits fewer concurrency problems than READ COMMITTED. In most situations, then, the default isolation level of REPEATABLE READ is acceptable.

### The concurrency problems prevented by each transaction isolation level

| Isolation level | Dirty reads | Lost updates | Nonrepeatable reads | Phantom reads |
|---|---|---|---|---|
| READ UNCOMMITTED | Allows | Allows | Allows | Allows |
| READ COMMITTED | Prevents | Allows | Allows | Allows |
| REPEATABLE READ | Prevents | Prevents | Prevents | Allows |
| SERIALIZABLE | Prevents | Prevents | Prevents | Prevents |

### The syntax of the SET TRANSACTION ISOLATION LEVEL statement

```
SET {GLOBAL|SESSION} TRANSACTION ISOLATION LEVEL
    {READ UNCOMMITTED|READ COMMITTED|REPEATABLE READ|SERIALIZABLE}
```

### Set the transaction isolation level to SERIALIZABLE for the next transaction

```
SET TRANSACTION ISOLATION LEVEL SERIALIZABLE
```

### Set the transaction isolation level to READ UNCOMMITTED for the current session

```
SET SESSION TRANSACTION ISOLATION LEVEL READ UNCOMMITTED
```

### Set the transaction isolation level to READ COMMITTED for all sessions

```
SET GLOBAL TRANSACTION ISOLATION LEVEL READ COMMITTED
```

### Description

- The *transaction isolation level* controls the degree to which transactions are isolated from one another. At the more restrictive isolation levels, concurrency problems are reduced or eliminated. However, at the least restrictive levels, performance is enhanced.
- To change the transaction isolation level, you use the SET TRANSACTION ISOLATION LEVEL statement.
- If you include the GLOBAL keyword, the isolation level is set globally for all new transactions in all sessions. If you include the SESSION keyword, the isolation level is set for all new transactions in the current session. If you omit both GLOBAL and SESSION, the isolation level is set for the next new transaction in the current session.
- The default transaction isolation level is REPEATABLE READ. This level places locks on all data that's used in a transaction, preventing other users from updating that data. However, this isolation level still allows inserts, so phantom reads can occur.
- The READ UNCOMMITTED isolation level doesn't set any locks and ignores locks that are already held. This level results in the highest possible performance for your query, but at the risk of every kind of concurrency problem. For this reason, you should only use this level for data that is rarely updated.
- The READ COMMITTED isolation level locks data that has been changed but not committed. This prevents dirty reads but allows all other types of concurrency problems.
- The SERIALIZABLE isolation level places a lock on all data that's used in a transaction. Since each transaction must wait for the previous transaction to commit, the transactions are handled in sequence. This is the most restrictive isolation level.

Figure 14-5 How to set the transaction isolation level

## How to lock selected rows

In some cases, the default isolation level of REPEATABLE READ doesn't work the way you want. For example, suppose you want to code a transaction that selects data and then inserts or updates data in related tables. In that case, because a SELECT statement doesn't lock the data it retrieves by default, another transaction could update or delete the rows read by the first transaction before that transaction is done modifying the related tables.

To solve this type of problem, MySQL provides two ways to lock the rows returned by a SELECT statement. First, you can add a FOR SHARE clause to the end of a SELECT statement. This locks the selected rows so other transactions can read them but can't modify them until your transaction commits. Second, you can add a FOR UPDATE clause to the end of a SELECT statement. This locks the selected rows and any associated indexes just like an UPDATE statement does. Then, other transactions can't read or modify these rows until your transaction commits.

When you use the FOR SHARE clause, the SELECT statement waits if it encounters rows that have been locked for update by another statement such as an UPDATE, DELETE, or SELECT...FOR UPDATE statement. That way, it can read the most current data. However, the FOR SHARE clause doesn't wait for rows that have been locked for share. On the other hand, the FOR UPDATE clause waits for rows that have been locked for share or for update. Because of this, the FOR SHARE clause provides better performance than the FOR UPDATE clause. As a result, you should use the FOR SHARE clause if you don't need to prevent other transactions from reading the same rows.

With MySQL 8.0 and later, you can also keep your transactions from waiting for locks to be released. To do that, you can add the NO WAIT or SKIP LOCKED option to the end of a FOR SHARE or FOR UPDATE clause. The NO WAIT option causes the statement to immediately return an error that the developer can handle. The SKIP LOCKED option skips any rows that have been locked and returns the rest.

Figure 14-6 presents a series of transactions that show how the FOR SHARE and FOR UPDATE clauses of a SELECT statement work. To start, transaction A executes a SELECT statement that uses the FOR SHARE clause to lock the row in the Sales_Reps table that has a rep_id value of 2. At this point, no other transactions can modify this row until transaction A completes. This makes sure that transaction A can modify the data in a child table before any other transaction can update or delete the corresponding row in the parent table.

In transaction B, the SELECT statement includes the FOR UPDATE clause. As a result, it attempts to lock 4 rows for update. If transaction A still has a lock on one of these rows, though, transaction B waits for that lock to be released. Once transaction A completes, the SELECT statement in transaction B is executed. This returns four rows with rep_id values of 1, 2, 3, and 4.

## Four transactions that show how to work with locking reads

### Transaction A

```
-- Execute each statement one at a time.
-- Alternate with Transactions B, C, and D as described.
START TRANSACTION;

-- lock row with rep_id of 2 in parent table
SELECT * FROM sales_reps WHERE rep_id = 2 FOR SHARE;

-- Transaction B waits for transaction A to finish
-- Transaction C returns an error immediately
-- Transaction D skips the locked row and returns the other rows immediately

 -- insert row with rep_id of 2 into child table
INSERT INTO sales_totals (rep_id, sales_year, sales_total)
VALUES (2, 2023, 138193.69);

COMMIT;  -- Transaction B executes now
```

### Transaction B

```
START TRANSACTION;
SELECT * FROM sales_reps WHERE rep_id < 5 FOR UPDATE;
COMMIT;
```

### Transaction C

```
START TRANSACTION;
SELECT * FROM sales_reps WHERE rep_id < 5 FOR UPDATE NOWAIT;
COMMIT;
```

### Transaction D

```
START TRANSACTION;
SELECT * FROM sales_reps WHERE rep_id < 5 FOR UPDATE SKIP LOCKED;
COMMIT;
```

## Description

- If you add the FOR SHARE clause to the end of a SELECT statement, the selected rows are locked so other transactions can read those rows but can't modify them until the transaction commits.
- If you add the FOR UPDATE clause to the end of a SELECT statement, the selected rows and any associated indexes are locked so other transactions can't read or modify them until the transaction commits. This works the same as the locks for an UPDATE statement.
- If a SELECT…FOR SHARE statement attempts to read any rows that have been locked for update by another transaction, it waits until that transaction commits so it retrieves the most current values.
- If a SELECT…FOR UPDATE statement attempts to read any rows that have been locked for share or for update by another transaction, it waits until that transaction commits so it can use the most current values.
- When the NOWAIT option is included on a FOR SHARE or FOR UPDATE clause, the statement doesn't wait for a lock to be released. Instead, it returns an error immediately. This allows a developer to handle the error instead of waiting for the lock to release.
- When the SKIP LOCKED option is included on a FOR SHARE or FOR UPDATE clause, the statement doesn't wait for a lock to be released. Instead, it skips the locked rows and returns any rows that are not locked.

Figure 14-6 How to lock selected rows

Transaction C works like transaction B, except that it includes the NO WAIT option. As a result, if transaction A still has a lock on any rows selected by transaction C, running its SELECT statement causes an error to occur immediately. This allows a developer to handle the error instead of having to wait for the lock to be released.

Transaction D also works like transaction B, except that it includes the SKIP LOCKED option. As a result, if transaction A still has a lock on any rows selected by transaction D, its SELECT statement executes but skips any locked rows. In this example, it skips the row with a rep_id value of 2 and returns three rows that have rep_id values of 1, 3, and 4.

## How to prevent deadlocks

A *deadlock* occurs when neither of two transactions can be committed because each has a lock on a resource needed by the other transaction. This is illustrated by the banking transactions in figure 14-7. Here, transaction A updates the savings account first and then the checking account, while transaction B updates the checking account first and then the savings account.

Now, suppose that the first statement in transaction A locks the savings account, and the first statement in transaction B locks the checking account. At that point, a deadlock occurs because transaction A needs the savings account and transaction B needs the checking account, but both are locked. Eventually, one of the transactions has to be rolled back so the other can proceed, and the loser is known as a *deadlock victim*.

To prevent deadlocks, you can use the four techniques that are presented in this figure. First, you shouldn't leave transactions open any longer than is necessary. That's because the longer a transaction remains open and uncommitted, the more likely it is that another transaction will need to work with that same resource.

So, when you're coding transactions, make sure to include the appropriate COMMIT and ROLLBACK statements. In addition, don't code statements that take a long time to execute between the START TRANSACTION statement that starts the transaction and the COMMIT or ROLLBACK statement that finishes the transaction.

Second, you shouldn't use a higher isolation level than you need. That's because the higher you set the isolation level, the more likely it is that two transactions will be unable to work with the same resource at the same time.

Third, you should schedule transactions that modify a large number of rows to run when no other transactions, or only a small number of other transactions, will be running. That way, it's less likely that the transactions will try to change the same rows at the same time.

Finally, you should consider how the SQL statements you write could cause a deadlock. To prevent the situation that's illustrated in this figure, for example, you should always update related accounts in the same sequence.

### Don't allow transactions to remain open for very long

- Keep transactions short.
- Keep SELECT statements outside of the transaction except when absolutely necessary.
- Never code requests for user input during a transaction.

### Don't use a transaction isolation level higher than necessary

- The default level of REPEATABLE READ is usually acceptable, but you should consider changing to READ COMMITTED if deadlocks become a problem.
- Reserve the use of the SERIALIZABLE level for short transactions that make changes to data where integrity is vital.

### Make large changes when you can be assured of nearly exclusive access

- If you need to change millions of rows in an active table, don't do so during hours of peak usage.
- If possible, give yourself exclusive access to the database before making large changes.

### Take locking behavior into consideration when coding your transactions

- If you need to code two or more transactions that update the same resources, code the updates in the same order in each transaction.

### UPDATE statements that illustrate deadlocking

#### Transaction A

```
START TRANSACTION;
UPDATE savings SET balance = balance - transfer_amount;
UPDATE checking SET balance = balance + transfer_amount;
COMMIT;
```

#### Transaction B (possible deadlock)

```
START TRANSACTION;
UPDATE checking SET balance = balance - transfer_amount;
UPDATE savings SET balance = balance + transfer_amount;
COMMIT;
```

#### Transaction B (prevents deadlocks)

```
START TRANSACTION;
UPDATE savings SET balance = balance + transfer_amount;
UPDATE checking SET balance = balance - transfer_amount;
COMMIT;
```

### Description

- A *deadlock* occurs when neither of two transactions can be committed because each transaction has a lock on a resource needed by the other transaction.

Figure 14-7 How to prevent deadlocks

# Perspective

In this chapter, you learned the ways that MySQL protects your data from the problems that can occur on a real-world system. Since the failure of one or more related SQL statements can violate data integrity, you learned how to prevent these problems by grouping the statements into transactions. Since multiple transactions can simultaneously modify the same data, you learned how to prevent concurrency problems by setting the transaction isolation level to change the default locking behavior. And since changing the isolation level can increase the chances of deadlocks, you learned defensive programming techniques to prevent deadlocks.

## Terms

transaction
commit a transaction
roll back a transaction
save point
concurrency
locking
lost update
dirty read
nonrepeatable read
phantom read
transaction isolation level
deadlock
deadlock victim

## Exercises

1. Write a script that creates and calls a stored procedure named test. This procedure should include a set of three SQL statements coded as a transaction to reflect the following change: United Parcel Service has been purchased by Federal Express Corporation and the new company is named FedUP. Rename one of the vendors and delete the other after updating the vendor_id column in the Invoices table.

   If these statements execute successfully, commit the changes. Otherwise, roll back the changes.

2. Write a script that creates and calls a stored procedure named test. This procedure should include a set of two SQL statements coded as a transaction to delete the row with an invoice ID of 114 from the Invoices table. To do this, you must first delete all line items for that invoice from the Invoice_Line_Items table.

   If these statements execute successfully, commit the changes. Otherwise, roll back the changes.

15

# How to create stored procedures and functions

In chapter 13, you learned how to code simple stored procedures that didn't use parameters. Now, you'll learn some additional skills for coding stored procedures, including how to use parameters. In addition, you'll learn how to code stored functions.

As you'll see, stored procedures allow you to store procedural logic such as data validation in a central location. In addition, they provide a powerful way to control how users are allowed to access the database.

# How to code stored procedures

A *stored procedure*, which can also be referred to as a *sproc* or just a *procedure*, is a database object that contains procedural SQL code. You can use stored procedures to retrieve or modify the data that's stored within a database. You learned the basic skills for coding stored procedures in chapter 13. Now, the topics that follow expand on those skills.

## How to create and call a stored procedure

Figure 15-1 shows how to use the CREATE PROCEDURE statement to create a stored procedure. To start, you code the CREATE PROCEDURE keywords followed by the name of the procedure. In this figure, for example, the statement creates a procedure named update_invoices_credit_total. This name clearly indicates that the procedure updates the credit_total column of the invoices table.

After the name of the procedure, you code a set of parentheses. Within the parentheses, you can code one or more *parameters* for the procedure. A parameter can be used to pass a value to the stored procedure from a calling program.

When you declare a parameter, you code the name of the parameter followed by its data type. If a procedure accepts more than one parameter, you must use commas to separate the parameters. When you declare a parameter, you code the name of the parameter followed by its data type. In this figure, for example, the procedure accepts two parameters. The first parameter is named invoice_id_param with a data type of INT, and the second parameter is named credit_total_param with a data type of DECIMAL.

After the parentheses, you code the body of the procedure. In most cases, the procedure body consists of a block of statements identified by the BEGIN and END keywords. Then, within the block, you can code most SQL statements, including the ones for writing procedural code presented in chapter 13 and the ones for working with transactions presented in chapter 14.

When you run the CREATE PROCEDURE statement, MySQL *compiles* the code for the procedure and stores the compiled code in the database. As part of this process, MySQL's compiler checks the syntax of the code within the procedure. If you've made a coding error, the system responds with an appropriate message and the procedure isn't created.

You can execute, or *call*, a stored procedure by using the CALL statement. In this figure, for example, the CALL statement calls the procedure that was created in the first example. This statement passes one value for each of the parameters that are defined by the procedure. Here, the first parameter is a literal value that specifies the invoice ID, and the second parameter is a literal value that identifies the new amount for the credit total.

When you use the CALL statement, you must pass parameters *by position*. In other words, you must code the parameters in the same order as they are coded in the CREATE PROCEDURE statement.

In chapter 18, you will learn how to grant INSERT, UPDATE, and DELETE privileges to specific users. However, if you want to have more fine-grained

## The syntax of the CREATE PROCEDURE statement

```
CREATE PROCEDURE procedure_name
(
    [parameter_name_1 data_type]
    [, parameter_name_2 data_type]...
)
procedure_body
```

## A script that creates a stored procedure that updates a table

```
DELIMITER //

CREATE PROCEDURE update_invoices_credit_total
(
  invoice_id_param      INT,
  credit_total_param    DECIMAL(9,2)
)
BEGIN
  DECLARE sql_error BOOL DEFAULT FALSE;

  DECLARE CONTINUE HANDLER FOR SQLEXCEPTION
    SET sql_error = TRUE;

  START TRANSACTION;

  UPDATE invoices
  SET credit_total = credit_total_param
  WHERE invoice_id = invoice_id_param;

  IF sql_error = FALSE THEN
    COMMIT;
  ELSE
    ROLLBACK;
  END IF;
END//
```

## A statement that calls the stored procedure

```
CALL update_invoices_credit_total(56, 300);
```

## Description

- You use the CREATE PROCEDURE statement to create a stored procedure. A *stored procedure* is an executable database object that contains procedural SQL code. A stored procedure can also be called a *sproc* or a *procedure*.
- You can use *parameters* to pass one or more values from the calling program to the stored procedure, from the procedure to the calling program, or both.
- To declare a parameter within a stored procedure, you code the name of the parameter followed by its data type. To declare two or more parameters, separate the parameters with commas.
- You can use the CALL statement to *call a procedure*. When a procedure accepts parameters, you pass them to the procedure by coding them within the parentheses that follow the procedure name, and by separating the parameters with commas.

Figure 15-1 How to create and call a stored procedure control over the privileges that you grant to users, you can create stored procedures that perform all of the types of data manipulation that you want to allow within your database. Then, you can grant privileges to execute these stored procedures. For systems where security is critical, this can be an excellent way to prevent both accidental errors and malicious damage to your data.

## How to code input and output parameters

Figure 15-2 shows how to code input and output parameters for a stored procedure. An *input parameter* is passed to the stored procedure from the calling program. You can explicitly identify an input parameter by coding the IN keyword before the name of the parameter. In this figure, for example, the first two parameters are identified as input parameters. However, if you omit this keyword, the parameter is assumed to be an input parameter. In figure 15-1, for example, both parameters are input parameters.

Within a procedure, you can use input parameters like variables. However, you can't change the value of the parameter. In this figure, for example, the procedure uses the first parameter within an UPDATE statement to specify the invoice ID for the invoice row to be updated.

An *output parameter* is returned to the calling program from the stored procedure. To code an output parameter, you must explicitly identify the parameter by coding the OUT keyword before the name of the parameter. In this figure, for example, the third parameter is an output parameter. If the UPDATE statement executes successfully, a SET statement stores a value of 1 in the output parameter. Otherwise, a SET statement stores a value of 0 in the output parameter. Either way, the value of the output parameter is returned to the calling program when the procedure finishes.

To show how a calling program works, this figure includes a script that calls the procedure. Here, initial values are supplied for the two input parameters. Then, a variable named @row_count is supplied for the output parameter. This variable is a special type of variable known as a *user variable*. A user variable is a global variable that's available to the user for the rest of the current session. You'll learn more about user variables later in this chapter.

After the procedure executes, the value of the output parameter is stored in the @row_count variable. Then, the calling program can access this variable. In this figure, for example, the script uses a SELECT statement to display the value of the variable. However, it could also use an IF statement to check the value of the variable and perform an appropriate action.

In addition to input and output parameters, MySQL provides for a parameter that can be used for both input and output. An *input/output parameter* can store an initial value that's passed in from the calling program like an input parameter. However, the procedure can change this value and return it to a calling program like an output parameter. To identify an input/output parameter, you must code the INOUT keyword before the name of the parameter. Although this can be useful in some situations, it can also be confusing. As a result, it often makes sense to avoid the use of input/output parameters.

### The syntax for declaring input and output parameters

```
[IN|OUT|INOUT] parameter_name data_type
```

### A stored procedure that uses input and output parameters

```
DELIMITER //

CREATE PROCEDURE update_invoices_credit_total
(
  IN  invoice_id_param    INT,
  IN  credit_total_param  DECIMAL(9,2),
  OUT update_count        INT
)
BEGIN
  DECLARE sql_error BOOL DEFAULT FALSE;

  DECLARE CONTINUE HANDLER FOR SQLEXCEPTION
    SET sql_error = TRUE;

  START TRANSACTION;

  UPDATE invoices
  SET credit_total = credit_total_param
  WHERE invoice_id = invoice_id_param;

  IF sql_error = FALSE THEN
    SET update_count = 1;
    COMMIT;
  ELSE
    SET update_count = 0;
    ROLLBACK;
  END IF;
END//
```

### A script that calls the stored procedure and uses the output parameter

```
CALL update_invoices_credit_total(56, 200, @row_count);
SELECT CONCAT('row_count: ', @row_count) AS update_count;
```

### Description

- *Input parameters* accept values that are passed from the calling program. These values cannot be changed by the body of the stored procedure. By default, parameters are defined as input parameters. As a result, the IN keyword is optional for identifying input parameters.
- *Output parameters* store values that are passed back to the calling program. These values must be set by the body of the stored procedure. To identify an output parameter, you must code the OUT keyword.
- *Input/output parameters* can store an initial value that's passed from the calling program. However, the body of the stored procedure can change this parameter. To identify an input/output parameter, you must code the INOUT keyword.
- When you work with output parameters or input/output parameters, the calling program typically passes a *user variable* to the parameter list.

Figure 15-2 How to code input and output parameters

## How to set a default value for a parameter

Figure 15-3 shows how to set a default value for a parameter. This is useful if a null value is passed for the parameter. Then, the default value can be used instead of the null value.

In this figure, the stored procedure sets a default value for the second parameter, which contains the credit total to be assigned to the credit_total column for an invoice. To do that, it uses an IF statement to check if the parameter contains a null value. If it does, the value of the parameter is set to 100.

The two CALL statements in this figure show two ways that you can provide values to the stored procedure. Here, the first CALL statement supplies a value for each parameter. As a result, the credit total for the invoice is set to 200. In contrast, the second CALL statement supplies a value of NULL for the second parameter. In that case, the credit total for the invoice is set to the default value of 100.

When you set default values for one or more parameters, it usually makes sense to code these parameters at the end of the parameter list. That way, when you call the stored procedure, you can code all the non-null values first.

## A CREATE PROCEDURE statement that provides a default value

```
DELIMITER //

CREATE PROCEDURE update_invoices_credit_total
(
  invoice_id_param      INT,
  credit_total_param    DECIMAL(9,2)
)
BEGIN
  DECLARE sql_error BOOL DEFAULT FALSE;

  DECLARE CONTINUE HANDLER FOR SQLEXCEPTION
    SET sql_error = TRUE;

  -- Set default values for NULL values
  IF credit_total_param IS NULL THEN
    SET credit_total_param = 100;
  END IF;

  START TRANSACTION;

  UPDATE invoices
  SET credit_total = credit_total_param
  WHERE invoice_id = invoice_id_param;

  IF sql_error = FALSE THEN
    COMMIT;
  ELSE
    ROLLBACK;
  END IF;
END//
```

## A statement that calls the stored procedure

```
CALL update_invoices_credit_total(56, 200);
```

## Another statement that calls the stored procedure

```
CALL update_invoices_credit_total(56, NULL);
```

## Description

- You can provide a default value for a parameter so that if the calling program passes a null value for the parameter, the default value is used instead.
- To set a default value for a parameter, you can use an IF statement to check if the parameter contains a null value. If it does, you can assign a default value to the parameter.
- It's a good programming practice to code your CREATE PROCEDURE statements so they list parameters that require values first, followed by parameters that allow null values.

Figure 15-3 How to set a default value for a parameter

## How to validate parameters and raise errors

Within a stored procedure, it's generally considered a good practice to prevent errors by checking the parameters before they're used to make sure they're valid. This is often referred to as *data validation*. Then, if the data isn't valid, you can execute code that makes it valid, or you can *raise an error*, which returns the error to the calling program.

Figure 15-4 shows how to raise an error using one of the predefined errors that are available from MySQL. To do that, you code the SIGNAL statement followed by the SQLSTATE keyword, followed by a SQLSTATE code. Then, you can optionally include a SET statement that sets a message and MySQL error code for the error.

In this figure, for example, the IF statement checks whether the value of the second parameter is less than zero. If it is, the SIGNAL statement raises an error with a SQLSTATE code of 22003, a MySQL code of 1146, and a message that indicates that the credit total column must be greater than or equal to 0. These SQLSTATE and MySQL codes are commonly used to validate parameters since they are used to indicate that the value is out of range for the column.

If the calling program doesn't contain code to catch this error, the system displays an error message. In this figure, for example, the CALL statement passes a negative value to the second parameter, which causes the error to be raised. As a result, the system displays an error message that contains the MySQL error code and message specified by the SIGNAL statement. Since this error code and message accurately describe the error, the programmer or user of the calling program should be able to identify and fix the problem.

On the other hand, if the calling program catches this error, it can include code that handles the error. For example, the calling program can handle the error by printing a user-friendly message and asking the user to input the data again.

## The syntax of the SIGNAL statement

```
SIGNAL SQLSTATE [VALUE] sqlstate_value
[SET MESSAGE_TEXT = message[, MYSQL_ERRNO = mysql_error_number]]
```

## A stored procedure that raises a predefined exception

```
DELIMITER //

CREATE PROCEDURE update_invoices_credit_total
(
  invoice_id_param     INT,
  credit_total_param   DECIMAL(9,2)
)
BEGIN
  -- Validate paramater values
  IF credit_total_param < 0 THEN
    SIGNAL SQLSTATE '22003'
      SET MESSAGE_TEXT =
        'The credit_total column must be greater than or equal to 0.',
      MYSQL_ERRNO = 1146;
  ELSEIF credit_total_param >= 1000 THEN
    SIGNAL SQLSTATE '22003'
      SET MESSAGE_TEXT =
        'The credit_total column must be less than 1000.',
      MYSQL_ERRNO = 1146;
  END IF;

  -- Set default values for parameters
  IF credit_total_param IS NULL THEN
    SET credit_total_param = 100;
  END IF;

  UPDATE invoices
  SET credit_total = credit_total_param
  WHERE invoice_id = invoice_id_param;
END//
```

## A statement that calls the procedure

```
CALL update_invoices_credit_total(56, -100);
```

### The response from the system

```
Error Code: 1146.
The credit_total column must be greater than or equal to 0.
```

## Description

- It's generally considered a good practice to validate the data within a stored procedure before using the data. This is referred to as *data validation*.
- The SIGNAL statement *raises* an error. When you raise an error, you must specify a SQLSTATE code as specified in chapter 13. In addition, you can optionally specify an error message or MySQL error number.
- When you raise an error, MySQL returns the error to the caller in the same way that it returns errors that are raised by the database engine. Then, the calling program can handle the error.

Figure 15-4 How to validate parameters and raise errors

## A stored procedure that inserts a row

Figure 15-5 presents a stored procedure that inserts new rows into the invoices table. This should give you a better idea of how you can use stored procedures.

This procedure uses six parameters that correspond to six of the columns in the Invoices table. All of these parameters are input parameters, and each parameter is assigned the same data type as the matching column in the Invoices table. As a result, if the calling program passes a value that can't be converted to the proper data type, an error will be raised when the procedure is called.

None of these parameters corresponds to the invoice_id column since that column is an auto increment column. Similarly, the stored procedure sets a default value for the last two parameters. As a result, if the calling program provides a null value for these parameters, the procedure automatically sets a default value for them.

The body of the procedure begins by declaring three variables. Of these variables, the first two have data types that correspond to columns in the invoices table. However, the third one uses the INT data type to store the number of days before the invoice is due.

All three of these variables have a suffix of "_var" while all of the parameters defined earlier have a suffix of "_param". This makes it easy to tell the difference between the parameters that are passed to the procedure from the calling program and the variables that are used within the procedure.

After the variables are declared, the procedure begins by using an IF statement to check the value of the parameter for the invoice_total column to see if it is less than zero. If so, the procedure uses the SIGNAL statement to raise an error with an appropriate error code and message. This statement exits the stored procedure and returns the error to the calling program. Similarly, the ELSEIF clause checks whether this parameter is greater than one million. If so, it raises an appropriate error. Although this figure only uses this IF statement to check for two conditions, it's common to code a series of IF statements like this one to provide more extensive data validation.

Next, another IF statement is used to check the terms_id parameter for a null value. If the parameter is null, a SELECT statement gets the value of the default_terms_id column for the vendor and stores it in the terms_id variable. If this parameter isn't null, the value of the terms_id parameter is assigned to the terms_id variable.

The next IF statement is similar. It checks the value of the parameter for the invoice_due_date column for a null value. If the parameter is null, a SELECT statement uses the value of the terms_id variable to get the number of days until the invoice is due from the terms table, and it stores this value in the terms_due_days variable. Then, it calculates a due date for the invoice by using the DATE_ADD function to add the number of days to the invoice date. If the invoice_due_date parameter isn't null, though, this code sets the invoice_due_date variable to the value that's stored in the parameter.

## A stored procedure that validates the data in a new invoice

```
DELIMITER //

CREATE PROCEDURE insert_invoice
(
  vendor_id_param        INT,
  invoice_number_param   VARCHAR(50),
  invoice_date_param     DATE,
  invoice_total_param    DECIMAL(9,2),
  terms_id_param         INT,
  invoice_due_date_param DATE
)
BEGIN
  DECLARE terms_id_var           INT;
  DECLARE invoice_due_date_var   DATE;
  DECLARE terms_due_days_var     INT;

  -- Validate paramater values
  IF invoice_total_param < 0 THEN
    SIGNAL SQLSTATE '22003'
      SET MESSAGE_TEXT =
        'The invoice_total column must be a positive number.',
      MYSQL_ERRNO = 1264;
  ELSEIF invoice_total_param >= 1000000 THEN
    SIGNAL SQLSTATE '22003'
      SET MESSAGE_TEXT =
        'The invoice_total column must be less than 1,000,000.',
      MYSQL_ERRNO = 1264;
  END IF;

  -- Set default values for parameters
  IF terms_id_param IS NULL THEN
    SELECT default_terms_id INTO terms_id_var
    FROM vendors WHERE vendor_id = vendor_id_param;
  ELSE
    SET terms_id_var = terms_id_param;
  END IF;
  IF invoice_due_date_param IS NULL THEN
    SELECT terms_due_days INTO terms_due_days_var
      FROM terms WHERE terms_id = terms_id_var;
    SELECT DATE_ADD(invoice_date_param, INTERVAL terms_due_days_var DAY)
      INTO invoice_due_date_var;
  ELSE
    SET invoice_due_date_var = invoice_due_date_param;
  END IF;

  INSERT INTO invoices
         (vendor_id, invoice_number, invoice_date,
          invoice_total, terms_id, invoice_due_date)
  VALUES (vendor_id_param, invoice_number_param, invoice_date_param,
          invoice_total_param, terms_id_var, invoice_due_date_var);
END//
```

Figure 15-5 A stored procedure that inserts a row (part 1 of 2)

After the values have been set for the variables for the terms_id and invoice_due_date columns, this procedure executes an INSERT statement. If this statement executes successfully, the row is inserted into the database.

In most cases, a stored procedure like this is called from an application program. However, to test a procedure before it's used by an application program, you can use CALL statements like the ones in part 2 of figure 15-5.

The first two CALL statements provide valid values that successfully insert a new row. Of these statements, the first supplies non-null values for all of the parameters for the procedure. The second supplies non-null values for the first four parameters, but not for the last two. This shows that the first four parameters are the only parameters that require non-null values.

The third CALL statement provides a negative number for the invoice total parameter. As a result, this CALL statement causes the stored procedure to raise an error. Since the CALL statement doesn't handle this error, an error message like the one shown in this figure is displayed. However, if you call the stored procedure from another stored procedure or from an application, you can include code that handles the error.

### Two statements that call the stored procedure

```
CALL insert_invoice(34, 'ZXA-080', '2023-01-18', 14092.59,
                    3, '2023-03-18');

CALL insert_invoice(34, 'ZXA-082', '2023-01-18', 14092.59,
                    NULL, NULL);
```

#### The message from the system for a successful insert

```
1 row(s) affected
```

### A statement that raises an error

```
CALL insert_invoice(34, 'ZXA-080', '2023-01-18', -14092.59,
                    NULL, NULL);
```

#### The message from the system when a validation error occurs

```
Error Code: 1264. The invoice_total column must be a positive number.
```

### Description

- If the data for each of the columns of the row is valid, the procedure executes an INSERT statement to insert the row. Otherwise, the procedure or database engine raises an error and exits the procedure.
- If an application program calls this procedure, it can handle any errors that are raised by the procedure or by the database engine.

Figure 15-5 A stored procedure that inserts a row (part 2 of 2)

## How to work with user variables

In figure 15-2, you saw an example that stores the value of an output parameter in a user variable. Now, figure 15-6 presents some additional skills for working with user variables.

A *user variable* is a special type of MySQL variable that's globally available to the current user. Unlike the variables you learned about in chapter 13, you don't need to code a DECLARE statement to declare the data type of a user variable. That's because a user variable can store various data types including string, numeric, and date/time types. Instead, you can create and work with a user variable simply by coding an at sign (@) in front of its name. For example, you can set the value of a user variable using the SET statement syntax shown at the top of this figure.

A user variable is only available to the current user as long as the user remains connected to the server. When the user disconnects, MySQL releases the variable. In addition, a user variable is only available to the current user and cannot be seen or accessed by other users.

Since a user variable is globally available to the current user, multiple stored programs can share the variable. In this figure, for instance, the stored procedure named set_global_count sets the user variable named @count to a specified INT value. Then, the stored procedure named increment_global_count increments the @count variable by a value of 1. To set the value of this user variable, both of these stored procedures use the SET statement.

Although user variables are often used within stored programs, you can also access user variables outside of stored programs. Then, you can use standard SQL statements such as the SELECT statement to work with them. In this figure, for instance, the SELECT statement displays the value of the @count variable after it has been set and incremented by CALL statements to the two stored procedures. You can also use the SET statement outside of a stored program to set the value of a user variable.

Note that the body of both stored procedures shown in this figure consist of a single statement. Because of that, they could be coded without using a block of code like this:

```
CREATE PROCEDURE set_global_count
(
  count_var INT
)
  SET @count = count_var;

CREATE PROCEDURE increment_global_count()
  SET @count = @count + 1;
```

The advantage of not specifying a block of code is that you don't have to change the delimiter or identify the start and end of the block of code. The disadvantage is that it's more difficult to add statements to the procedure if you ever need to do that. In most cases, you'll want to code the body of a stored procedure within a block.

## The syntax for setting a user variable

```
SET @variable_name = expression
```

## Two stored procedures that work with the same user variable

```
DELIMITER //

CREATE PROCEDURE set_global_count
(
  count_var INT
)
BEGIN
  SET @count = count_var;
END//

CREATE PROCEDURE increment_global_count()
BEGIN
  SET @count = @count + 1;
END//
```

## Two statements that call these stored procedures

```
CALL set_global_count(100);
CALL increment_global_count();
```

## A SELECT statement that directly accesses the user variable

```
SELECT @count AS count_var
```

| count_var |
|---|
| 101 |

## Description

- A *user variable* is a special type of MySQL variable that's globally available to the current user.
- To identify a variable as a user variable, you code an at sign (@) in front of the variable name.
- A user variable is only available to the current user and cannot be seen or accessed by other users.
- A user variable is available as long as the user remains connected to the server, but it is released when the user disconnects.
- A user variable can store various data types including string, numeric, and date/time types. However, you don't have to declare a data type for a user variable.
- A user variable is available from statements coded both inside and outside of stored programs.

Figure 15-6 How to work with user variables

## How to work with prepared statements

A *prepared statement* is a pre-compiled statement that can include placeholders for parameters whose values can vary. Then, when you execute the statement, you can set the values of those parameters. MySQL 8.0 and later provides support for prepared statements, and figure 15-7 shows how to work with them using the PREPARE, EXECUTE, and DEALLOCATE PREPARE statements.

The example in this figure begins by creating a stored procedure named select_invoices. This stored procedure includes two input parameters for the minimum date and the minimum total.

Within the stored procedure, the PREPARE statement creates a prepared SELECT statement that includes two question marks as placeholders. These placeholders indicate where the parameter values will be substituted when the stored procedure is called. In this case, the value of the date parameter will be substituted for the first placeholder, and the value of the total parameter will be substituted for the second placeholder. Note that these placeholders are coded where you would normally code a literal value such as a date or a number. You can't code a placeholder anywhere you wouldn't code a literal value, such as for a SQL keyword, a table name, or a column name.

After the SELECT statement is prepared, the two SET statements create user variables to store the values of the two parameters of the procedure. This is necessary because the EXECUTE statement only accepts user variables in its USING clause.

Next, the EXECUTE statement executes the prepared statement and names the two variables to be passed as parameters. This returns the result set of the SELECT statement. For this to work, the USING clause must name the user variables in the same sequence that the placeholders are coded in the SELECT statement. In addition, the number of user variables must match the number of placeholders in the SELECT statement.

Finally, the DEALLOCATE PREPARE statement releases the resources used by the prepared statement. Once a prepared statement is released, it can no longer be executed. In general, it's a good practice to deallocate prepared statements after you're done using them.

Prepared statements provide several benefits. To start, they allow you to dynamically change values used by a SQL statement. When executed more than once, they are also more efficient than regular statements because they are precompiled and optimized. In addition, they prevent most types of SQL injection attacks. In a *SQL injection attack*, an attacker can append SQL statements to a parameter that's passed to your procedure. Because the EXECUTE statement can only execute one statement at a time, however, this type of injection attack will fail.

Although it's not shown in this figure, you should know that you can also use prepared statements with *dynamic SQL*. Dynamic SQL lets you use procedural code to build a string that contains a SQL statement that includes the values of one or more parameters that have been inserted into it. Then, you can use the statements shown in this figure to prepare and execute the dynamic SQL.

## The syntax of the PREPARE statement

```
PREPARE statement FROM preparable_statement
```

## The syntax of the EXECUTE statement

```
EXECUTE statement [USING @var1 [, @var2] ...]
```

## The syntax of the DEALLOCATE PREPARE statement

```
{DEALLOCATE | DROP} PREPARE statement
```

## A script that creates a stored procedure that uses a prepared statement

```
DELIMITER //

CREATE PROCEDURE select_invoices
(
  min_date_param   DATE,
  min_total_param  DECIMAL(9,2)
)
BEGIN
  PREPARE statement FROM
    'SELECT invoice_id, invoice_number, invoice_date, invoice_total
     FROM invoices
     WHERE invoice_date > ? AND invoice_total > ?';

  SET @date = min_date_param;
  SET @total = min_total_param;

  EXECUTE statement USING @date, @total;

  DEALLOCATE PREPARE statement;
END//
```

## A statement that calls the stored procedure

```
CALL select_invoices('2022-07-25', 100);
```

| invoice_id | invoice_number | invoice_date | invoice_total |
|---|---|---|---|
| 114 | 963253249 | 2022-08-02 | 127.75 |
| 113 | 547480102 | 2022-08-01 | 224.00 |
| 112 | 0-2436 | 2022-07-31 | 10976.06 |

## Description

- *Prepared statements* were introduced with MySQL 8.0. They run more efficiently than regular SQL statements when executed repeatedly, and they are more secure than using dynamic SQL statements.
- The PREPARE statement creates a precompiled statement that can use question marks (?) to identify placeholders whose values can be supplied when the procedure is called.
- The EXECUTE statement can pass user variables to the prepared statement, with the first variable being substituted for the first placeholder, the second variable for the second placeholder, and so on.
- The values that are passed to a prepared statement must be stored as user variables.
- In general, it's a good practice to release the system resources for a prepared statement after you're done using it by deallocating the prepared statement.

Figure 15-7 How to work with prepared statements

Unfortunately, the use of dynamic SQL makes your code vulnerable to a SQL injection attack. As a result, you should avoid using dynamic SQL unless you understand the security risks and are comfortable with them.

## How to drop a stored procedure

Figure 15-8 shows how to drop a stored procedure. To do that, you can code the DROP PROCEDURE keywords followed by the name of the procedure. In this figure, the first example uses the CREATE PROCEDURE statement to create a procedure named clear_invoices_credit_total. Then, the second example uses the DROP PROCEDURE statement to drop that procedure.

If you attempt to drop a stored procedure that doesn't exist, MySQL returns an error. To prevent this error, you can add the optional IF EXISTS keywords to the DROP PROCEDURE statement as shown by the third example. Then, MySQL only attempts to drop the stored procedure if it exists.

If you drop a table or view used by a procedure, you should be sure to drop the procedure as well. If you don't, the procedure can still be called by any user or program that has been granted the appropriate privileges. Then, an error will occur because the table or view that the procedure depends on no longer exists.

## The syntax of the DROP PROCEDURE statement

```
DROP PROCEDURE [IF EXISTS] procedure_name
```

## A statement that creates a stored procedure

```
DELIMITER //

CREATE PROCEDURE clear_invoices_credit_total
(
  invoice_id_param  INT
)
BEGIN
  UPDATE invoices
  SET credit_total = 0
  WHERE invoice_id = invoice_id_param;
END//
```

## A statement that drops the stored procedure

```
DROP PROCEDURE clear_invoices_credit_total
```

## A statement that drops the stored procedure only if it exists

```
DROP PROCEDURE IF EXISTS clear_invoices_credit_total
```

## Description

- To drop a stored procedure from the database, use the DROP PROCEDURE statement.

Figure 15-8 How to drop a stored procedure

# How to code stored functions

In chapter 9, you learned about some of MySQL's built-in functions. Now, you'll learn how to create your own functions. These functions are referred to as *stored functions*, or just *functions*.

If you've worked with databases other than MySQL, you may be familiar with functions that return a result set. With MySQL, though, a function can only return a single value. This type of function is called a *scalar function*.

In many ways, the code for creating a function works similarly to the code for creating a stored procedure. The primary difference between stored procedures and functions is that a MySQL function always returns a single value.

## How to create and call a function

To create a function, you use the CREATE FUNCTION statement shown in figure 15-9. To start, you code the CREATE FUNCTION keywords, followed by the name of the function. In this figure, the first example shows how to create a function named get_vendor_id.

After the name of the function, you code a set of parentheses. Within the parentheses, you code the parameters for the function. In this figure, for example, the function contains a single parameter of the VARCHAR type that's named vendor_name_param. Since this is similar to the way you declare parameters for a stored procedure, you shouldn't have much trouble understanding how this works. The main difference is that functions only allow input parameters. In other words, functions don't allow output or input/output parameters.

After the parentheses, you code the RETURNS keyword, followed by the data type that's returned by the function. In this figure, the example returns a value of the INT type.

After the declaration of the return type, you can code one or more characteristics that describe the function. In this example, the function includes the DETERMINISTIC and READS SQL DATA characteristics. You'll learn more about these and other characteristics in the next figure.

After any characteristics, you code the body of the function. In this figure, the procedure consists of a block of code that begins by declaring a variable of the INT type named vendor_id_var. Then, it uses a SELECT statement to get the vendor ID value that corresponds to the vendor name parameter and to store this value in the variable. Finally, it uses the RETURN statement to return this value to the calling program.

To call a function, you can use it in an expression as if it's one of MySQL's built-in functions. Then, the value that's returned by the function is substituted for the function. In this figure, the last example shows how to use the get_vendor_id function within a SELECT statement to return the vendor ID value for the vendor with the name of "IBM".

If you find yourself repeatedly coding the same expression within a SQL statement, you may want to create a scalar function for the expression. Then, you can use that function in place of the expression, which can save you coding time and make your code easier to maintain.

## The syntax of the CREATE FUNCTION statement

```
CREATE FUNCTION function_name
(
    [parameter_name_1 data_type]
    [, parameter_name_2 data_type]...
)
RETURNS data_type
[NOT] DETERMINISTIC
{CONTAINS SQL|NO SQL|READS SQL DATA|MODIFIES SQL DATA}
function_body
```

## A function that returns the vendor ID that matches a vendor's name

```
DELIMITER //

CREATE FUNCTION get_vendor_id
(
   vendor_name_param VARCHAR(50)
)
RETURNS INT
DETERMINISTIC READS SQL DATA
BEGIN
  DECLARE vendor_id_var INT;

  SELECT vendor_id
  INTO vendor_id_var
  FROM vendors
  WHERE vendor_name = vendor_name_param;

  RETURN(vendor_id_var);
END//
```

## A SELECT statement that uses the function

```
SELECT invoice_number, invoice_total
FROM invoices
WHERE vendor_id = get_vendor_id('IBM');
```

### The response from the system

| | invoice_number | invoice_total |
|---|---|---|
| ▶ | QP58872 | 116.54 |
| | Q545443 | 1083.58 |

## Description

- A *stored function*, or just *function*, is an executable database object that contains procedural SQL code.
- With MySQL, you can only create *scalar functions*, which return a single value.
- To identify the data type that's returned by a function, you use the RETURNS keyword in the declaration for the function. Then, in the body of the function, you use the RETURN keyword to specify the value that's returned.
- A function can accept input parameters that work like the input parameters for a stored procedure.
- When you create a function, you can include one or more characteristics that describe the function.
- To call a stored function, you can use it in an expression just like a built-in function.

Figure 15-9 How to create and call a function

## How to use function characteristics

Figure 15-10 describes some of the characteristics you can code on the CREATE FUNCTION statement. If binary logging is enabled, you must code at least one of the DETERMINISTIC, NO SQL, or READS SQL DATA characteristics on a function. If you don't code at least one of these characteristics, MySQL displays an error and doesn't create the function. That's because these characteristics affect how statements that change the contents of a database are recorded in the *binary log*, which is a log that's used to record all changes that have been made to the contents of a database. This log is enabled by default with MySQL 8.0 but not with earlier releases of MySQL.

The DETERMINISTIC characteristic indicates that a function always produces the same results given the same input values and the same data. In figure 15-9, for example, the get_vendor_id function is *deterministic* because it always returns the same vendor ID value from the Vendors table for a given vendor name.

The get_vendor_id function also includes the READS SQL DATA characteristic. This indicates that it reads data from a database but doesn't write data to the database. This characteristic is optional, but it can improve the performance of the function.

In general, it's more common to use a stored procedure to modify the data in a database than it is to use a function. If a function modifies the data in a database, it should be marked as deterministic if two identical databases will remain identical after the function is executed with the same input values. In addition, you can mark the function with the optional MODIFIES SQL DATA characteristic to indicate that the function modifies data.

If you compare the get_vendor_id function in figure 15-9 to the rand_int function in this figure, you should get a better idea of how the DETERMINISTIC characteristic works. The rand_int function uses the built-in RAND function to get a random number between 0 and 1. Then, it multiplies that number by 1000, rounds it to a whole number, and returns the result. Because the RAND function can return a different number each time it's executed, the rand_int function can return any integer between 0 and 1000. That means it's *non-deterministic*. Because the NOT DETERMINISTIC characteristic is the default characteristic, you don't need to code it. However, it's included in this example to make it clear to other programmers that this function is non-deterministic.

The rand_int function also includes the NO SQL characteristic. This characteristic indicates that the function doesn't include any SQL statements. It's required because binary logging is enabled and the DETERMINISTIC and READS SQL DATA characteristics don't apply.

If you don't code a NO SQL, READS SQL DATA, or MODIFIES SQL DATA characteristic in a function, it will default to CONTAINS SQL. This characteristic indicates that the function doesn't use SQL statements to read from or write to a database. However, it may contain other statements such as a SET statement that sets global variables. In most cases, that's not what you want. As a result, it's a good practice to include one of the other characteristics. In most cases, that means including the READS SQL DATA characteristic.

## Some of the characteristics for a MySQL function

| Characteristic | Description |
|---|---|
| DETERMINISTIC | Indicates that the function always produces the same results given the same input values. |
| NOT DETERMINISTIC | Indicates that the function does not always produce the same results given the same input values. This is the default. |
| READS SQL DATA | Indicates that the function contains one or more SQL statements such as SELECT statements that read data from a database but no statements that write data. |
| MODIFIES SQL DATA | Indicates that the function contains SQL statements such as INSERT, UPDATE, and DELETE statements that write data to a database. |
| CONTAINS SQL | Indicates that the function contains one or more SQL statements such as SET statements that don't read from or write to a database. This is the default. |
| NO SQL | Indicates that the function doesn't contain SQL statements. |

## A function that gets a random number

```
DELIMITER //

CREATE FUNCTION rand_int()
RETURNS INT
NOT DETERMINISTIC
NO SQL
BEGIN
  RETURN ROUND(RAND() * 1000);
END//
```

## A SELECT statement that uses the function

```
SELECT rand_int() AS random_number;
```

| random_number |
|---|
| 315 |

## Description

- If binary logging is enabled, which it is by default with MySQL 8.0 and later, each function must include the DETERMINISTIC, NO SQL, or READS SQL DATA characteristic. To override this requirement, you can set the log_bin_trust_function_creators system variable to 1 (ON). For more information on working with system variables, see chapter 17.
- The *binary log* contains a record of all the changes that have been made to the contents of a database. It can be used for replication between two servers.
- Unless you code the DETERMINISTIC keyword, a function is considered to be *non-deterministic*. This affects the type of information that's stored in the binary log.
- It's more common to use a stored procedure rather than a function to modify a database.

Figure 15-10 How to use function characteristics

## A function that calculates balance due

Figure 15-11 shows a function that calculates the balance due for an invoice. To do that, this function accepts a parameter that contains an invoice ID value. Then, the body of the function calculates the balance due, stores the result of the calculation in a variable named balance_due_var, and uses the RETURN statement to return that value.

The SELECT statement in this figure uses this function to return the balance due for the specified invoice ID value. Note that calling the function like this:

```
get_balance_due(invoice_id) AS balance_due
```

has the same effect as performing a calculation like this:

```
invoice_total - payment_total - credit_total AS balance_due
```

However, using a function has two advantages. First, the code is shorter, which makes it easier to type. Second, the code for calculating the balance due is stored in a single location. As a result, if the formula for calculating the balance due changes, you only need to change it in one location.

## A function that calculates balance due

```
DELIMITER //

CREATE FUNCTION get_balance_due
(
   invoice_id_param INT
)
RETURNS DECIMAL(9,2)
DETERMINISTIC READS SQL DATA
BEGIN
  DECLARE balance_due_var DECIMAL(9,2);

  SELECT invoice_total - payment_total - credit_total
  INTO balance_due_var
  FROM invoices
  WHERE invoice_id = invoice_id_param;

  RETURN balance_due_var;
END//
```

## A statement that calls the function

```
SELECT vendor_id, invoice_number,
       get_balance_due(invoice_id) AS balance_due
FROM invoices
WHERE vendor_id = 37
```

### The response from the system

| vendor_id | invoice_number | balance_due |
|---|---|---|
| 37 | 547481328 | 0.00 |
| 37 | 547479217 | 0.00 |
| 37 | 547480102 | 224.00 |

## Description

- This function accepts a single parameter that specifies the ID for an invoice, and it returns the balance due for that invoice.

Figure 15-11 A function that calculates balance due

## How to drop a function

Figure 15-12 shows how to drop a function. To do that, you code the DROP FUNCTION keywords followed by the name of the function. This is illustrated by the third example in this figure. In addition, the fourth example illustrates how you can add the IF EXISTS keywords to check if a function exists before dropping it.

To start, though, the first example presents another function named get_sum_balance_due. This function uses the aggregate SUM function described in chapter 5 to return the sum of the total balance due for the specified vendor. What's interesting here is that this function calls the get_balance_due function presented in the previous figure. In other words, this function "depends" on the get_balance_due function.

Then, the second example shows a SELECT statement that uses the get_sum_balance_due function. This statement gets the invoice number and balance due for each invoice for the vendor with an ID of 37. In addition, it gets the total balance due for that vendor.

Like stored procedures, functions depend on underlying database objects such as tables and views as well as other procedures and functions. Because of that, if you drop a database object that a function depends on, the function won't work properly. For example, if you drop the get_balance_due function, the get_sum_balance_due function won't work. As a result, you should avoid dropping any database objects that other database objects depend on.

## The syntax of the DROP FUNCTION statement

```
DROP FUNCTION [IF EXISTS] function_name
```

## A statement that creates a function

```
DELIMITER //

CREATE FUNCTION get_sum_balance_due
(
   vendor_id_param INT
)
RETURNS DECIMAL(9,2)
DETERMINISTIC READS SQL DATA
BEGIN
  DECLARE sum_balance_due_var DECIMAL(9,2);

  SELECT SUM(get_balance_due(invoice_id))
  INTO sum_balance_due_var
  FROM invoices
  WHERE vendor_id = vendor_id_param;

  RETURN sum_balance_due_var;
END//
```

## A statement that calls the function

```
SELECT vendor_id, invoice_number,
       get_balance_due(invoice_id) AS balance_due,
       get_sum_balance_due(vendor_id) AS sum_balance_due
FROM invoices
WHERE vendor_id = 37;
```

### The response from the system

| vendor_id | invoice_number | balance_due | sum_balance_due |
|---|---|---|---|
| 37 | 547481328 | 0.00 | 224.00 |
| 37 | 547479217 | 0.00 | 224.00 |
| 37 | 547480102 | 224.00 | 224.00 |

## A statement that drops the function

```
DROP FUNCTION get_sum_balance_due;
```

## A statement that drops the function only if it exists

```
DROP FUNCTION IF EXISTS get_sum_balance_due;
```

## Description

- To delete a function from the database, use the DROP FUNCTION statement. If you want to check whether the function exists before you drop it, add the optional IF EXISTS keywords.
- The function in this figure uses the get_balance_due function that's presented in the previous figure. As a result, if you drop the get_balance_due function, the function in this figure won't work.

Figure 15-12 How to drop a function

# How to use Workbench with procedures and functions

MySQL Workbench provides some basic features for working with stored procedures and functions. Figure 15-13 describes these features. Collectively, stored procedures and functions are sometimes referred to as *stored routines*.

## How to view and edit stored routines

To start, this figure shows how to use MySQL Workbench to view stored procedures and functions. To do that, you can connect to the server and then expand the Stored Procedures or Functions node for the appropriate database. In this figure, for example, I have expanded the Stored Procedures and Functions nodes for the AP database so you can see all of the procedures and functions that were presented in this chapter.

After you display the stored procedures or functions for a database, you can view the code for a procedure or function by right-clicking on its name and selecting the appropriate Alter item. Then, MySQL Workbench displays the procedure or function in a tab as shown in this figure. This may come in handy if you need to work with stored procedures or functions that were created by other programmers and you don't understand what they do. It may also come in handy if you need to modify one of these stored procedures or functions.

## How to create stored routines

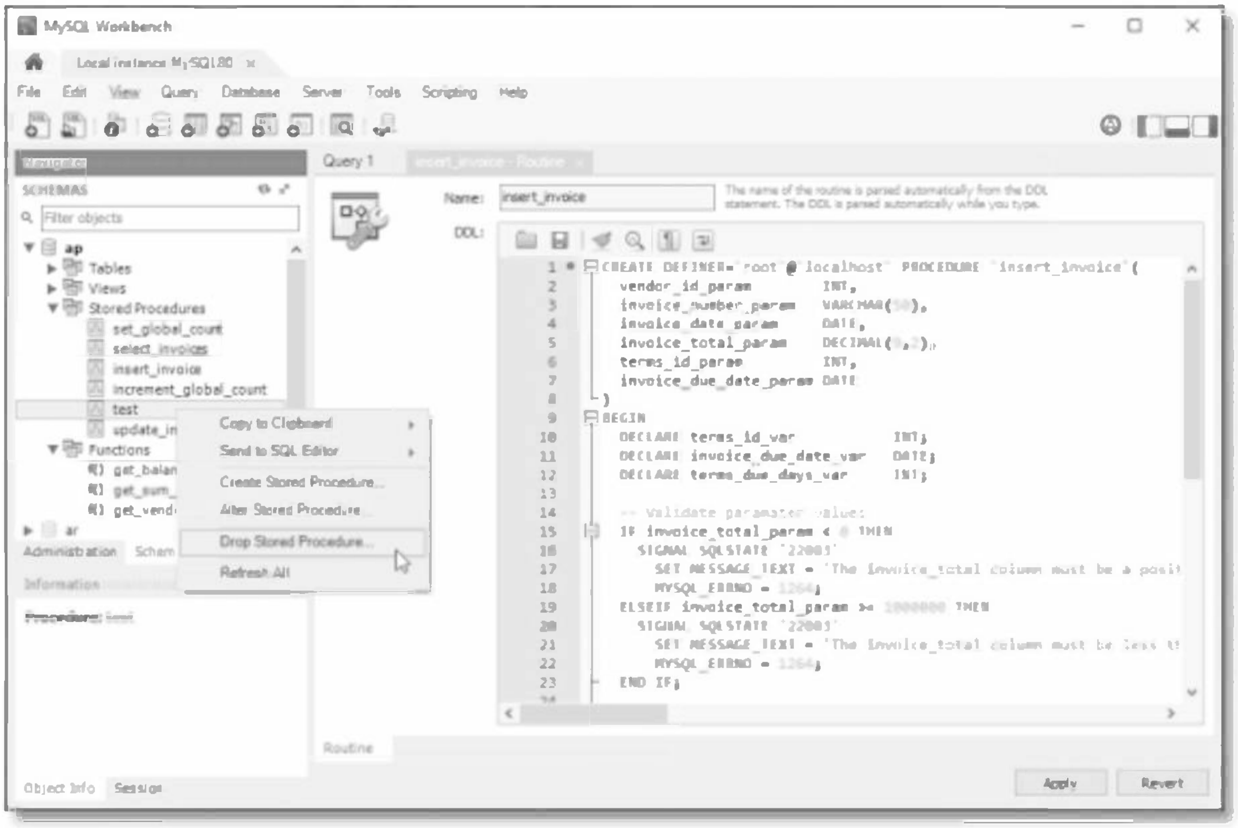
You can use MySQL Workbench to help you get started writing scripts that create stored procedures and functions. To do that, you can right-click on the Stored Procedures or Functions node and then select Create Stored Procedure or Create Function. When you do, Workbench generates some basic code for a procedure or function that includes a DELIMITER statement, a CREATE PROCEDURE or CREATE FUNCTION statement, and BEGIN and END keywords. Then, you can modify this code as necessary and add the code that's specific to the stored procedure or function you're creating.

After you create a stored procedure or function, it won't appear in the Navigator window right away. To display it, you can refresh the Navigator window. The easiest way to do that is to click the Refresh button near the upper right corner of the Navigator window.

## How to drop stored routines

Once a stored procedure or function is displayed in the Navigator window, you can drop it by right-clicking on it and selecting Drop Procedure or Drop Function. Then, you can use the resulting dialog box to confirm the drop.

### A stored procedure displayed in MySQL Workbench




## Description

- To view the stored procedures and functions for a database, you can expand the node for the database. Then, you can expand the Stored Procedures or Functions node.
- To view the code for an existing procedure or function, right-click on its name and select Alter Stored Procedure or Alter Function.
- To create a new stored procedure, right-click on the Stored Procedures node and select Create Stored Procedure.
- To create a new function, right-click on the Functions node and select Create Function.
- After you create a new procedure or function, you can refresh the Navigator window to include it in the list of stored procedures or functions. To do that, click the Refresh button near the upper right corner of the Navigator window.
- To drop a procedure or function, right-click on its name and select Drop Stored Procedure or Drop Function. Then, use the resulting dialog box to confirm the drop.
- You can use the SHOW PROCEDURE STATUS and SHOW FUNCTION STATUS statements to display information about the stored procedures and functions on a server. For more information, see the MySQL Reference Manual.

Figure 15-13 How to create, view, and drop stored routines

# Perspective

In this chapter, you learned how to create two types of stored programs: procedures and functions. The focus of this chapter has been on the skills that SQL developers typically need for working with procedures and functions. However, you should know that there's a lot more to coding procedures and functions than what this chapter has shown. You can learn more by looking up "Stored Procedures and Functions" in the online documentation.

## Terms

stored procedure
sproc
procedure
parameter
compiling a procedure
calling a procedure
passing parameters by position
input parameter
output parameter
input/output parameter
user variable
data validation
raising an error
prepared statement
dynamic SQL
SQL injection attack
stored function
function
scalar function
binary log
deterministic function
non-deterministic function
stored routine

## Exercises

1. Write a script that creates and calls a stored procedure named insert_glaccount. First, code a statement that creates a procedure that adds a new row to the General_Ledger_Accounts table in the AP schema. To do that, this procedure should have two parameters, one for each of the two columns in this table. Then, code a CALL statement that tests this procedure. (Note that this table doesn't allow duplicate account descriptions.)
2. Write a script that creates and calls a stored function named test_glaccounts_description. First, create a function that tests whether an account description is already in the General_Ledger_Accounts table. To do that, this function should accept one parameter for the account description, and it should return a value of TRUE if the account description is in the table or FALSO if it isn't. (Note: If a SELECT statement doesn't return any data, it raises a NOT FOUND condition that your function can handle.)
3. Modify the script that you created in exercise 1 so it creates and calls a stored procedure named insert_glaccount_with_test. This procedure should use the function that you created in exercise 2 to test whether the account description is a duplicate before it issues the INSERT statement. If the account description is a duplicate, this procedure should raise an error with a SQLSTATE code of 23000, a MySQL code of 1062, and a message that says "Duplicate account description."
4. Write a script that creates and calls a stored procedure named insert_terms. First, code a statement that creates a procedure that adds a new row to the Terms table in the AP schema. To do that, this procedure should have two parameters: one for the terms_due_days column and another for the terms_description column.

   If the value for the description column is null, the stored procedure should be able to create a default value for the description column based on the value of the due days column. For example, for a due days column of 120, the description column should have a default value of "Net due 120 days". Then, code a CALL statement that tests this procedure.

# 16

# How to create triggers and events

Now that you've learned how to work with stored procedures and functions, you're ready to learn about two more types of stored programs: triggers and events. Triggers can be executed before or after an INSERT, UPDATE, or DELETE statement is executed on a table. As a result, they provide a powerful way to enforce data consistency, log changes to the database, and implement business rules. Events can be executed at a scheduled time. As a result, they provide a convenient way to automatically perform any task that needs to be run regularly, such as scheduled maintenance of tables.

# How to work with triggers

A *trigger* is a named database object that is executed, or *fired*, automatically when a particular type of SQL statement is executed. When using MySQL, a trigger is fired when an INSERT, UPDATE, or DELETE statement is executed on a table.

## How to create a BEFORE trigger

Figure 16-1 presents the syntax for the CREATE TRIGGER statement. To start, you code the CREATE TRIGGER keywords followed by the name of the trigger. In this figure, for instance, the first example creates a trigger named vendors_before_update. This name indicates that the trigger is associated with the Vendors table and that it is fired before an update. This chapter uses a similar naming convention for the other triggers.

After the name of the trigger, you code the BEFORE or AFTER keyword to indicate when the trigger is fired. Then, you identify the statement that causes the trigger to fire. Next, you code an ON clause that identifies the name of the table. In this figure, for instance, the first example creates a trigger that's executed before any UPDATE statements on the Vendors table.

Although each trigger is associated with a single table, you can code multiple BEFORE and AFTER triggers for the same event on the same table. Since this can be confusing to manage and debug, however, I recommend you have no more than one BEFORE and one AFTER trigger for each event.

After the ON clause, you code the FOR EACH ROW keywords. These keywords indicates that the trigger is a *row-level trigger* that fires for each row that's modified. For example, an UPDATE statement that updates five rows would cause the trigger to be executed five times, once for each row. Although some databases support other types of triggers, MySQL only supports row-level triggers.

Within the body of a trigger, you can use the NEW keyword to work with the new values in a row that's being inserted or updated. In this figure, for example, the NEW keyword gets and sets the value for the vendor_state column of the new row. If you try to use this keyword with a row that's being deleted, you'll get an error since this row doesn't have any new values.

You can also use the OLD keyword to work with the old values in a row that's being updated or deleted. You can't use this keyword with a row that's being inserted, though, since a new row doesn't have any old values.

The body of a trigger typically contains a block of code that's identified by the BEGIN and END keywords. In this figure, for example, the body of the trigger contains a block of code with a single statement that updates the vendor_state column so state codes are always stored with uppercase letters. To accomplish that, this statement uses the UPPER function to convert the new value for the vendor_state column to uppercase.

## The syntax of the CREATE TRIGGER statement

```
CREATE TRIGGER trigger_name
  {BEFORE|AFTER} {INSERT|UPDATE|DELETE} ON table_name
  FOR EACH ROW
trigger_body
```

## A CREATE TRIGGER statement that capitalizes state abbreviations

```
DELIMITER //

CREATE TRIGGER vendors_before_update
  BEFORE UPDATE ON vendors
  FOR EACH ROW
BEGIN
  SET NEW.vendor_state = UPPER(NEW.vendor_state);
END//
```

## An UPDATE statement that fires the trigger

```
UPDATE vendors
SET vendor_state = 'wi'
WHERE vendor_id = 1
```

## A SELECT statement that shows the new row

```
SELECT vendor_name, vendor_state
FROM vendors
WHERE vendor_id = 1
```

| vendor_name | vendor_state |
|---|---|
| US Postal Service | WI |

## Description

- A *trigger* is a named database object that executes, or *fires*, in response to an INSERT, UPDATE, or DELETE statement.
- You can fire a trigger before or after an INSERT, UPDATE, or DELETE statement is executed on a table.
- You must specify the FOR EACH ROW keywords after the table name. This creates a *row-level trigger* that fires once for each row that's modified.
- You can use the OLD and NEW keywords to get and set the values for the columns. OLD refers the values of an existing row before it's updated or deleted, and NEW refers to either the values of a new row being inserted or the values of an existing row after it's updated.

Figure 16-1 How to create a BEFORE trigger

In the last chapter, you learned that if the body of a stored procedure or function consists of a single statement, it can be coded without specifying a block of code. The same thing applies to triggers. For example, the trigger in this figure could be coded like this:

```
CREATE TRIGGER vendors_before_update
  BEFORE UPDATE ON vendors
  FOR EACH ROW
  SET NEW.vendor_state = UPPER(NEW.vendor_state);
```

Like stored procedures and functions, the advantage of not specifying a block of code for a trigger is that you don't have to change the delimiter or identify the start and end of the block of code. The disadvantage is that it's more difficult to add statements to the trigger if you later decide that you want the trigger to do more work.

## How to use a trigger to enforce data consistency

Triggers are commonly used to enforce data consistency. For example, the sum of line item amounts for an invoice in the Invoice_Line_Items table should always be equal to the corresponding invoice total amount in the Invoices table. Unfortunately, you can't enforce this rule using a constraint on either the Invoices table or the Invoice_Line_Items table. However, you can use a trigger like the one in figure 16-2 to enforce this rule when an invoice amount is updated.

The trigger shown here fires before an UPDATE statement attempts to update the invoice_total column in the Invoices table. When this trigger fires, it checks if the sum of the line items is equal to the invoice total. If it isn't, the trigger raises an error with an SQLSTATE code of "HY000", which indicates a general error. Then, the application that issued the UPDATE statement can handle the error.

Although this example isn't entirely realistic, you can use triggers like this to enforce business rules or to verify data consistency. Since you can program a trigger to accommodate many situations, triggers are more flexible than constraints.

## A trigger that validates line item amounts when updating an invoice

```
DELIMITER //

CREATE TRIGGER invoices_before_update
  BEFORE UPDATE ON invoices
  FOR EACH ROW
BEGIN
  DECLARE sum_line_item_amount DECIMAL(9,2);

  SELECT SUM(line_item_amount)
  INTO sum_line_item_amount
  FROM invoice_line_items
  WHERE invoice_id = NEW.invoice_id;

  IF sum_line_item_amount != NEW.invoice_total THEN
    SIGNAL SQLSTATE 'HY000'
      SET MESSAGE_TEXT = 'Line item total must match invoice total.';
  END IF;
END//
```

## An UPDATE statement that fires the trigger

```
UPDATE invoices
SET invoice_total = 600
WHERE invoice_id = 100
```

### The message from the system

```
Error Code: 1644. Line item total must match invoice total.
```

## Description

- Triggers can be used to enforce rules for data consistency that can't be enforced by constraints.

Figure 16-2 How to use a trigger to enforce data consistency

## How to create an AFTER trigger

Triggers are commonly used to store information about actions that occur in a database so these actions can be reviewed later. In particular, AFTER triggers are used to store information about a statement after it executes. Figure 16-3 shows how this works.

To start, this figure shows a CREATE TABLE statement that creates a table named Invoices_Audit. This table contains five columns that store information about the action that occurred on the Invoices table. Of these columns, the first three store values from the Invoices table, and the last two store information about the action that caused the statement to execute.

After the CREATE TABLE statement, this figure shows two CREATE TRIGGER statements that add rows to the Invoices_Audit table. The first CREATE TRIGGER statement creates a trigger that executes after an INSERT statement is executed on the Invoices table. This trigger inserts the new values for the vendor_id, invoice_number, and invoice_total columns into the Invoices_Audit table. In addition, it inserts a string value of "Inserted" to indicate that the row has been inserted, and it uses the NOW function to insert the date and time of the action.

The second CREATE TRIGGER statement works similarly, but it executes after a DELETE statement. It inserts a string value of "Deleted" to indicate that the row has been deleted.

Note that the first trigger inserts the new values for the row that's being inserted since there aren't any old values for this row. However, the second trigger inserts the old values for the row that's being deleted since there aren't any new values for this row.

Although the example that's presented in this figure has been simplified, it presents all of the skills that you need for creating more complex audit tables. For example, if you're having a problem updating rows in a database, you can create an audit table and a trigger to store whatever data you want about each update. Then, the next time the update problem occurs, you can review the data in the audit table to identify the cause of the problem.

## A statement that creates an audit table for actions on the invoices table

```
CREATE TABLE invoices_audit
(
  vendor_id          INT              NOT NULL,
  invoice_number     VARCHAR(50)      NOT NULL,
  invoice_total      DECIMAL(9,2)     NOT NULL,
  action_type        VARCHAR(50)      NOT NULL,
  action_date        DATETIME         NOT NULL
)
```

## Two AFTER triggers that insert rows into the audit table

```
DELIMITER //

CREATE TRIGGER invoices_after_insert
  AFTER INSERT ON invoices
  FOR EACH ROW
BEGIN
    INSERT INTO invoices_audit VALUES
    (NEW.vendor_id, NEW.invoice_number, NEW.invoice_total,
    'INSERTED', NOW());
END//

CREATE TRIGGER invoices_after_delete
  AFTER DELETE ON invoices
  FOR EACH ROW
BEGIN
    INSERT INTO invoices_audit VALUES
    (OLD.vendor_id, OLD.invoice_number, OLD.invoice_total,
    'DELETED', NOW());
END//
```

## An INSERT statement that causes the first trigger to fire

```
INSERT INTO invoices VALUES
(115, 34, 'ZXA-080', '2023-02-01', 14092.59, 0, 0, 3, '2023-03-01', NULL)
```

## A DELETE statement that causes the second trigger to fire

```
DELETE FROM invoices WHERE invoice_id = 115
```

## A SELECT statement that retrieves the rows in the audit table

```
SELECT * FROM invoices_audit
```

| vendor_id | invoice_number | invoice_total | action_type | action_date |
|---|---|---|---|---|
| 34 | ZXA-080 | 14092.59 | INSERTED | 2023-07-27 10:04:40 |
| 34 | ZXA-080 | 14092.59 | DELETED | 2023-07-27 10:04:47 |

## Description

- You can use an AFTER trigger to insert rows into an audit table.

Figure 16-3 How to create an AFTER trigger

## How to view or drop triggers

When you're working with triggers, you often need to view all of the triggers that have been created for a database. Then, you can review information about those triggers, and you can drop them if they are no longer needed.

Figure 16-4 starts by showing how to use the SHOW TRIGGERS statement to view all the triggers in the current database. Usually, that's what you want. In some cases, though, you may want to use the IN clause to specify the database as shown in the second example.

The result set for the second example shows that the AP database contains four triggers, and it provides detailed information about each trigger. First, the Trigger column shows the name of each trigger. Second, the Event column shows the type of statement that causes the trigger to fire. Third, the Table column shows the table for the trigger. Here, three of these triggers are associated with the Invoices table and one with the Vendors table. Fourth, the Statement column shows the code for the body of the trigger. Fifth, the Timing column indicates whether the trigger is a BEFORE trigger or an AFTER trigger. After that, there are four other columns of information.

If a database contains a large number of triggers, you may want to use the LIKE clause to display just the triggers with names that match a specified pattern. In this figure, for instance, the third SHOW TRIGGERS statement only shows triggers that start with "ven". As a result, this statement shows just the UPDATE trigger that has been defined for the Vendors table.

Because MySQL doesn't provide a way to alter a trigger, you have to drop it and then create a new trigger to change the way it works. To drop a trigger, you code the DROP TRIGGER keywords followed by the name of the trigger. If you want, you can add the optional IF EXISTS keywords. Since this drops the trigger only if it exists, it prevents an error from occurring if the trigger doesn't exist.

MySQL doesn't provide a way to disable a trigger either. Instead, you have to drop the trigger and then create it again later. For example, you may want to drop the triggers for one or more tables before inserting a large number of rows. This can help the INSERT statements run faster, and it lets you insert data that isn't allowed by the triggers.

### A statement that lists all triggers in the current database

```
SHOW TRIGGERS
```

### A statement that lists all triggers in the specified database

```
SHOW TRIGGERS IN ap
```

| Trigger | Event | Table | Statement | Timing | Created |
|---|---|---|---|---|---|
| invoices_after_insert | INSERT | invoices | BEGIN INSERT INTO invoices_audit VALUES ... | AFTER | 2023-07-2 |
| invoices_before_update | UPDATE | invoices | BEGIN DECLARE sum_line_item_amount DECI... | BEFORE | 2023-07-2 |
| invoices_after_delete | DELETE | invoices | BEGIN INSERT INTO invoices_audit VALUES ... | AFTER | 2023-07-2 |
| vendors_before_update | UPDATE | vendors | BEGIN SET NEW.vendor_state = UPPER(NEW.... | BEFORE | 2023-07-2 |

### A statement that lists all triggers in a database that begin with "ven"

```
SHOW TRIGGERS IN ap LIKE 'ven%'
```

| Trigger | Event | Table | Statement | Timing | Created |
|---|---|---|---|---|---|
| vendors_before_update | UPDATE | vendors | BEGIN SET NEW.vendor_state = UPPER(NEW.... | BEFORE | 2023-07-2 |

### A statement that drops a trigger

```
DROP TRIGGER vendors_before_update
```

### A statement that drops a trigger only if it exists

```
DROP TRIGGER IF EXISTS vendors_before_update
```

### Description

- To view triggers, use the SHOW TRIGGERS statement. To filter the result set that's returned, include an IN clause or a LIKE clause.
- To drop a trigger, use the DROP TRIGGER statement. To be sure a trigger exists before it's dropped, include the IF EXISTS keywords.

Figure 16-4 How to view or drop triggers

# How to work with events

An *event*, or *scheduled event*, is a named database object that executes, or *fires*, according to the *event scheduler*. With MySQL 8.0 and later, the event scheduler is on by default. As a result, if you don't need to use events, you should turn the event scheduler off to save system resources.

## How to turn the event scheduler on or off

Figure 16-5 begins by showing how to check if the event scheduler is on. To do that, you can use the SHOW VARIABLES statement to view the variable named event_scheduler. Then, if the event scheduler isn't on, you'll need to turn it on before you can work with events. To do that, you can use the SET statement to set the value of the event_scheduler variable to ON.

Here, the ON keyword is a synonym for the INT value of 1. Conversely, the OFF keyword is a synonym for the INT value of 0. Since the ON and OFF keywords are easier to read than 1 and 0, this chapter uses these keywords.

When you use a SET statement to change the event_scheduler variable as shown in this figure, the change only applies until the server is restarted. However, if you want to make this change permanent, you can change this variable in MySQL's configuration file as described in the next chapter.

## How to create an event

Figure 16-5 also shows how to use the CREATE EVENT statement to create an event. You can use this statement to create a *one-time event* that occurs only once or a *recurring event* that repeats at a regular interval.

The first CREATE EVENT statement in this figure creates a one-time event named one_time_delete_audit_rows. To do that, this trigger uses the AT keyword to specify that the event should be executed one month from the current date and time. Then, it uses the DO keyword to identify the statements that the event should execute. Here, the statements include the BEGIN and END keywords that identify a block of code. Within that block, a single DELETE statement deletes all rows from the Invoices_Audit table that are more than one month old.

Like the code for other stored programs, the code for an event doesn't have to be coded within a block if it consists of a single statement. In this case, then, the event could have been coded like this:

```
CREATE EVENT one_time_delete_audit_rows
ON SCHEDULE AT NOW() + INTERVAL 1 MONTH
DO DELETE FROM invoices_audit
   WHERE action_date < NOW() - INTERVAL 1 MONTH;
```

This has the same advantage and disadvantage as it does with other stored programs.

## A statement that checks if the event scheduler is on

```
SHOW VARIABLES LIKE 'event_scheduler'
```

| Variable_name | Value |
|---|---|
| event_scheduler | ON |

## A statement that turns the event scheduler on

```
SET GLOBAL event_scheduler = ON
```

## The syntax of the CREATE EVENT statement

```
CREATE EVENT [IF NOT EXISTS] event_name
ON SCHEDULE
  {AT timestamp | EVERY interval [STARTS timestamp] [ENDS timestamp]}
DO event_body
```

## A CREATE EVENT statement that executes only once

```
DELIMITER //

CREATE EVENT one_time_delete_audit_rows
ON SCHEDULE AT NOW() + INTERVAL 1 MONTH
DO BEGIN
  DELETE FROM invoices_audit WHERE action_date < NOW() - INTERVAL 1 MONTH;
END//
```

## A CREATE EVENT statement that executes every month

```
DELIMITER //

CREATE EVENT monthly_delete_audit_rows
ON SCHEDULE EVERY 1 MONTH
STARTS '2023-06-01'
DO BEGIN
  DELETE FROM invoices_audit WHERE action_date < NOW() - INTERVAL 1 MONTH;
END//
```

## Description

- An *event*, or *scheduled event*, is a named database object that executes, or *fires*, according to the *event scheduler*.
- Before you begin working with events, you need to be sure that the event scheduler is on. With MySQL 8.0 and later, it's on by default.
- To check the status of the event scheduler, you can use the SHOW VARIABLES statement to view the variable named event_scheduler.
- To turn the event scheduler on or off, you can use the SET statement to set the value of the event_scheduler variable to ON or OFF. Here, the ON and OFF keywords are synonyms for the INT values of 1 and 0.
- An event can be a *one-time event* that occurs once or a *recurring event* that occurs regularly at a specified interval.

Figure 16-5 How to create an event

The second CREATE EVENT statement in figure 16-5 creates a recurring event named monthly_delete_audit_rows. This statement works much like the first statement, except that it uses the EVERY keyword to specify that the event should be executed every month, and it uses the STARTS keyword to specify a starting date of midnight on June 1, 2023. As a result, at the end of every month, this event deletes all audit rows that are more than 1 month old.

The CREATE EVENT statement uses the date/time intervals that work with date functions. As a result, you can use the INTERVAL keyword along with other keywords such as MINUTE, HOUR, DAY, WEEK, MONTH, and YEAR to specify a time.

Although it's not illustrated here, you can also code the IF NOT EXISTS keywords on the CREATE EVENT statement. That way, the statement generates a warning instead of an error if the event already exists. If this statement is part of a script, that means that the script will continue executing instead of stopping at the error.

## How to view, alter, or drop events

The skills that you learned for viewing and dropping triggers are similar to the skills that you use to view and drop events. As a result, once you learn how to view and drop triggers, you shouldn't have much trouble viewing and dropping events. For instance, the first three examples in figure 16-6 show how to use the SHOW EVENTS statement to view events, and the last two examples show how to use the DROP EVENT statement to drop an event. Note that the last example includes the IF EXISTS keywords so a warning is generated instead of an error if the event doesn't exist. That way, if this statement is part of a script, the script will continue executing instead of stopping at the error.

When working with events, you can also use the ALTER EVENT statement to temporarily enable or disable an event or to rename an event. For instance, the fourth example in this figure shows how to use the ALTER EVENT statement to disable an event. To do that, you code the ALTER EVENT keywords, followed by the name of the event and the DISABLE keyword. Then, the fifth example shows how to use the ENABLE keyword to enable an event that has been disabled. Finally, the sixth example shows how to use the RENAME TO keywords to rename an event.

### A statement that lists all events on the server

```
SHOW EVENTS
```

### A statement that lists all events in a database

```
SHOW EVENTS IN ap
```

| | Db | Name | Definer | Time zone | Type | Execute at | Interval value |
|---|---|---|---|---|---|---|---|
| ▸ | ap | monthly_delete_audit_rows | root@localhost | SYSTEM | RECURRING | NULL | 1 |
| | ap | one_time_delete_audit_rows | root@localhost | SYSTEM | ONE TIME | 2023-08-27 10:09:55 | NULL |

### A statement that lists all events in a database that begin with "mon"

```
SHOW EVENTS IN ap LIKE 'mon%'
```

| | Db | Name | Definer | Time zone | Type | Execute at | Interval value | Interv field |
|---|---|---|---|---|---|---|---|---|
| ▸ | ap | monthly_delete_audit_rows | root@localhost | SYSTEM | RECURRING | NULL | 1 | MONTH |

### A statement that disables an event

```
ALTER EVENT monthly_delete_audit_rows DISABLE
```

### A statement that enables an event

```
ALTER EVENT monthly_delete_audit_rows ENABLE
```

### A statement that renames an event

```
ALTER EVENT one_time_delete_audit_rows RENAME TO one_time_delete_audits
```

### A statement that drops an event

```
DROP EVENT monthly_delete_audit_rows
```

### A statement that drops an event only if it exists

```
DROP EVENT IF EXISTS monthly_delete_audit_rows
```

### Description

- To view events, use the SHOW EVENTS statement. To filter the result set that's returned, include an IN clause or a LIKE clause.
- To enable or disable an event, use the ALTER EVENT statement with the ENABLE or DISABLE keyword.
- To rename an event, use the ALTER EVENT statement with the RENAME TO keywords, followed by the new name.
- To drop an event, use the DROP EVENT statement. To be sure an event exists before it's dropped, include the IF EXISTS keywords.

Figure 16-6 How to view, alter, or drop events

# Perspective

In this chapter, you learned how to use triggers to perform tasks that would be difficult or impossible to perform with other features like constraints. At this point, you should be able to create and use triggers that enforce data consistency, implement business rules, and log changes to the database. In addition, you should be able to use events to automatically perform tasks according to a schedule.

## Terms

trigger
fire a trigger
row-level trigger
event
scheduled event
fire an event
event scheduler
one-time event
recurring event

## Exercises

1. Open the trigger named invoices_before_update that was shown in figure 16-2. Then, modify it so it also raises an error whenever the payment total plus the credit total becomes larger than the invoice total in a row. Then, test this trigger with an appropriate UPDATE statement.
2. Create a trigger named invoices_after_update. This trigger should insert the old data about the invoice into the Invoices_Audit table after the row is updated. Then, test this trigger with an appropriate UPDATE statement. If the Invoices_Audit table doesn't exist, you can use the code shown in figure 16-3 to create it.
3. Check whether the event scheduler is turned on. If it isn't, code a statement that turns it on. Then, create an event that inserts a test row that contains test values into the Invoices_Audit table every minute. To make sure that this event has been created, code a SHOW EVENTS statement that views this event and a SELECT statement that views the data that's inserted into the Invoices_Audit table. Once you're sure this event is working correctly, code a DROP EVENT statement that drops the event.

# Section 5

## Database administration

If you want to become a database administrator, this section should get you started. Although it doesn't show you everything there is to know about database administration, it does teach you the skills you need to be the database administrator for a MySQL database that runs on a single, local server. This should be enough for many types of projects, such as a database that's used by a medium-sized website or a database that's used for a departmental system.

In chapter 17, you'll get an overview of database administration. In addition, you'll learn some practical skills that you can use to monitor and configure a server and work with its logs. In chapter 18, you'll learn how to secure a database and work with user accounts. Finally, in chapter 19, you'll learn how to back up and restore a database.

At this point, you'll have a solid foundation in database administration. Then, in chapter 20, you'll learn some additional skills for administering a database that's hosted in the cloud.

# 17

# An introduction to database administration

This chapter begins by presenting an overview of database administration, including the responsibilities of a database administrator and the various types of files that are used by a database. Then, this chapter presents some practical skills that you can use to get started with database administration. These skills include monitoring the server, configuring the server, and working with the server's logs.

# Database administration concepts

Before you learn practical skills for administering a database, it helps to understand some general concepts. To start, you should have a clear understanding of the responsibilities of a database administrator. In addition, you should understand the types of files that are used by MySQL.

## Database administrator responsibilities

A *database administrator (DBA)* has many responsibilities that vary depending on the database. Some common DBA responsibilities are summarized in figure 17-1. For most databases, a DBA designs and creates the database. Once created, a DBA may be responsible for securing the database. A DBA may also be responsible for making sure that the database is backed up regularly so it can be restored if necessary.

When a database goes into production, the DBA is responsible for monitoring the server to make sure it can handle its workload. If necessary, the DBA may need to configure the server to fix a problem or to get it to work more efficiently. To help with these tasks, the DBA may need to review logs to monitor database performance or to identify problems such as queries that run slowly.

A database can also be administered by multiple people. For example, a large, mission-critical database might be designed and created by a specialist before being handed over to another DBA who is responsible for monitoring it. Or, if the database is hosted remotely, one DBA at the remote site might be responsible for certain administrative tasks while another DBA might perform other administrative tasks remotely.

This chapter and the next two chapters focus on the skills that a DBA needs to administer a database that's running on a single, locally hosted server. However, it makes sense to run some databases on multiple servers either locally or in the cloud. For example, you can often improve the performance of a large database by running the MySQL server on multiple machines and then running the database on each machine. Then, you can use *database replication* to synchronize the databases so any change made to one database is automatically propagated to the other databases. When you do this, you identify one server as the *source* and the other servers as the *replicas*.

Note that if a database is hosted in the cloud, the responsibilities of a DBA may differ from what's shown here. For example, some of these responsibilities, such as backing up the database, can be automated. However, it's still important to understand the responsibilities that may be required.

### Common database administrator responsibilities

**Maintenance**

- Monitor the server
- Configure the server
- Maintain log files

**Design**

- Design the database
- Create the database

**Security**

- Maintain user accounts
- Secure the server and its databases

**Backup**

- Backup the database regularly
- Restore the database
- Migrate data to another server

**Miscellaneous**

- Start or stop the server
- Optimize the server
- Update software
- Enable and manage replication

### Description

- A *database administrator (DBA)* has many responsibilities that vary depending on the database.
- *Database replication* involves setting up two or more MySQL servers, usually running on different machines, where one server is the *source* and the other servers are the *replicas*. Then, any changes made to databases on one server are automatically propagated to the databases on the other servers.

Figure 17-1 Database administrator responsibilities

## Types of database files

Figure 17-2 summarizes three types of database files used by MySQL server. When it starts, MySQL reads a *configuration file*. For Windows, this file is named my.ini and it's usually stored in the parent directory of the data directory. For macOS and Unix/Linux, this file is named my.cnf and is usually stored in the /private/etc or /etc directory.

MySQL's data directory contains subdirectories and files that MySQL uses to store the data for its databases. Here, each subdirectory corresponds to a database. For example, the AP database is stored within a directory named AP. Within a subdirectory, the files correspond to the tables and other objects of the database. The table files differ depending on the release of MySQL and whether the tables use the InnoDB or MyISAM storage engine. For example, with MySQL 8.0 and later, InnoDB uses one file per table with the extension .ibd, and MyISAM uses two files per table with the extensions .myd and .myi. By contrast, with MySQL 5.7 and earlier, both InnoDB and MyISAM use one additional file with the extension .frm. In addition to subdirectories, the data directory may contain *log files* that contain information that's written by the server.

By default, MySQL's data directory is hidden. To view this directory with Windows, you need to change the settings for File Explorer so it shows hidden files, folders, and drives. To do that, display File Explorer, click the View tab, and check the "Hidden items" option in the Show/hide group. To view the data directory with macOS, open Finder and press Command+Shift+. (a period).

## Types of log files

Figure 17-2 also summarizes the different types of log files that MySQL can create. To start, a *general log* contains a record of client connections, SQL statements received from the clients, and other information. This file is useful for monitoring the server. An *error log* contains messages about server startup and shutdown as well as error messages. This file is useful for troubleshooting problems with starting or stopping the server. And a *slow query log* contains a list of SQL statements that take a long time to execute. This file is useful for identifying queries that need to be rewritten to optimize database performance.

A *binary log* consists of an index file and a series of numbered binary files. The index file contains a list of the binary files, and the binary files contain a record of the changes that have been made to the database. This log can be used with backups to restore a database after a crash. It can also be used to enable replication between a source server and a replica server.

Like a binary log, a *relay log* consists of an index file and a series of numbered binary files. These files are used on a replica server to relay any changes that have been made on the source server to the replica server. This log is only necessary when you're using replication.

Not all logs are enabled by default. So if you want to use a log, you may first need to enable it. Alternately, you may want to disable one or more logs to speed up performance.

## Types of database files

| File type | Description |
|---|---|
| Configuration | Files that contain configuration options that the MySQL server uses to set its defaults when it starts. For Windows, this file is named my.ini. For macOS and Unix/Linux, this file is named my.cnf. |
| Data | Files that define the tables, indexes, and other database objects. These files also store any data that's used by the database objects. With MySQL 8.0 and later, InnoDB uses one file per table (.ibd) and MyISAM uses two files per table (.myd and .myi). Both InnoDB and MyISAM use one additional file with MySQL 5.7 and earlier (.frm). Other files are used for other database objects such as views and triggers. |
| Log | Files that contain information that's written (logged) by the database server. You can configure your server to turn these files on or off and to control how they work. |

## Types of log files

| Log type | Description |
|---|---|
| General | A text file that contains a record of client connections, SQL statements received from the clients, and other information. |
| Error | A text file that contains messages about server startup and shutdown and error messages. |
| Slow query | A text file that contains SQL statements that take a long time to execute. |
| Binary | One or more binary files that contain a record of changes that have been made to the database. These files can be used with backups to restore a database after a crash. These files can also be used to enable replication between a source server and a replica server. |
| Relay | One or more binary files that are used on a replica machine to relay any changes that have been made on the source machine. This log is only necessary when you're using replication. |

## The base and data directories for Windows

```
C:\Program Files\MySQL\MySQL Server 8.0
C:\ProgramData\MySQL\MySQL Server 8.0\Data
```

## The base and data directories for macOS and Unix/Linux

```
usr/local/mysql/
usr/local/mysql/Data
```

## Description

- The database server uses several types of files, including *configuration files*, *data files*, and *log files*.
- By default, MySQL's data directory is hidden. As a result, you need to be able to view hidden files to see this directory.
- Before you can use some logs, you need to enable them.

Figure 17-2 Types of database and log files

# How to monitor the server

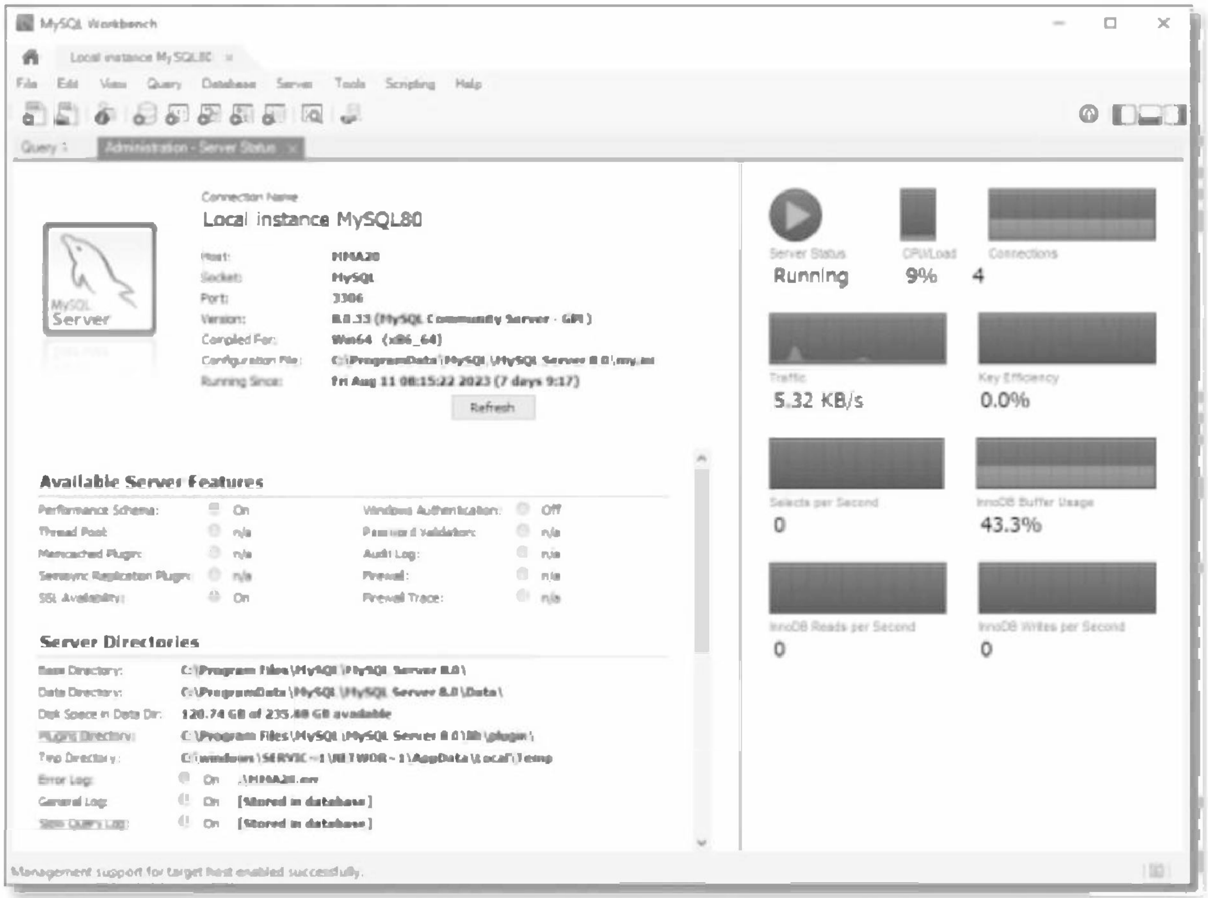
When a database is running on a server, you should monitor the server to make sure that it's running efficiently. That includes making sure the server isn't using more of the system's CPU and memory than it should, and that the number of connections and traffic aren't too much for the server. To do that, you can view the process list, status variables, and system variables.

## How to view the server status

To view information about the server's status, connect to the server in Workbench and then select Server→Server Status to display a Server Status window like the one shown in figure 17-3. Alternately, you can display this window by clicking Server Status in the Administration tab of the Navigator window.

The information in the Server Status window is divided into two sections. To the left, you can see the name and version of the server and other information, such as available features and whether some of the logs are enabled. To the right, you can see if the server is running, along with graphs of the amount of CPU and memory being used by the server, the number of connections, the traffic in kilobytes per second, and so on. By viewing these graphs, you can get an idea of whether the server has enough resources to handle its connections and traffic.

## The Server status window




## Description

- To view the server status, start MySQL Workbench and open a connection to the server. Then, select Server→Server Status. Or, select Server Status from the Administration tab of the Navigator window.
- By viewing the server status, you can get an idea of whether the server has enough resources to handle its connections and traffic.

Figure 17-3    How to view the server status

## How to view and kill processes

A *process* is a connection to the database. To view a list of all the processes that are running, you can open a connection to the server. Then, you can select the Client Connections item to display a Client Connections window like the one shown in figure 17-4. If you display this window and the process list is empty, you can click on the Refresh button to display the processes. Alternatively, you can change the Refresh Rate option so the list is refreshed at the rate you specify.

This window shows information about the connections to the database. In this figure, eight connections have been established. The first connection is for the event scheduler that you learned about in chapter 16. Since no events are currently being processed, the Command column for this connection indicates that it is sleeping.

The second connection is for the MySQL Server process itself. Here, the Command column refers to the name of the process, called the *mysqld program* or the *MySQL daemon*.

The third and fourth connections are for the root user that MySQL Workbench used when it connected to the server to display the SQL Editor tab. Since no processing is currently being performed in this tab, the Command column for these connections indicates that they are sleeping.

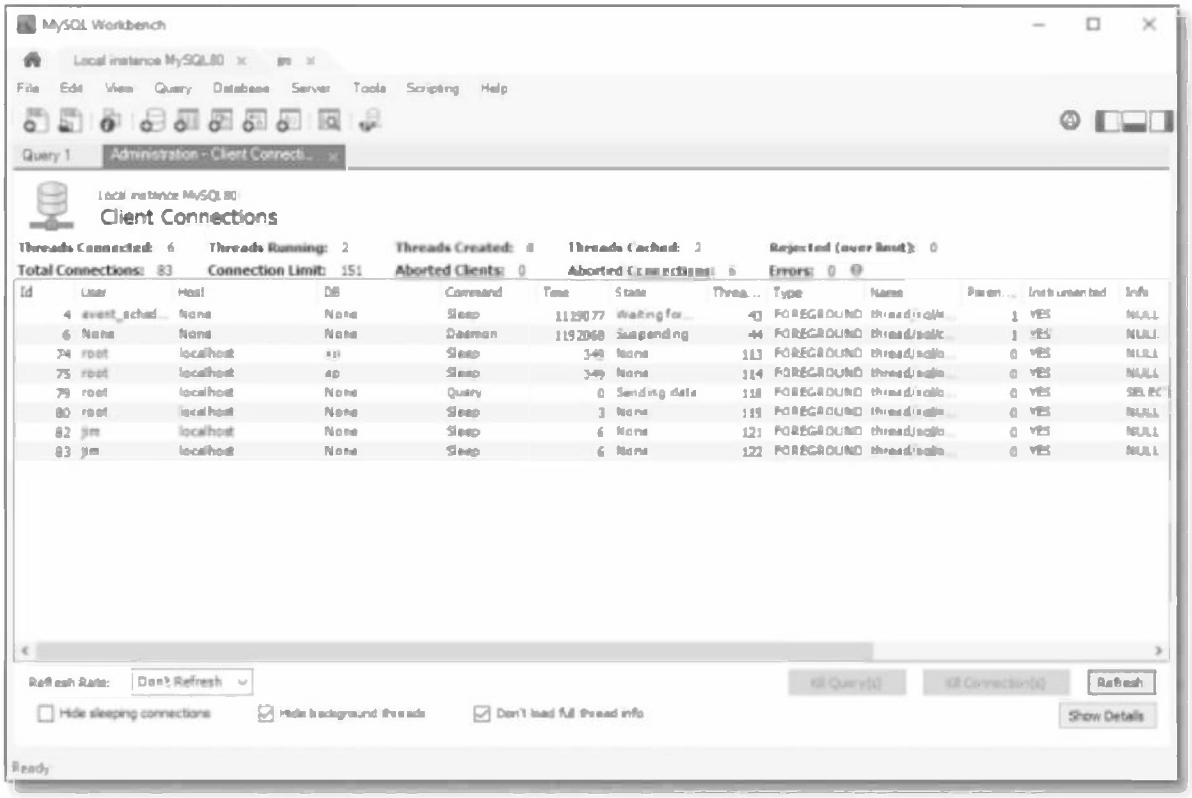
The fifth and sixth connections are also for the root user, but they were used by MySQL Workbench to connect to the server to display the Administration tab for the Client Connections window. The Command column for the first connection indicates that it is being used to execute a query. Specifically, the SHOW PROCESSLIST statement is being executed on this connection. This is the statement that displays the information in the Client Connections window.

The last two connections are for a user named jim. You'll learn more about working with users other than the root user in the next chapter.

If necessary, you can stop one or more processes by selecting them and clicking on the Kill Connection(s) button. For example, you might want to do that if a process isn't responding. You can also stop one or more queries by selecting them and clicking on the Kill Query(s) button. You might want to do that if a query is stuck or is taking too long to run. This stops the query, but doesn't stop the process.

Since the Client Connections window of MySQL Workbench provides a convenient way to view the process list and stop a query or process, you'll usually want to use it to perform these operations. However, if you don't have access to MySQL Workbench, you can use the SHOW PROCESSLIST statement to view a list of processes from the MySQL Command Line Client. You can also use the KILL statement to stop a query or process whenever that's necessary. For more information about these statements, you can look them up in the MySQL Reference Manual.

## The process list




## Description

- A *process* is a connection to the database.
- To view the processes that are running for a connection from MySQL Workbench, select Server→Client Connections, or select Client Connections from the Administration tab of the Navigator window.
- If the Refresh Rate option is set to Don't Refresh, click the Refresh button to display the process list.
- To stop a query, select it and click the Kill Query(s) button.
- To stop a process, select it and click the Kill Connection(s) button.
- To manually view a list of processes, use the SHOW PROCESSLIST statement. To manually stop a query or process, use the KILL statement. For more information about these statements, you can refer to the MySQL Reference Manual.

Figure 17-4 How to view and kill processes

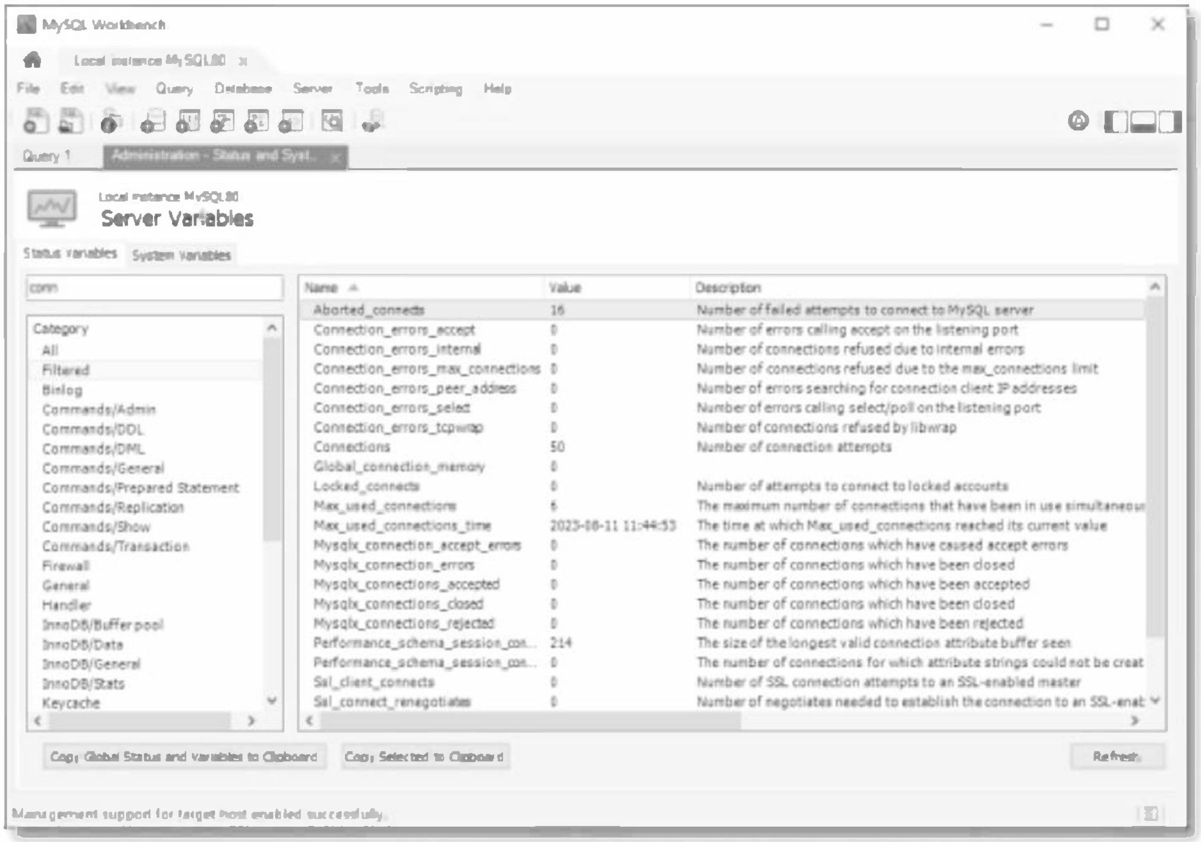
## How to view the status variables

Although viewing the process list is often enough to determine whether a server is performing adequately, you can view the *status variables* if you need additional information about the status of the server. To view these variables, you select Status and System Variables to display the Server Variables window. Then, if the Status Variables tab isn't displayed, you can click on it to display it instead of the System Variables tab. Finally, you can click on one of the categories to display the variables in that category. For example, you can click on the Binlog category to view all status variables that are associated with binary logs. You can click on the Replication category to view all status variables that are associated with replication. And so on. To display all the variables at once, you click on the All category.

As figure 17-5 shows, the Status Variables tab includes the name of each status variable along with its current value. In addition, most variables have a description. Although you might not understand the information that all of these variables provide, you'll learn a lot about the status of your server by reviewing them.

You can also use the search box in the Status Variables tab to search for specific variables. In this figure, for example, the tab displays only the status variables that include "conn" somewhere in the variable name. As a result, this search displays most status variables that display information about connections to the server.

## Status variables




## Description

- A *status variable* is a variable that contains information about the status of the MySQL server.
- To view status variables from MySQL Workbench, select Server→Status and System Variables, or select Status and System Variables from the Administration tab of the Navigator window. If necessary, click the Status Variables tab. Within the Status Variables tab, you can click on any of the categories to display  the variables in that category.
- To search for a status variable, use the Search box at the top of the tab.
- To manually view status variables, use the SHOW STATUS statement in a query window.

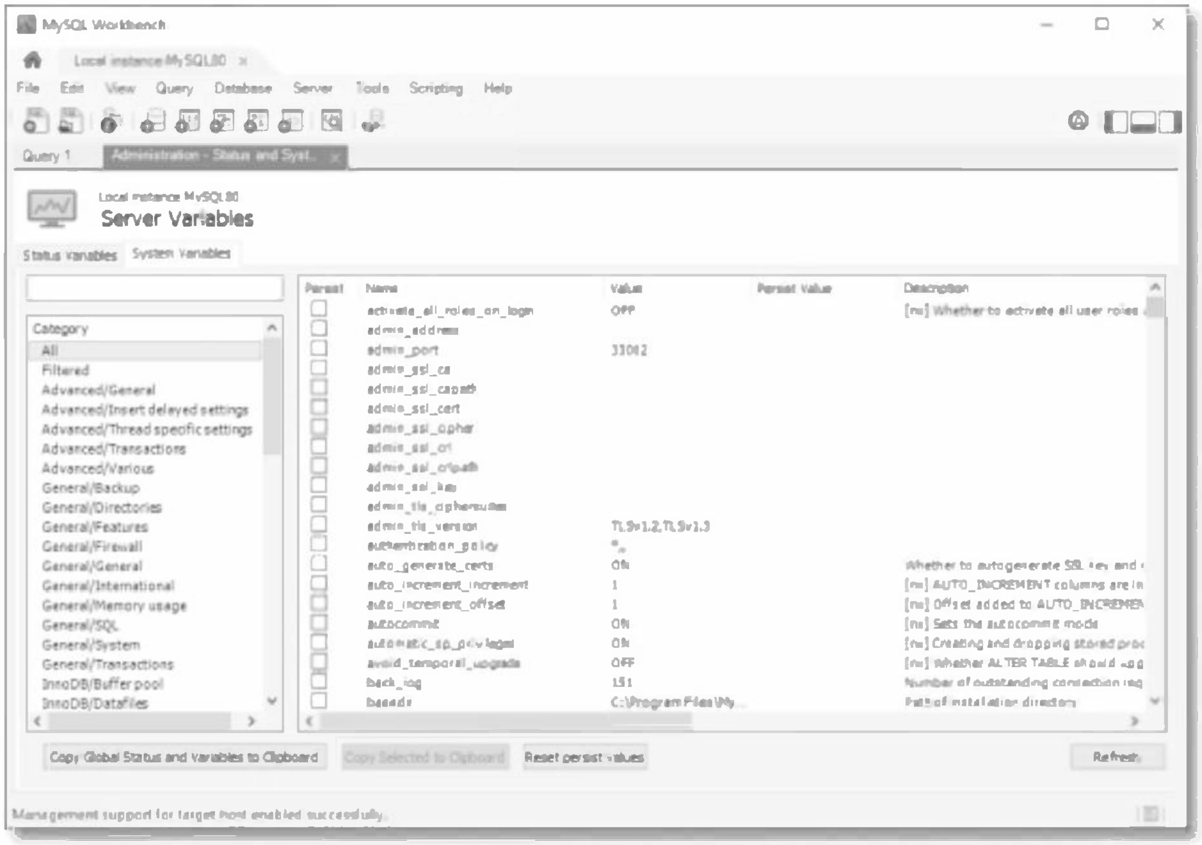
Figure 17-5   How to view the status variables

## How to view the system variables

If you need to check how the MySQL server is currently configured, you can view its *system variables* as shown in figure 17-6. In general, viewing system variables works like viewing status variables. As a result, if you understand how to view status variables, you shouldn't have any trouble viewing system variables.

In the next few figures, you'll learn how to set system variables. As you do, you'll learn more about how these variables work and what they can do.

## System variables




## Description

- A *system variable* is a variable that stores a setting for the current configuration of the MySQL server.
- To view system variables, select Server→Status and System Variables, or select Status and System Variables from the Administration tab of the Navigator window. If necessary, click the System Variables tab. From that tab, you can click any of the categories to display the variables in that category.
- To search for a system variable, use the Search box at the top of the tab.
- To manually view system variables, use the SHOW VARIABLES statement in a query window.

Figure 17-6 How to view the system variables

# How to configure the server

When you install MySQL, the MySQL Server Instance Configuration Wizard generates a configuration file that's appropriate for your system. For example, if you followed the instructions in the appendixes of this book to install MySQL on your computer, it has been configured appropriately for a developer who is using MySQL for learning and testing. However, if you install MySQL for a production system, you can use this wizard to configure the server so it's appropriate for that system.

If you need to change the server configuration after installing it, you can do that by editing MySQL's configuration file with either MySQL Workbench or a text editor. This sets the system variables for the server. Then, MySQL reads the system variables from the configuration file every time it starts.

You can also use SET statements to set system variables dynamically. When you do that, the settings go into effect immediately and aren't saved in the configuration file. This allows you to change a system variable without having to restart the server. This is sometimes useful if you want to experiment with different settings to see if they work correctly before you change them in the configuration file.

## How to set system variables using MySQL Workbench

Figure 17-7 shows how to use MySQL Workbench to set system variables in the configuration file. To do that, you select Server→Options File to display the Options File window. Then, you click on an appropriate tab and use it to change options.

In this figure, the General tab shows some of the options that you can change. For example, you can use the basedir and datadir variables to change the base directory and the data directory that are used by MySQL.

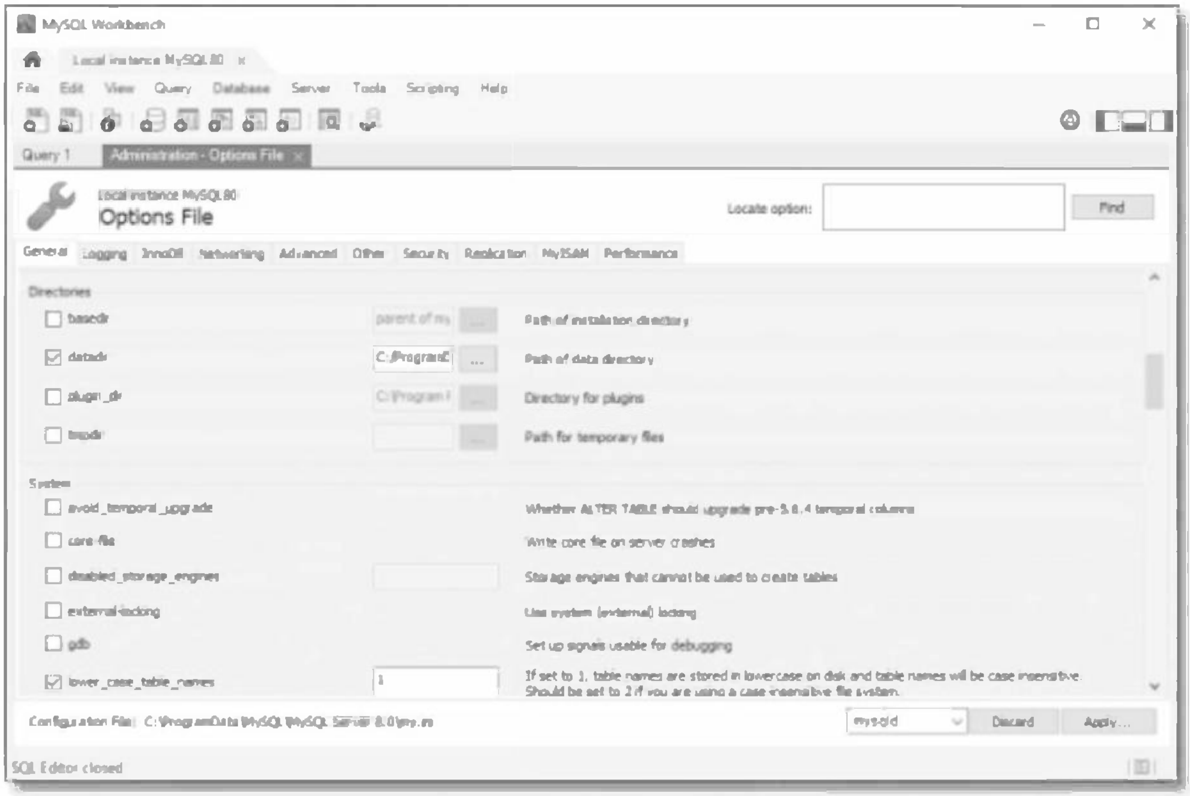
When you're done making changes, you can click the Apply button to write the changes to the configuration file. However, MySQL only reads the configuration file when it starts. As a result, your changes won't go into effect until you stop and restart the server.

If Workbench isn't able to write your changes to the configuration file, it may be because it doesn't have appropriate privileges. In that case, you may be able to solve the problem by running Workbench as an administrator.

You also won't be able to make your changes if the connection isn't pointing to the correct configuration file. In this figure, for example, the bottom of the window shows the configuration file that Workbench is attempting to modify. In this case, that file is correct for my Windows system. If this file isn't correct for your system, you can use a text editor to set system variables as shown in the next figure.

On macOS, the bottom of this window typically points to the my.cnf file in the etc directory. However, a default install of MySQL doesn't create this file.

## Server configuration options




## Description

- When MySQL starts, it reads the server configuration file and uses it to set system variables.
- To use MySQL Workbench to change the server configuration file, select Server→Options File, or select Options File from the Administration tab of the Navigator window. Then, click an appropriate tab and use it to change options. Finally, click the Apply button to write the changes to the configuration file.
- To use MySQL Workbench to change the server configuration file, you may need to run it as an administrator. To do that on a Windows system, right-click the MySQL Workbench icon and then select "Run as administrator".
- If the configuration file shown at the bottom of the window isn't correct for your system, you won't be able to use Workbench to make changes to your system configuration. In that case, you can use a text editor to set system variables as shown in the next figure.
- On macOS, the configuration file isn't created when you install MySQL. Instead, it is created when you use Workbench to apply changes to the default configuration. It's often stored in the /private/etc directory with a name of my.cnf.
- The MySQL server only reads the configuration file when it starts. As a result, your changes won't go into effect until you restart the server.

Figure 17-7 How to set system variables using MySQL Workbench

Instead, Workbench creates this file only after you use the Options File window to apply changes to the configuration file.

## How to set system variables using a text editor

Another way to set system variables is to use a text editor to edit the configuration file directly. On Windows, the configuration file is named my.ini and is typically stored in MySQL's data directory. On macOS or Unix/Linux, this file is named my.cnf and is typically stored in the /private/etc or /etc directory.

Figure 17-8 shows an excerpt from a typical configuration file for a Windows system. Here, I have stripped out the settings for the MySQL clients, and I have stripped out most comments. This makes it easy to see the system variables that are set in a typical MySQL configuration file.

To start, the first line of the configuration file specifies that the following system variables apply to the mysqld program. In the first group of variables, the port variable sets the port to 3306. Then, the basedir and datadir variables set MySQL's base and data directories. These directories are typical for a Windows system. Next, the character-set-server and default-storage-engine variables set the default character set and storage engine for the server. Notice that the names of these variables use dashes instead of underscores. This is acceptable only when you enter a variable name in a configuration file.

The second and third groups of variables begin with a comment that indicates that these variables only apply to MyISAM and InnoDB tables respectively. This shows that you can code a comment by using a pound sign (#) to start the line. Then, the variable values show that when editing these or any other variable that uses a number of bytes, you can add a suffix to specify kilobytes (K), megabytes (M), or gigabytes (G).

As you review the settings for these variables, you should know that MySQL provides over 300 system variables. However, MySQL defines default values for these system variables. As a result, the configuration file only needs to override the system variables when you want to change the default value that's defined by MySQL.

If you start MySQL server from a command line, you should know that you can code system variables by preceding the variable name with two dashes like this:

```
--port=3307
```

Instructions for how to do this for each operating system are provided at the top of the configuration file.

## Part of a configuration file for Windows

```
[mysqld]
port=3306
basedir="C:/Program Files/MySQL/MySQL Server 8.0/"
datadir=C:/ProgramData/MySQL/MySQL Server 8.0/Data
character-set-server=utf8mb4
default-storage-engine=INNODB
default_authentication_plugin=caching_sha2_password
sql-mode="STRICT_TRANS_TABLES,NO_ENGINE_SUBSTITUTION"
log-output=FILE
general-log=0
general_log_file="JOEL-PC.log"
slow-query-log=1
slow_query_log_file="JOEL-PC-slow.log"
long_query_time=10
log-bin="JOEL-PC-bin"
log-error="JOEL-PC.err"
server-id=1
lower_case_table_names=1
secure-file-priv="C:/ProgramData/MySQL/MySQL Server 8.0/Uploads"
max_connections=151
table_open_cache=2000
tmp_table_size=35M
thread_cache_size=10

#*** MyISAM Specific options
myisam_max_sort_file_size=100G
myisam_sort_buffer_size=62M
key_buffer_size=8M
read_buffer_size=64K
read_rnd_buffer_size=256K

#*** INNODB Specific options ***
innodb_flush_log_at_trx_commit=1
innodb_log_buffer_size=1M
innodb_buffer_pool_size=8M
innodb_log_file_size=48M
innodb_thread_concurrency=9
```

## Description

- To edit the configuration file directly, use a text editor. This file is named my.ini (Windows) or my.cnf (macOS or Unix/Linux).
- With Windows, you may need to start your text editor as an administrator. To do that, right-click the shortcut for your text editor and select "Run as administrator".
- With macOS, you may need to use Finder to give yourself permission to read and write the my.cnf file with a text editor. To do that, go to the /private/etc directory, Ctrl-click on the my.cnf file, select Get Info, click the lock icon, and modify the permissions. When you're done editing the file, revoke your write permission.
- When specifying a number of bytes, you can add a suffix to a number to specify kilobytes (K), megabytes (M), or gigabytes (G).

Figure 17-8 How to set system variables using a text editor

# How to set system variables using the SET statement

In the previous two figures, you learned how to edit the configuration file so changes to the system variables are stored permanently and read by MySQL when the server starts. Now, figure 17-9 shows how to use the SET statement to set system variables dynamically. When you use this approach, you don't need to restart the server for the changes to take effect. As a result, you can use this approach to experiment with different values for system variables. Then, if you want to make these changes permanent, you can add them to the configuration file as described in the previous two figures.

When you use the SET statement to set system variables, you can set most of them at either the global level or the session level. When you set variables at the global level, any new connections start with these settings. Then, you can override these settings for individual sessions if you need to. However, some variables can only be set at the global level.

The first example in this figure uses a SET statement with the GLOBAL keyword to set the variable named autocommit at the global level. This statement sets this variable to a value of ON, which is a synonym for 1. Then, the second example uses the SESSION keyword to set this variable at the session level to a value of OFF, which is a synonym for 0. If you don't specify the GLOBAL or SESSION keyword, MySQL sets the session variable if it exists. As a result, the SESSION keyword is optional for setting session variables.

When specifying the value of a system variable, you can use the DEFAULT keyword to specify the default value that's compiled into MySQL. For instance, the third example sets the autocommit variable to its default value.

The fourth and fifth examples show how to set the max_connections variable. This variable specifies the maximum number of connections for the server, not the session. As a result, it can only be set at the global level.

When specifying a value that's a number of bytes, you can't use suffixes like you can in a configuration file. However, you can specify the number of bytes as shown in the sixth example or use an expression as shown in the seventh example. Both of these examples specify a value of 35 megabytes.

After you set a system variable, it's often helpful to be able to view it to make sure it's set correctly. To get the value of a system variable, you code two at signs (@@), the GLOBAL or SESSION keyword, a period, and the name of the variable in a SELECT statement as shown in the next to last example. If you don't specify the GLOBAL or SESSION keyword, MySQL returns the session value if it exists as shown in the last example. Otherwise, it returns the global value.

When you use SET GLOBAL, you should know that it only affects the currently running instance of the MySQL server. So when you restart the server, the variable will be reset to its original value. If that's not what you want, you can use SET PERSIST instead so the value of the variable is maintained across restarts. To use SET PERSIST, however, you have to have sufficient privileges. For more information, see the topic on persisted variables in the MySQL Reference Manual.

## The syntax for setting a system variable

### Global variables

```
SET GLOBAL var_name = var_value;
```

### Session variables

```
SET [SESSION] var_name = var_value;
```

## Examples that set system variables

```
SET GLOBAL  autocommit = ON;
SET SESSION autocommit = OFF;
SET GLOBAL  autocommit = DEFAULT;

SET GLOBAL  max_connections = 90;
SET GLOBAL  max_connections = DEFAULT;

SET GLOBAL  tmp_table_size = 36700160;
SET GLOBAL  tmp_table_size = 35 * 1024 * 1024;
```

## The syntax for getting a system variable

### Global variables

```
@@GLOBAL.var_name
```

### Session variables

```
@@[SESSION.]var_name
```

## Examples that get system variables

### Get the global and session values of a variable

```
SELECT @@GLOBAL.autocommit, @@SESSION.autocommit
```

| @@global.autocommit | @@session.autocommit |
|---|---|
| 1 | 0 |

### Get the session value if it exists or the global value if it doesn't

```
SELECT @@autocommit
```

| @@autocommit |
|---|
| 0 |

## Description

- You can use the SET statement to set the values of system variables dynamically.
- If you don't specify the GLOBAL or SESSION keyword when setting the value of a system variable, MySQL sets the session variable if it exists.
- If you don't specify the GLOBAL or SESSION keyword when getting the value of a system variable, MySQL returns the session value if it exists. Otherwise, it returns the global value.
- The LOCAL keyword is a synonym for the SESSION keyword.
- You can use the DEFAULT keyword to set the value of a variable to the default value that's compiled into MySQL.
- When specifying a number of bytes, you can't use suffixes (K, M, G), but you can use expressions.

Figure 17-9 How to set system variables using the SET statement

# How to work with logging

Earlier in this chapter, you learned about the types of logs that the MySQL server can create. If these logs aren't enabled on your system, you can enable them and then configure them so they work the way you want and view them whenever necessary. Finally, if you use logs, you need to manage them so they don't consume too much disk space.

## How to enable and disable logging

When you enable a log, the server does extra work to write data to the log. In addition, the log takes extra disk space. And since logs can contain sensitive data, they can compromise the security of your data if you don't secure the files properly. As a result, you shouldn't enable a log unless you have a good reason to do so, and you should disable any logs you don't use.

However, logs can also provide useful information. For example, the general query log can help you monitor the server. The error log can help you find and fix errors. The binary log can help you restore data. And the slow query log can help you optimize a database. So, if you need help with any of these tasks, you can enable the appropriate log if it isn't already enabled.

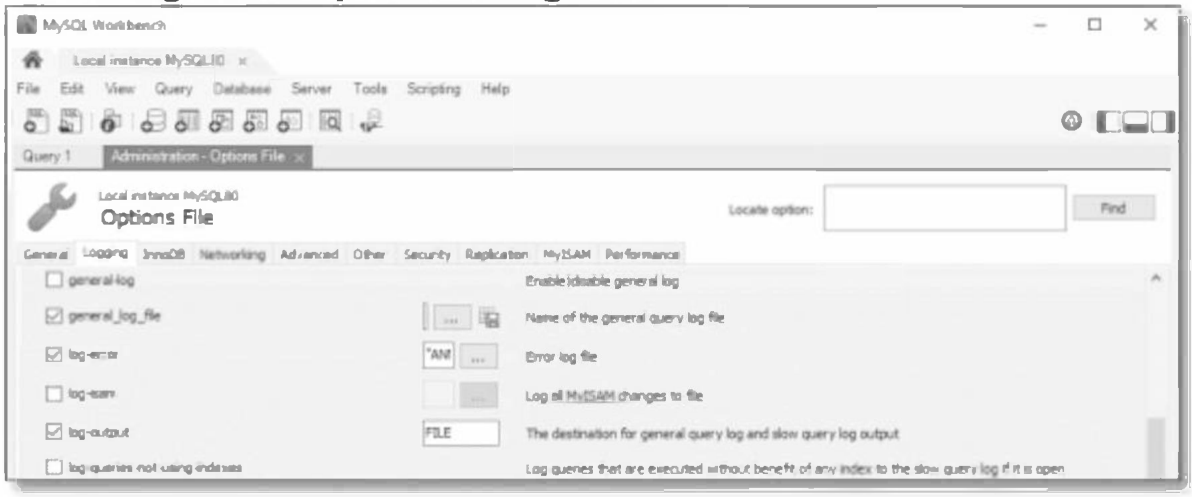
Figure 17-10 shows how to enable logging. To start, it shows the Logging tab of the Options File window that you saw earlier in this chapter. Here, the options in the Logging tab enable the general and error logs. Of course, you can also use this tab to disable logs if you no longer need them. Although you can't see all of the logging options here, you can use this tab to set all of the options described in this figure.

In addition to enabling the logs, these options allow you to specify a directory and name for each log file. If you don't specify a name, MySQL uses the default names shown in this figure, which include the name of the host machine. Similarly, if you don't specify a directory, MySQL stores the log files in its data directory.

If you want to edit the configuration file to set the logging options, you can do that too. In this figure, for instance, the code example shows how to set all six options. Here, the first line enables the general log, and the second line specifies a name and directory for its log file. The third line enables the error log and specifies a name and directory for its log file. The fourth line enables the binary log and specifies a name and directory for its files. And the last two lines enable the slow query log and specify a name and directory for its log file. Note that this code works on a Windows, macOS, or Unix/Linux system. Although you typically use backslashes for Windows, front slashes work as well. So, whenever it makes sense, we've used front slashes in this book.

So, when would you want to store a log file in a directory other than the default directory (the data directory)? Typically, you'd want to do that if you're using binary log files to incrementally back up your data. Then, you can store the log files on a drive other than the drive that's running the MySQL server. That way, if the drive that the server is running on fails, you can still access the binary files and restore the server.

## Server configuration options for log files




## System variables for enabling logging

| Variable | Description |
|---|---|
| **general_log** | Enables the general log with a default name of HOST-NAME.log. |
| **general_log_file=logname** | Specifies the name of the general log file. |
| **log_error[=logname]** | Enables the error log. If no name is specified, MySQL uses a name of HOSTNAME.err. |
| **log_bin[=logname]** | Enables the binary log. If no name is specified, MySQL uses a name of HOSTNAME-bin. Since MySQL provides its own extensions (.index, .000001, .000002, etc.) for the binary log files, you don't need to specify an extension for the log name. |
| **slow_query_log** | Enables the slow query log with a default name of HOSTNAME-slow.log. |
| **slow_query_log_file=logname** | Specifies the name of the slow log file. |

## Logging options set in the server configuration file

```
general_log
general_log_file = "/murach/mysql/general.log"

log_error = "/murach/mysql/error.log"

log_bin = "/murach/mysql/bin-log"

slow_query_log
slow_query_log_file = "/murach/mysql/slow.log"
```

## Description

- Logs can help you monitor the database, find and fix errors, restore data, replicate changes, and optimize your database.
- Log files can take a significant amount of disk space, reduce server speed, and if you don't secure the log files properly, compromise security.
- If you don't specify a directory for a log file, the file is stored in MySQL's data directory.

Figure 17-10 How to enable and disable logging

To specify a drive on a Windows system, you just code the drive letter at the beginning of the path like this:

```
log_bin="c:/murach/mysql/bin-log"
```

To specify a drive on a Unix/Linux system, you code the Volumes directory and the name of the drive at the beginning of the path like this:

```
log_bin="volumes/archive/murach/mysql/bin-log"
```

In this example, Archive is the name of the drive.

Unfortunately, you can't specify a directory for the binary log on a macOS system. If you attempt to do that, the server won't start. As a result, if you're using macOS, you must store your binary log files in the default directory.

## How to configure logging

If logging is enabled, you can configure it so it works the way you want. To do that, you can use any of the techniques shown in this chapter for setting system variables. Figure 17-11 summarizes some of the most commonly used system variables for configuring logging.

The configuration file in this figure shows some examples of how to set these options. To start, the log_output example sends the output of the general and slow query logs to tables instead of to files. This causes these logs to be written to the General_Log and Slow_Log tables of the database named mysql. That way, you can use SELECT statements to view the data that's written to these logs. In addition, you can use events to automatically manage these tables.

The log_error_verbosity example sets the level of warnings that are logged about connections to the highest level (3). As a result, the server logs errors, warnings, and informational messages.

The expire_logs_days example deletes binary log files that are more than seven days old. This setting is appropriate if you back up your database once a week. That way, if you need to restore your database, you can use the database backup to restore it to somewhere within seven days of the current date. Then, you can use the binary log to apply any changes that have been made since that backup, as described in chapter 19.

The max_binlog_size example sets the maximum size of the binary log file to one megabyte. As a result, when the server reaches this limit, it starts a new binary log file with a new number. However, if MySQL is logging a transaction when it reaches the limit, it finishes the transaction before starting a new file. So, the binary log files may be slightly larger than the size indicated by the max_binlog_size setting.

The long_query_time example causes the server to write queries to the slow query log if they take longer than five seconds. By default, this value is set to ten seconds, but you can set it to a lower value if you want to include queries that take a shorter time to run. Conversely, you can set it to a higher value if you only want to include queries that take a longer time to run.

## System variables that apply to multiple types of logs

| Variable | Description |
| --- | --- |
| `log_output[=target]` | Sends the output for the general log and the slow query log to a file (FILE), a table (TABLE), or nowhere (NONE). If you want to send the output to both a file and a table, you can separate the two targets with a comma (but no spaces). |
| `log_warnings[=level]` | Determines whether errors (1), errors and warnings (2), or errors, warnings, and informational messages (3) are logged. The default is 2. |

## System variables for the binary log

| Variable | Description |
| --- | --- |
| `expire_logs_days[=days]` | Deletes binary log files that are more than the specified number of days old. The default is 0, which means files aren't deleted. |
| `max_binlog_size[=bytes]` | Sets the maximum size of the binary log. The server starts a new log file when the binary log reaches its maximum size. The default is 1073741824 (1GB). |

## A system variable for the slow query log

| Variable | Description |
| --- | --- |
| `long_query_time[=seconds]` | Sets the number of seconds that defines a slow query. The default is 10. |

## Logging options set in the server configuration file

```
# stores the output of the general and slow query logs in a table
log_output = TABLE

# logs errors, warnings, and informational messages
log_error_verbosity = 3

# deletes binary log files that are more than 7 days old
expire_logs_days = 7

# sets the maximum binary log file size to 1MB
max_binlog_size = 1048576

# writes queries to the slow query log if they take longer than 5 seconds
long_query_time = 5
```

## Description

- You can use any of the techniques for setting global system variables that are described in this chapter to set logging options.
- Many variables are available for configuring logging in addition to those shown above. For a complete list, check the MySQL documentation.

Figure 17-11 How to configure logging

## How to view text-based logs

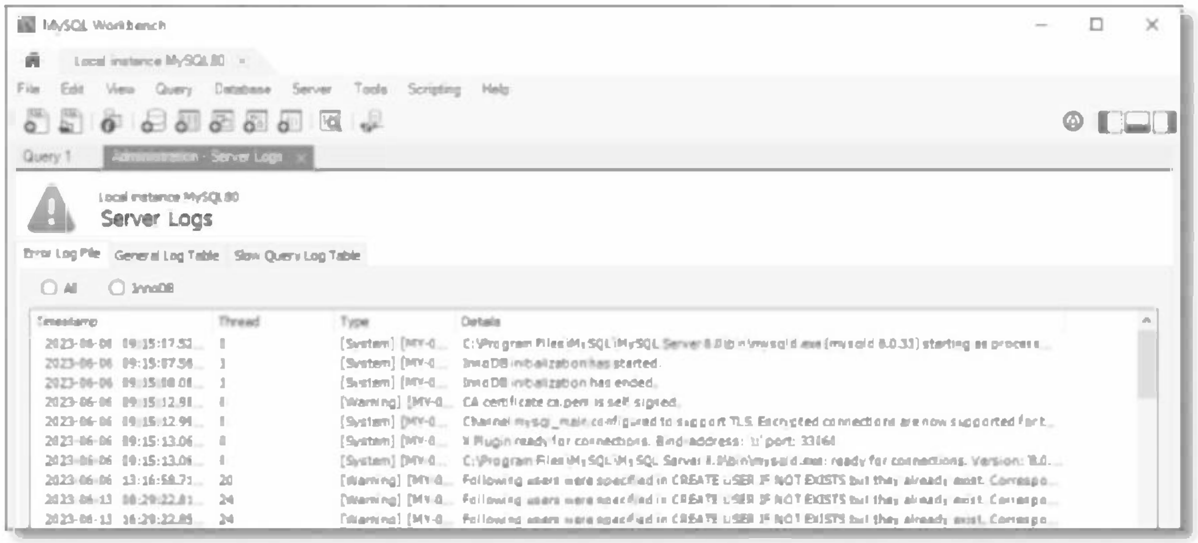
By default, the general, error, and slow query logs are stored in text files. As a result, you can use any text editor to open and view them. Or, you can use MySQL Workbench to view them. To do that, select the Server Logs item, and click on the tab for the log you want to view. In figure 17-12, for example, the error log is opened in Workbench. Here, the error log shows some messages that the server logs when it starts and stops. In addition, this Server Logs window contains a tab for the slow query log file, since this log is enabled. However, it doesn't include a tab for the general query log, since this log isn't enabled.

If you configure your system so it stores the general and slow query logs in tables as shown in the previous figure, you can use MySQL Workbench to view these tables, just as you would use it to view a log file. In addition, you can use a SELECT statement to view them. In this figure, for example, the first SELECT statement selects all rows from the General_Log table that's stored in the database named mysql. Of course, if you wanted to, you could easily modify this SELECT statement so it uses the event_time column to display just the most recent rows of this table.

Notice that this SELECT statement also includes a column that displays the text in the argument column. To do that, it converts this column to the CHAR data type. That's necessary with MySQL 5.7 and later because the argument column is a BLOB type.

The second SELECT statement selects all rows from the Slow_Log table of the mysql database. In this figure, this SELECT statement doesn't retrieve any rows because no queries have run slowly enough. As a result, the server hasn't inserted any rows into the table. If the server had written rows to this table, you could use the data in each row to help determine why the query is running so slowly.

## The error log displayed in MySQL Workbench




## How to view the log files when they are written to tables

### The general log

```
SELECT *, CHAR(argument) AS argument_text FROM mysql.general_log
```

| event_time | user_host | thread_id | server_id | command_type | argument | argu |
|---|---|---|---|---|---|---|
| 2023-08-04 10:23:24.098886 | skip-grants user[] @ [] | 0 | 1 | Execute | BLOB | BLOB |
| 2023-08-04 10:23:28.855908 | [root] @ localhost [::1] | 8 | 1 | Connect | BLOB | BLOB |
| 2023-08-04 10:23:28.862688 | root[root] @ localhost [::1] | 8 | 1 | Query | BLOB | BLOB |
| 2023-08-04 10:23:28.862996 | root[root] @ localhost [::1] | 8 | 1 | Query | BLOB | BLOB |

### The slow query log

```
SELECT * FROM mysql.slow_log
```

| start_time | user_host | query_time | lock_time | rows_sent | rows_examined | db | last_insert_id | insert_id | serv |
|---|---|---|---|---|---|---|---|---|---|

## Description

- By default, the general, error, and slow query logs are stored in text files. As a result, you can use any text editor to open them and view them.
- You can also use MySQL Workbench to view logs. To do that, select Server→Server Logs, or select Server Logs from the Administration tab of the Navigator window. Then, click the tab for the log file.
- If you configure your system so it stores the general and slow query logs in tables, you can use MySQL Workbench to view these tables, just as you would use it to view a log file. In addition, you can use a SELECT statement to view them.

Figure 17-12 How to view the text-based logs

## How to manage logs

Since logs can use a large amount of disk space and reduce server efficiency, you should disable any logs that you don't need. For example, since the general log contains all queries that are sent to the server, it can quickly grow to be very large. As a result, it's common to disable the general log. Then, if you want to monitor all queries sent to the server, you can temporarily enable this log. Similarly, when you're done optimizing the queries on your server, you may want to disable the slow query log.

On the other hand, it's usually a good idea to keep the error log enabled since it contains useful information that can help you troubleshoot problems with the server. In addition, if you're using the binary log to provide for incremental point-in-time recovery, you can't disable it.

If you enable any logs, you need to manage them so they don't consume too much disk space. For the text-based logs (general, error, and slow query), you can use the log rotation strategy described in figure 17-13. With this strategy, you delete any old log files. Then, you rename the current log file. When you do, MySQL server starts a new error log file.

For example, let's say you have an old error log named error.old and the current error log is named error.log. In that case, you can start by deleting the file named error.old. Then, you can rename the current error log (error.log) to error.old. When you do, MySQL starts a new error log named error.log. As a result, you never have more than two error logs on your server at a time.

To get started, you can manage logs by manually deleting and renaming files. Later, you can automate your log management. For example, you can create a batch file for a Windows system or a bash file for a macOS or Unix/Linux system. You can also create a timer to execute these files at regular intervals. Since the details for doing this vary depending on the operating system, they're not described here.

If you store the general log and the slow query logs in a table, you can use SQL statements to rotate the log tables. You can also create an event that rotates the log tables at a specified interval. For example, this figure shows an event that rotates the general log table once every month.

To start, the DROP TABLE statement drops the table named general_log_old if it exists. Then, the CREATE TABLE statement creates a table named general_log_old that has the same structure and data as the table named general_log. Finally, the TRUNCATE statement deletes all rows from the general_log table. As a result, the general_log_old table now contains the log rows from the previous month, and the general_log table is empty and ready to store the log rows for the current month. Here, you must use a TRUNCATE statement instead of a DELETE statement because the DELETE statement doesn't work with the general_log table.

Since the binary log uses an index file to keep track of its numbered binary files, you can't just delete the old binary files that you no longer want. However, you can use the expire_logs_days system variable that was described in figure 17-11 to delete old binary logs after the specified number of days. This deletes the old binary files and updates the index file.

## Strategies for managing logs

| Strategy | Description |
|---|---|
| `Log rotation` | Applies to text-based logs (general, error, and slow query). To rotate logs, you can save the current log file under a new name and let the server create a new log file. Then, you can delete any old log files when they're no longer needed. If necessary, you can create a series of numbered logs. |
| `Age-based expiration` | Applies to the binary log. For this log, you can use the expire_logs_days system variable shown in figure 17-11 to delete the old binary logs after the specified number of days. |

## An event that rotates the general log every month

```
USE mysql;

DELIMITER //

CREATE EVENT general_log_rotate
ON SCHEDULE EVERY 1 MONTH
DO BEGIN
  DROP TABLE IF EXISTS general_log_old;

  CREATE TABLE general_log_old AS
  SELECT *
  FROM general_log;

  TRUNCATE general_log;
END//
```

## Description

- It's generally considered a good practice to disable any logs that you don't need.
- You can manually manage the text-based log files (general, error, and slow query) by deleting and renaming log files.
- You can automatically manage text-based log files (general, error, and slow query) by creating batch files (Windows) or bash files (macOS or Unix/Linux) that run on a specified schedule.
- If you send the output of the general and slow query logs to a table, you can create an event that uses SQL statements to manage the log tables.
- You can't just delete files from the binary or relay log, since an index is used to keep track of the files in these logs. However, you can set the expire_logs_days system variable to delete files from the binary log after a specified number of days.

Figure 17-13 How to manage logs

# Perspective

In this chapter, you were introduced to the responsibilities of a database administrator. In addition, you learned how to perform some of these responsibilities, including how to monitor the server, configure the server, and work with log files.

In the next two chapters, you'll learn how to perform two more critical responsibilities of a DBA. First, in chapter 18, you'll learn how to secure a database. Then, in chapter 19, you'll learn how to backup and restore a database.

## Terms

database administrator (DBA)
database replication
source
replica
configuration file
data file
log file
general log
error log
slow query log
binary log
relay log
process
mysqld program
MySQL daemon
status variable
system variable

## Exercises

1. Start MySQL Workbench and open the Client Connections window. If the process list isn't displayed, click on the Refresh button in the lower right corner to display it. Review the list to see that it includes two processes for the current database. Then, return to the Home tab, open another connection for the root user, and select a different database as the current database. Next, return to the Client Connections window to see that it includes two additional processes for the new connection.
2. Use Workbench's Server Variables window to view these status variables: connections, threads_connected, bytes_received, and bytes_sent. Read the descriptions for these variables to get an idea of what they do.
3. Use Workbench's Server Variables window to view the system variables named basedir and datadir. Note the paths to these directories. Then, view the system variables named log_error and log_bin. Note whether the log_bin variable is set to a value of ON or OFF and whether the log_error variable is set to the name of an error log, indicating that it is on.

4. Use File Explorer (Windows) or Finder (macOS) to view MySQL's data directory. To do that, you may have to modify your operating system settings so you can see hidden directories and files. With macOS, you may also need to change the permissions for the directory to give yourself the read privilege. Note that the subdirectories of the data directory correspond to the databases that are running on your system. If the data directory contains any log files, note the names of these files.
5. View the files in the AP subdirectory and note how the names of the files correspond to the tables of this database. To do this on a Mac, you may need to change the permissions for the directory to give yourself the read privilege for the directory.
6. Use Workbench's Options File window to enable the error log and the binary log, if they aren't already enabled. Use whatever directories and names you want for the logs. If you get an error indicating that access is denied, you may need to stop Workbench and run it as an administrator. After you enable these logs, restart the server.
7. Use File Explorer (Windows) or Finder (macOS) to find MySQL's configuration file. Note the directory and name of this file on your computer.
8. Use Workbench's Server Logs window to view the error log. Note that it includes messages about the startup and shutdown of the server.
9. Write and execute an INSERT statement that inserts a new row into the Invoices table.
10. Use a SET statement to temporarily enable the general log. Then, to make sure that this variable was set, use a SELECT statement to view the variable. If you get an error indicating that access is denied, you may need to stop Workbench and run it as an administrator.
11. Use a SELECT statement to select all rows from the Invoices table.
12. Use Workbench's Server Logs window to view the general log, and click on the Refresh button. Note that it includes the SELECT statement from the previous step.
13. Use a SET statement to disable the general log. Then, to make sure that this variable was set, use a SELECT statement to view the variable.

# 18

# How to secure a database

If you have installed MySQL on your own computer and you have only been working with sample databases, security hasn't been much of a concern. However, when you use MySQL in a production environment, you must configure security to prevent misuse of your data. In this chapter, you'll learn how to do that by writing SQL statements to create users that have restricted access to your database. In addition, you'll learn how to use MySQL Workbench to perform many of the security-related tasks that you can perform with SQL code.

# An introduction to user accounts

Before you learn the details of managing database security, you should have a general idea of how user accounts work. That's what you'll learn in this topic.

## An introduction to SQL statements for user accounts

Figure 18-1 presents a script that contains the SQL statements that are used to create two users and grant them privileges. You'll learn more about how the statements in this script work later in this chapter. For now, we just want to introduce you to the concepts of users and privileges.

This script starts with CREATE USER statements that create two users named ap_admin and ap_user. Both users can only connect from the local server, and both have a password of "pa55word". Although this password isn't realistic, it illustrates how these statements work.

After the users are created, the GRANT statements set up privileges for each user. Here, the user named ap_admin is granted all the privileges on the AP database. As a result, this user can select, insert, update, and delete data from the tables of the AP database. In addition, this user has many other privileges such as creating or dropping tables, indexes, and views in the AP database. By contrast, the user named ap_user can only select, insert, update, and delete data in the AP database.

If you want to view the privileges for a user, you can use the SHOW GRANTS statement. In this figure, for example, you can see the privileges for the user named ap_admin.

## A script that creates two users and grants them privileges

```
CREATE USER ap_admin@localhost IDENTIFIED BY 'pa55word';
CREATE USER ap_user@localhost IDENTIFIED BY 'pa55word';

GRANT ALL
ON ap.*
TO ap_admin@localhost;

GRANT SELECT, INSERT, UPDATE, DELETE
ON ap.*
TO ap_user@localhost;
```

## A statement that displays the privileges for the ap_admin user

```
SHOW GRANTS FOR ap_admin@localhost
```

| Grants for ap_admin@localhost |
|---|
| GRANT USAGE ON *.* TO \`ap_admin\`@\`localhost\` |
| GRANT ALL PRIVILEGES ON \`ap\`.* TO \`ap_admin\`@\`localhost\` |

## Description

- You use the CREATE USER statement to create a user that has no privileges.
- You use the GRANT statement to grant privileges to a user.
- You use the SHOW GRANTS statement to view the privileges for a user.

Figure 18-1 An introduction to SQL statements for user accounts

## A summary of privileges

Figure 18-2 summarizes some of the common *privileges* that a database user can have. To start, a user can have privileges to work with the data that's stored in a database. These privileges allow a user to execute DML statements, such as the SELECT, UPDATE, INSERT, and DELETE statements. They also allow a user to execute stored procedures and functions. These are the most common types of privileges, since most users need to be able to work with the data that's stored in a database.

A user can also have privileges to modify the definition of a database. These privileges allow a user to execute DDL statements such as the CREATE TABLE, ALTER TABLE, DROP TABLE, CREATE INDEX, and DROP INDEX statements. These privileges are common for administrative users of a database such as database administrators and programmers, but they aren't commonly granted to the end users of a database.

In addition, a user can have privileges to work with the stored programs of a database. These privileges allow a user to execute the statements that you learned about in chapters 15 and 16. For example, the CREATE ROUTINE privilege allows a user to execute the CREATE PROCEDURE and CREATE FUNCTION statements.

### Privileges for working with data

| Privilege | Description |
|---|---|
| `SELECT` | Select data from a table. |
| `INSERT` | Insert data into a table. |
| `UPDATE` | Update data in a table. |
| `DELETE` | Delete data from a table. |
| `EXECUTE` | Execute a stored procedure or function. |

### Privileges for modifying the database structure

| Privilege | Description |
|---|---|
| `CREATE` | Create a database or a table. |
| `ALTER` | Alter a table. |
| `DROP` | Drop a database or a table. |
| `INDEX` | Create or drop an index. |
| `CREATE VIEWS` | Create views. |
| `CREATE ROUTINE` | Create a stored procedure or function. |
| `ALTER ROUTINE` | Alter or drop a stored procedure or function. |
| `TRIGGER` | Create or drop a trigger on a table. |
| `EVENT` | Create, alter, drop, or view an event for a database. |

### Description

- The *privileges* a user has control the operations that the user can perform on the database.
- Privileges for working with the data in a database are typically given to all users of the database, including end users.
- Privileges for modifying the structure of a database are typically given only to database administrators and programmers.

Figure 18-2 A summary of privileges (part 1 of 2)

The privileges you learned about in part 1 of figure 18-2 are called *object privileges* because they allow the user to create and work with database objects, such as tables, views, and stored procedures. The exact privileges that are available for an object depend on the type of object. In contrast to object privileges, *administrative privileges* allow the user to create new user accounts and roles, show the databases available from the server, shut down the server, and so on. These privileges are listed in the first table in part 2 of this figure.

The second table lists some other privileges you'll use frequently. The ALL privilege grants all privileges available at the specified level except the GRANT OPTION privilege. In general, you only grant the ALL privilege to users like database administrators or programmers. In some cases, you may also want to grant these users the GRANT OPTION privilege. If you do, they can grant privileges to other users.

The USAGE privilege doesn't grant any privileges to a user. In most cases, you'll use this privilege when you want to give a user the ability to grant privileges to other users. In that case, this privilege indicates that the existing privileges for the user shouldn't be changed. You'll see an example of how this works later in this chapter.

Before you go on, you should know that MySQL provides many privileges other than the ones shown here. As a result, if the privileges presented in this chapter aren't adequate for your security needs, you can use the SHOW PRIVILEGES statement to view a list of all the privileges that are available with your version of MySQL. Then, you can refer to the MySQL documentation for information on any of these privileges.

## Administrative privileges

| Privilege | Description |
|---|---|
| CREATE USER | Create new user accounts. |
| CREATE ROLE | Create a new role. |
| SHOW DATABASES | Show the names of all databases on the server. |
| SHUTDOWN | Shut down the server. |

## Other privileges

| Privilege | Description |
|---|---|
| ALL [PRIVILEGES] | All privileges available at the specified level except the GRANT OPTION privilege. |
| GRANT OPTION | Allows a user to grant his or her privileges to other users. |
| USAGE | No privileges. It can be used to modify existing accounts without changing the privileges for that account. |

## Description

- *Object privileges* allow the user to create and work with database objects such as tables, views, and stored procedures. The privileges that are available for an object depend on the type of object.
- *Administrative privileges* allow the user to create users, grant privileges, and manage operations on the server. They are not specific to a particular database.
- To see a list of the privileges that are supported by your version of MySQL along with their definitions, use the SHOW PRIVILEGES statement.

Figure 18-2 A summary of privileges (part 2 of 2)

## The four privilege levels

To understand how privileges work, you need to understand that MySQL grants them at the four different levels shown in the first table in figure 18-3: global, database, table, and column. *Global privileges* provide a user access to all the tables in all the databases. *Database privileges* provide a user access to all tables in a specific database. *Table privileges* provide a user access to all columns on a specified table. And *column privileges* provide a user access only to specific columns on specific tables.

## The grant tables in the mysql database

To store user and privilege information, MySQL uses the *grant tables* in an internal database named mysql. The second table in figure 18-3 summarizes some of these tables. The table named User stores the usernames, passwords, and global privileges for all users on the server. The table named DB stores information about the database privileges for each user. The table named Tables_Priv stores information about the table and column privileges for each user. The table named Columns_Priv stores information about the column privileges for each user. And the table named Procs_Priv stores information about the privileges for accessing stored procedures and functions.

You may be interested to know that the User and DB tables list each privilege in a separate column that's defined as ENUM('N','Y') that indicates if a privilege is enabled or disabled. By contrast, the other three tables use SET columns that list the privileges that are enabled. This illustrates a practical use for the ENUM and SET types that you learned about in chapter 8.

When you grant users access to the databases on a server, you typically want to restrict all users other than administrative users from accessing the mysql database. That's because if a user has access to the mysql database, they can change the user or privilege information directly. For example, the user could insert a row into the User table to create a user with global privileges, or the user could change the privileges of other users. If you restrict access to administrative users, though, this security risk is greatly reduced.

### The four privilege levels

| Level | Description |
|---|---|
| Global | All databases and all tables. |
| Database | All tables in the specified database. |
| Table | All columns in the specified table. |
| Column | Only the specified column or columns. |

### Some of the grant tables in the mysql database

| Table name | Description |
|---|---|
| `user` | Stores the usernames and passwords for all users on the server. In addition, stores the global privileges that apply to all databases on the server. |
| `db` | Stores the database privileges. |
| `tables_priv` | Stores the table and column privileges. |
| `columns_priv` | Stores the column privileges. |
| `procs_priv` | Stores the privileges for accessing stored procedures and functions. |

### Description

- You can use MySQL to grant privileges at four different levels.
- MySQL stores all users for the server and their privileges in *grant tables* in an internal database named mysql.

Figure 18-3 MySQL's privilege levels and grant tables

# How to work with users and privileges

Now that you have a basic understanding of users and privileges, you're ready to learn the details for working with users and privileges. This includes creating and dropping users, granting and revoking privileges, and changing the password for an existing user.

## How to create, rename, and drop users

Figure 18-4 shows how to work with users. To start, when you use the CREATE USER statement, you typically specify the name of the user, followed by the @ sign, followed by the name of the host that the user can connect from. This is usually followed by the IDENTIFIED BY clause, which specifies a password for the user. If you omit this clause, no password is assigned, which isn't usually what you want.

The first example in this figure illustrates how this works. Here, the CREATE USER statement creates a user named joel that can connect from the host named localhost with a password of "sesame". In other words, joel can only connect from the same computer where MySQL server is running.

If you don't use the @ sign to specify a host, MySQL uses a percent sign (%) as the name of the host. This indicates that the user can connect from any host. In the second example, for instance, the CREATE USER statement creates a user named jane that can connect from any host with a password of "sesame". This statement also includes the IF NOT EXISTS clause so the statement isn't executed if the user already exists. If the user does exist and this clause is included, a warning is generated instead of an error. That way, if the statement is included in a script, the script will continue executing instead of aborting.

You can also code the PASSWORD EXPIRE, PASSWORD HISTORY, and PASSWORD REUSE INTERVAL clauses on the CREATE USER statement. The PASSWORD EXPIRE clause allows you to control how often a password needs to be changed. In the third example in this figure, for instance, this clause causes the password to expire immediately. As a result, the CREATE USER statement doesn't specify a password because the user will have to change the password the next time she connects.

The PASSWORD HISTORY and PASSWORD REUSE INTERVAL clauses became available with MySQL 8.0. The PASSWORD HISTORY clause allows you to control how many of the most recent passwords can't be reused when a user's password is changed. This is illustrated by the fourth example, which prevents the user from using the last five passwords.

The PASSWORD REUSE INTERVAL clause is similar to the PASSWORD HISTORY clause, except that it controls the number of days during which a user can't reuse a previously used password. For instance, the fifth example specifies that the user can't reuse a password for a year.

## How to create a user

### The simplified syntax of the CREATE USER statement

```
CREATE USER [IF NOT EXISTS] username [IDENTIFIED BY password]
[PASSWORD EXPIRE [DEFAULT|NEVER|INTERVAL days DAY] |
 PASSWORD HISTORY {DEFAULT|number_passwords} |
 PASSWORD REUSE INTERVAL {DEFAULT|days DAY}]
```

### A statement that creates a user from a specific host

```
CREATE USER joel@localhost IDENTIFIED BY 'sesame'
```

### A statement that creates a user from any host

```
CREATE USER IF NOT EXISTS jane IDENTIFIED BY 'sesame'    -- creates jane@%
```

### A statement that creates a user whose password expires immediately

```
CREATE USER anne@localhost PASSWORD EXPIRE
```

### A statement that creates a user whose last five passwords can't be reused

```
CREATE USER jim IDENTIFIED BY 'sesame' PASSWORD HISTORY 5
```

### A statement that creates a user whose passwords can't be reused for 365 days

```
CREATE USER john IDENTIFIED BY 'sesame' PASSWORD REUSE INTERVAL 365 DAY
```

## How to rename a user

### The syntax of the RENAME USER statement

```
RENAME USER username TO new_username
```

### A statement that renames a user from a specific host

```
RENAME USER joel@localhost TO joelmurach@localhost
```

## How to drop a user

### The syntax of the DROP USER statement

```
DROP USER [IF EXISTS] username
```

### A statement that drops a user from a specific host

```
DROP USER joelmurach@localhost
```

### A statement that drops a user from any host

```
DROP USER IF EXISTS jane                                    -- drops jane@%
```

## Description

- You use the CREATE USER statement to create a user that has no privileges.
- When you code a username, you can specify the host that a user can connect from.
- The PASSWORD EXPIRE clause determines how often the specified password needs to be changed. If no option is coded, the password expires immediately.
- The PASSWORD HISTORY clause determines how many of the most recent passwords can't be reused.
- The PASSWORD REUSE INTERVAL clause determines the number of days until a previously used password can be used again.
- You can use the RENAME USER statement to change the name of a user.
- You can use the DROP USER statement to drop a user.

Figure 18-4 How to create, rename, and drop users

After you use the CREATE USER statement to create a user, the user has no privileges. However, you can use the GRANT statement to assign privileges to the user as you'll see shortly.

The sixth example in figure 18-4 uses the RENAME USER statement to change the name of the user named joel@localhost to joelmurach@localhost. If this user has privileges, the privileges are transferred to the new name.

The last two examples use the DROP USER statement to drop the users named joelmurach@localhost and jane@%. These statements delete the user accounts and their privileges from the mysql database. Of these statements, the second includes the IF EXISTS clause. That way, if the user doesn't exist, the statement generates a warning instead of an error. This allows a script to continue executing instead of being stopped. Before dropping users, remember that they are for all databases on the server. As a result, you should check with anyone else who is using the server to make sure that the user isn't needed.

## How to specify user account names

In the last figure, you saw some examples of user account names. Now, figure 18-5 presents the details for coding these names. Here, the first example shows the account name for a user named john who can connect only from the local host.

The second example shows how to code an account name for the same user using quotation marks. In this example, neither the username nor the hostname contains special characters. As a result, these quotation marks are optional.

In this book, we typically code the quotation marks only when they're necessary. However, some programmers prefer to always code them for consistency. Also, when we use quotes in this book, we typically use single quotation marks ('). However, you can use double quotation marks (") or backticks (`) if you prefer.

The third example shows yet another way to code the same user as the first example. For the host, this example uses an IP address of 127.0.0.1, which is synonymous with the localhost keyword. Although it isn't shown in this figure, you can use an IP address to identify a remote server too if necessary.

The fourth example shows how to create a user that can connect from any host, local or remote. In this example, the account name doesn't use the @ sign to specify a host. As a result, MySQL automatically uses the percent sign (%) wildcard character for the hostname. This indicates that the user can connect from any host.

The fifth example shows how to explicitly code the hostname for a user that can connect from any computer. In this example, the percent sign (%) must be enclosed in quotes because it's a special character.

The sixth and seventh examples show an account name for a user that can connect from a host for a specific domain. Since the percent sign is coded before the domain name, the user can connect from any computer within a domain name that ends with murach.com. In both examples, the hostname must be enclosed in quotes since it includes the percent sign (%). In addition, the username in the seventh example must be enclosed in quotes since it includes dashes (-).

### The syntax of an account name

```
username[@hostname]
```

### A user that can only connect from the same server as MySQL

```
john@localhost
```

### The same user with optional quotation marks

```
'john'@'localhost'
```

### The same user with an IP address instead of the localhost keyword

```
john@127.0.0.1
```

### A user that can connect from any computer

```
john
```

### The same user but with the wildcard character explicitly coded

```
john@'%'
```

### A user that can only connect from the murach.com domain

```
john@'%.murach.com'
```

### A username that needs to be coded with quotes

```
'quinn-the-mighty'@'%.murach.com'
```

### Description

- If you want to specify the host that a user can connect from, you can code the username, followed by the @ character, followed by the hostname.
- If you specify a user without specifying a hostname, MySQL uses a percent sign (%) as a wildcard character to indicate that the user can connect from any host.
- The username and hostname do not need to be quoted if they are legal as unquoted identifiers. Quotes are necessary to specify a username string containing special characters such as a dash (-), or a hostname string containing special characters or wildcard characters such as a percent sign (%).
- To quote a username or hostname, you can enclose it in single quotation marks ('), double quotation marks ("), or backticks (`).

Figure 18-5 How to specify user account names

## How to grant privileges

Figure 18-6 shows several ways to grant privileges to users. The first statement grants all privileges on all databases to a user named jim@%. To do that, this statement uses the ALL privilege. In addition, the ON clause is coded with an asterisk for both the database name and table name. These asterisks are wildcards that indicate that the user has privileges on all databases and all tables. In other words, this user is given a global privilege level. Finally, this statement includes the WITH GRANT OPTION clause. This grants the GRANT OPTION privilege to the user, which means that they can grant any of their privileges to other users.

Note that when you code the WITH GRANT OPTION clause, the user is only given the GRANT OPTION privilege at the level that's specified on the ON clause. In this example, the user is granted global privileges, so he will be able to grant all of his privileges to other users. If you want to restrict the privileges a user can grant to other users, you grant individual database, table, or column privileges instead. Then, the user will only be able to grant privileges on those objects.

Although using the ALL keyword makes it easy to grant all privileges to a user, it also makes it easy to grant more privileges than the user needs. And that can make your database less secure. In general, then, it's a good practice to grant users just the privileges that they need.

The second statement grants just SELECT, INSERT, and UPDATE privileges to all tables in the AP database. These privileges are given to a user named joel on the local host. The third statement is similar, except it grants privileges on just the Vendors table in the AP database.

The fourth statement grants privileges to specific columns of a table. Specifically, it grants the SELECT privilege on three columns of the Vendors table, and it grants the UPDATE privilege on another column. To do that, the column names are listed in parentheses after each privilege.

The fifth statement assumes that the AP database is the current database. As a result, this statement doesn't specify the database name. Although this can simplify the code for granting privileges, it risks granting privileges to the wrong database. As a result, it's a good idea to specify the database when you use the GRANT statement.

The sixth statement gives the user the ability to grant their privileges to other users. To do that, it includes the WITH GRANT OPTION clause. Unlike the first example that uses this clause, though, the USAGE privilege is specified. As a result, no additional privileges are given to the user. If you want to grant additional privileges to a user, you can code those privileges instead of the USAGE privilege.

### The syntax of the GRANT statement

```
GRANT privilege_list
ON [db_name.]table
TO user1 [, user2 ]...
[WITH GRANT OPTION]
```

### A statement that grants global privileges to a user

```
GRANT ALL
ON *.*
TO jim
WITH GRANT OPTION
```

### A statement that grants database privileges to a user

```
GRANT SELECT, INSERT, UPDATE
ON ap.*
TO joel@localhost
```

### A statement that grants table privileges to a user

```
GRANT SELECT, INSERT, UPDATE
ON ap.vendors
TO joel@localhost
```

### A statement that grants column privileges to a user

```
GRANT SELECT (vendor_name, vendor_state, vendor_zip_code),
      UPDATE (vendor_address1)
ON ap.vendors
TO joel@localhost
```

### A statement that uses the current database

```
GRANT SELECT, INSERT, UPDATE, DELETE
ON vendors
TO ap_user@localhost
```

### A statement that gives a user the ability to grant privileges to other users

```
GRANT USAGE
ON *.*
TO anne@localhost
WITH GRANT OPTION
```

### Description

- You use the GRANT statement to grant privileges to an existing user.
- The ON clause determines the level at which the privileges are granted. You can use the asterisk (*) to specify all databases or tables. If you don't specify a database, MySQL uses the current database.
- WITH GRANT OPTION allows the user to grant their privileges to other users.
- The USAGE keyword indicates that no privileges are being granted to the user. Instead, the user account is being modified in some way.

Figure 18-6 How to grant privileges

## How to view privileges

When you're done granting privileges, you may want to view the privileges that have been granted to make sure that you have granted the correct privileges to each user. To do that, you can use the techniques described in figure 18-7.

To start, if you want to get a list of users for the current server, you can use a SELECT statement like the one shown in the first example. This statement queries the table named User in the mysql database.

In this figure, the server has twelve users. Here, the root user is the admin user for MySQL. Note that the Host column for this user specifies localhost. Similarly, the users named anne, ap_admin, ap_tester, and ap_user have a Host value of localhost. In addition, the built-in users named mysql.infoschema, mysql.session, and mysql.sys have a Host value of localhost. By contrast, the users named jane, jim and john have a Host value of %.

Once you know the names of the users and hosts, you can use the SHOW GRANTS statement to view the privileges for a user. For instance, the second example shows how to view the privileges for a user from any host. In particular, it shows how to view the privileges for the user named jim@%. The result set for this user shows that it has all privileges, including the GRANT OPTION privilege, for all tables and databases on the server.

The third example shows how to view the privileges for a user from a specific host. In particular, it shows how to view the privileges for the user named ap_user@localhost. Here, the result set shows that this user has a global USAGE privilege (*.*). By itself, this privilege only allows the user to view the mysql database. It doesn't allow the user to view or work with any other databases. However, this user also has SELECT, INSERT, UPDATE, and DELETE privileges for all tables on the database named AP. As a result, they can work with the data in that database.

The fourth example shows how to view the privileges for the current user. To do that, you can execute a SHOW GRANTS statement without a FOR clause. Here, the result set is for the root user. This user has all privileges, including the GRANT OPTION privilege. This user also has the PROXY privilege, which allows the user to impersonate another user.

### A statement that displays a list of users

```
SELECT User, Host FROM mysql.user
```

| User | Host |
|---|---|
| jane | % |
| jim | % |
| john | % |
| anne | localhost |
| ap_admin | localhost |
| ap_tester | localhost |
| ap_user | localhost |
| joel | localhost |
| mysql.infoschema | localhost |
| mysql.session | localhost |
| mysql.sys | localhost |
| root | localhost |

### The syntax of the SHOW GRANTS statement

```
SHOW GRANTS [FOR user]
```

### A statement that shows the privileges for a user from any host

```
SHOW GRANTS FOR jim
```

| Grants for jim@% |
|---|
| GRANT SELECT, INSERT, UPDATE, DELETE, CREATE, DROP, RELOAD, SHUTDOWN, ... |
| GRANT BACKUP_ADMIN,BINLOG_ADMIN,CONNECTION_ADMIN,ENCRYPTION_KEY_... |

### A statement that shows the privileges for a user from a specific host

```
SHOW GRANTS FOR ap_user@localhost
```

| Grants for ap_user@localhost |
|---|
| GRANT USAGE ON *.* TO \`ap_user\`@\`localhost\` |
| GRANT SELECT, INSERT, UPDATE, DELETE ON \`ap\`.* TO \`ap_user\`@\`localhost\` |

### A statement that shows the privileges for the current user

```
SHOW GRANTS
```

| Grants for root@localhost |
|---|
| GRANT SELECT, INSERT, UPDATE, DELETE, CREATE, DROP, RELOAD, SHUTDOWN, ... |
| GRANT BACKUP_ADMIN,BINLOG_ADMIN,CONNECTION_ADMIN,ENCRYPTION_KEY_... |
| GRANT PROXY ON ''@'' TO 'root'@'localhost' WITH GRANT OPTION |

### Description

- You can query the User table in the mysql database to get a list of users for the current MySQL server.
- You can use the SHOW GRANTS statement to display the privileges for a user.

Figure 18-7 How to view privileges

## How to revoke privileges

After you've created users and granted privileges to them, you may later need to revoke privileges. To do that, you can use the REVOKE statement as shown in figure 18-8. This statement works similarly to the GRANT statement.

Here, the first statement shows how to revoke all privileges from a user named jim. To do that, you can code a REVOKE statement that uses the ALL keyword to revoke all privileges. In addition, you must specify GRANT OPTION to revoke the GRANT OPTION privilege. This revokes all privileges from the user on all databases. To be able to use this syntax, you must be logged in as a user who has the CREATE USER privilege. Otherwise, you won't have the privileges you need to execute the REVOKE statement.

The second statement works like the first statement. However, it revokes all privileges from two users. To do that, this statement separates the usernames in the FROM clause with a comma.

This statement also uses the IF EXISTS and IGNORE UNKNOWN USER keywords that were introduced with MySQL 8.0.30. The IF EXISTS keywords cause a warning to occur instead of an error if any of the users don't have one or more of the specified privileges. That way, the privileges will still be revoked for the users who do have the specified privileges. The IGNORE UNKNOWN USER keywords are similar, except they allow privileges to be revoked for all specified users who exist. In other words, any users who don't exist are ignored. These keywords are typically used together so the revoke statement is executed for all existing users with the existing privileges.

The third statement revokes specific privileges from a user. To do that, you separate the privileges with commas. For example, this statement revokes the INSERT and UPDATE privileges on the Invoices table in the AP database from the user joel@localhost. To be able to use this syntax, you must be logged in as a user that has the GRANT OPTION privilege and the privileges that you're revoking.

### The syntax of the REVOKE statement for all privileges

```
REVOKE [IF EXISTS] ALL[ PRIVILEGES], GRANT OPTION
FROM user1[, user2]...
[IGNORE UNKNOWN USER]
```

### A statement that revokes all privileges from a user

```
REVOKE ALL, GRANT OPTION
FROM jim
```

### A statement that revokes all privileges from multiple users

```
REVOKE IF EXISTS ALL, GRANT OPTION
FROM ap_user, anne@localhost
IGNORE UNKNOWN USER
```

### The syntax of the REVOKE statement for specific privileges

```
REVOKE [IF EXISTS] privilege_list
ON [db_name.]table
FROM user1[, user2]...
[IGNORE UNKNOWN USER]
```

### A statement that revokes specific privileges from a user

```
REVOKE INSERT, UPDATE
ON ap.vendors FROM joel@localhost
```

### Description

- You can use the REVOKE statement to revoke privileges from a user.
- To revoke all privileges, you must have the global CREATE USER privilege.
- To revoke specific privileges, you must have the GRANT OPTION privilege and you must have the privileges that you are revoking.
- If any of the specified privileges don't exist for a user, an error occurs and the statement isn't executed. To change this error to a warning and allow the statement to execute for privileges that do exist, include the IF EXISTS keywords.
- If any of the specified users don't exist, an error occurs and the statement isn't executed. To change this error to a warning and allow the statement to execute for users who do exist, include the IGNORE UNKNOWN USER keywords.

Figure 18-8 How to revoke privileges

## How to change passwords

To change a password, you can use the ALTER USER statement. The syntax and examples at the top of figure 18-9 show how this works.

To change the password for a user other than the user who's currently logged on, you code the name of the user, followed by the IDENTIFIED BY clause with the new password. This is illustrated by the first example. For this to work, the current user must have the CREATE USER privilege or the UPDATE privilege for the mysql database.

You use a similar technique to change the password for the current user. Instead of coding the name of the user, though, you code the USER function. This is illustrated by the second example.

The third example includes the IF EXISTS clause to check that the user exists before changing the password. Then, it uses the PASSWORD EXPIRE clause to set the password to expire in 90 days. This clause, as well as the PASSWORD HISTORY and PASSWORD REUSE INTERVAL clauses, work just like they do for the CREATE USER statement.

For security reasons, you typically assign a password to each user. Another option, however, is to include the PASSWORD EXPIRE keywords without an option on the CREATE USER or ALTER USER statement so the password expires immediately. That way, the first time a user tries to connect to the server, they will be asked to enter a password.

To make sure that every user either has a password or that their password has expired, you can execute a SELECT statement like the one in this figure. This statement retrieves information from the User table of the mysql database for each user who doesn't have an authentication string, which is typically the password in encrypted format, and whose password hasn't expired. In this case, the SELECT statement returned an empty result set. However, if this statement returns a result set, you can set a password for each user in the result set or change the password so it has expired. Or, if those users aren't needed, you can drop them.

## How to use the ALTER USER statement

### The syntax

```
ALTER USER [IF EXISTS] {username|USER()} [IDENTIFIED BY 'password']
[PASSWORD EXPIRE [DEFAULT|NEVER|INTERVAL days DAY] |
 PASSWORD HISTORY {DEFAULT|number_passwords} |
 PASSWORD REUSE INTERVAL {DEFAULT|days DAY}]
```

### A statement that changes a user's password

```
ALTER USER john IDENTIFIED BY 'pa55word'
```

### A statement that changes the current user's password

```
ALTER USER USER() IDENTIFIED BY 'secret'
```

### A statement that forces a user to change their password every 90 days

```
ALTER USER IF EXISTS john PASSWORD EXPIRE INTERVAL 90 DAY
```

## A SELECT statement that selects all users that don't have passwords

```
SELECT Host, User
FROM mysql.user
WHERE authentication_string = ''
  AND password_expired = 'N'
```

| Host | User |
|---|---|
| NULL | NULL |

## Description

- You can use the ALTER USER statement to change a password.
- To change the password for another user, you must have the CREATE USER privilege or the UPDATE privilege for the mysql database.
- To change the password for the current user, include the USER function instead of a user name.
- The PASSWORD EXPIRE, PASSWORD HISTORY, and PASSWORD REUSE INTERVAL clauses of the ALTER USER statement work just like they do for the CREATE USER statement.
- To be sure you've assigned passwords to all users, you can select data from the User table of the mysql database for all users without authentication strings.

Figure 18-9 How to change passwords

## A script that creates users

Figure 18-10 presents a script that creates users and grants privileges for the AP database. This script starts with DROP USER statements that delete the users named john, jane, jim, and joel if they exist.

Next, the CREATE USER statements create these same users. Because these statements are coded within a script, passwords are omitted for security reasons. Then, the PASSWORD EXPIRE clause is included with no option. That way, the first time each of these users tries to connect to the server, they will be asked to enter their old password as well as a new password. Because no passwords are assigned here, however, the old password can be left blank.

After the CREATE USER statements execute, the users exist but they don't have any privileges. Then, the GRANT statements grant specific privileges to each user. Here, because the user named joel is a developer, he is given access to all databases and tables on the server. In addition, he is given the GRANT OPTION privilege. As a result, he can work with the data or structure of any table of any database on the server, and he can grant his privileges to other users. However, he can only connect from the local host. This helps prevent hackers from connecting as this user. In general, it's considered a best practice to limit connectivity in this way whenever possible, especially for administrative users.

Unlike the user named joel, the user named jim can only work with data in the AP database. In other words, jim can't modify the structure of the AP database by adding, altering, or dropping objects. That makes sense because jim is a manager, not an administrator. However, jim can grant all of his privileges to other users. For example, he might need to grant privileges to users that he manages. In addition, jim can connect from any host computer. Although this is a security risk, at least a hacker who is able to connect as jim only has access to the AP database.

The users named john and jane have the fewest privileges, since they are end users. These users can work with data in the AP database, but only with the specified tables and privileges. Specifically, they can select, insert, update, and delete data in the Vendors, Invoices, and Invoice_Line_Items tables. However, they can only select data from the General_Ledger_Accounts and Terms tables. Like jim, these users can connect from a computer on any host. Again, this is a security risk, but a hacker who can connect as john or jane has even fewer privileges and can do less damage.

## A script that sets up the users and privileges for a database

```
-- drop the users
DROP USER IF EXISTS john;
DROP USER IF EXISTS jane;
DROP USER IF EXISTS jim;
DROP USER IF EXISTS joel@localhost;

-- create the users
CREATE USER john PASSWORD EXPIRE;
CREATE USER jane PASSWORD EXPIRE;
CREATE USER jim PASSWORD EXPIRE;
CREATE USER joel@localhost PASSWORD EXPIRE;

-- grant privileges to a developer (joel)
GRANT ALL ON *.* TO joel@localhost WITH GRANT OPTION;

-- grant privileges to the ap manager (jim)
GRANT SELECT, INSERT, UPDATE, DELETE ON ap.* TO jim WITH GRANT OPTION;

-- grant privileges to ap users (john, jane)
GRANT SELECT, INSERT, UPDATE, DELETE ON ap.vendors TO john, jane;
GRANT SELECT, INSERT, UPDATE, DELETE ON ap.invoices TO john, jane;
GRANT SELECT, INSERT, UPDATE, DELETE ON ap.invoice_line_items TO john, jane;
GRANT SELECT ON ap.general_ledger_accounts TO john, jane;
GRANT SELECT ON ap.terms TO john, jane;
```

Figure 18-10 A script that creates users

# How to work with roles

Now that you've learned how to work with users and privileges, you can set up basic security on your database. If a system has many users, however, granting and revoking privileges one by one would require a lot of coding. To help reduce the amount of coding and to help you keep your database security organized, you can use a feature of MySQL 8.0 and later called roles.

## How to create, manage, and drop roles

A *role* is a collection of privileges. When you assign a user to a particular role, you grant them all of the privileges associated with that role. Figure 18-11 presents the statements for working with roles.

To start, you use the CREATE ROLE statement to create one or more roles. The example in this figure creates a single role named invoice_entry. Note that you can code the IF NOT EXISTS clause on this statement. When you do, a warning will be generated instead of an error if the role already exists. That way, if the statement is part of a script, the script will continue executing instead of stopping at the error.

After you create a role, you grant privileges to it. To do that, you use the GRANT statement. This statement works just like it does for granting privileges to users, except that you name one or more roles. In this figure, the first GRANT statement grants INSERT and UPDATE privileges on the Invoices table to the invoice_entry role, and the second statement grants INSERT and UPDATE privileges on the Invoice_Line_Items table to the invoice_entry role.

To assign a user to a role, you use another format of the GRANT statement. With this format, you list the roles you're assigning the users to instead of listing the privileges you're granting. The example in this figure assigns the users named john and jane to the invoice_entry role.

Notice that you can also code the WITH ADMIN OPTION when you assign users to role. If you do, the users you assign to the role will be able to assign the role to other users.

The last example in part 1 of this figure shows how to display the privileges that have been granted to a role. To do that, you use the SHOW GRANTS statement just like you do to display the privileges for a user, except that you name a role. In this figure, the privileges for the invoice_entry role are displayed.

## How to create a role

### The syntax of the CREATE ROLE statement

```
CREATE ROLE [IF NOT EXISTS] role1[, role2]...
```

### A statement that creates a new role

```
CREATE ROLE invoice_entry
```

## How to grant privileges to roles

```
GRANT INSERT, UPDATE
ON invoices
TO invoice_entry

GRANT INSERT, UPDATE
ON invoice_line_items
TO invoice_entry
```

## How to assign users to roles

### The syntax of the GRANT statement for assigning users to roles

```
GRANT role1[, role2]...
TO user1[, user2]...
[WITH ADMIN OPTION]
```

### A statement that assigns two users to the new role

```
GRANT invoice_entry TO john, jane
```

## How to display the privileges for a role

```
SHOW GRANTS FOR invoice_entry
```

| Grants for invoice_entry@% |
| --- |
| GRANT USAGE ON *.* TO \`invoice_entry\`@\`%\` |
| GRANT INSERT, UPDATE ON \`ap\`.\`invoice_line_items\` TO \`invoice_entry\`@\`%\` |
| GRANT INSERT, UPDATE ON \`ap\`.\`invoices\` TO \`invoice_entry\`@\`%\` |

## Description

- A *role* is a collection of privileges that you can assign to one or more users. Roles were introduced with MySQL 8.0.
- You use the CREATE ROLE statement to create one or more roles. For this to work, you must have the CREATE USER or CREATE ROLE privilege.
- If you code the IF NOT EXISTS clause on the CREATE ROLE statement, a warning is generated instead of an error if the role already exists.
- You use the GRANT statement to grant privileges to a role. The syntax of this statement is the same as for granting privileges to users except that you name one or more roles.
- You also use the GRANT statement to assign users to roles. When you assign a user to a role, the user is granted all the privileges of that role. If you code the WITH ADMIN OPTION clause, the user can also grant the roles to other users.
- You use the SHOW GRANTS statement to display the privileges associated with a role. The syntax of this statement is the same as for displaying the privileges for a user, except that you name a role.

Figure 18-11 How to create, manage, and drop roles (part 1 of 2)

Part 2 of figure 18-11 presents some additional statements for working with roles. To start, it shows how to use the SET DEFAULT ROLE statement to set the roles that are activated by default when a user connects to the server. If you specify NONE on this statement, none of the roles that the user is assigned to are activated. In that case, the user only has the privileges that they have been assigned directly. If you specify ALL, the user is given all of the privileges of all of the roles that they have been assigned. And if you specify one or more roles, the user is given the privileges of all those roles. In the example in this figure, the users named john and jane are assigned a default role of invoice_entry.

Note that you can also assign one or more default roles to a user when you create the user. To do that, you use the DEFAULT ROLE clause of the CREATE USER statement.

The SET ROLE statement allows a user to change the roles that are currently active during a session. This is particularly useful if you need to try different roles during testing to be sure they provide the privileges a user needs. You can code the NONE or ALL option or a list of user roles on this statement just like you can on the SET DEFAULT ROLE statement. You can also code the DEFAULT option to change the active roles to the defaults specified by the SET DEFAULT ROLE statement. And you can code the ALL EXCEPT option followed by the names of one or more roles to activate all of the roles that a user is assigned to except for the ones you name. In this figure, the SET ROLE statement simply sets the active role to the invoice_entry role.

If you change the active roles during a session, you may at some point want to display the roles that are currently active. To do that, you can use the CURRENT_ROLE function as shown in this figure.

To revoke privileges from one or more roles, you use the REVOKE statement just like you do to revoke privileges from users. In this figure, the REVOKE statement revokes the UPDATE privilege on the Invoice_Line_Items table from the invoice_entry role.

You also use the REVOKE statement to remove users from roles. On this statement, you name the roles that you're removing the users from, and you name the users you're removing on the FROM clause. In the REVOKE statement in this figure, the user named john is removed from the invoice_entry role. Notice that, just as when you revoke privileges from users, you can include the IF EXISTS and IGNORE UNKNOWN USER keywords when you remove a user from a role. That way, the statement will still execute if a user doesn't exist or if a user hasn't been assigned to a role.

To drop one or more roles, you list them on the DROP ROLE statement. In this figure, the invoice_entry role is dropped. You can also code the IF EXISTS clause on this statement. Then, if the role doesn't exist, a warning is generated instead of an error.

## How to set the default roles

### The syntax of the SET DEFAULT ROLE statement

```
SET DEFAULT ROLE {NONE|ALL|role1[, role2]...}
TO username1[, username2]...
```

### A statement that sets the default role for two users

```
SET DEFAULT ROLE invoice_entry TO john, jane
```

## How to change the active roles

### The syntax of the SET ROLE statement

```
SET ROLE {DEFAULT|NONE|ALL|ALL EXCEPT role1[, role2]...|role1[, role2]...}
```

### A statement that changes the active role

```
SET ROLE invoice_entry
```

## How to display the roles that are currently active

```
SELECT CURRENT_ROLE()
```


## How to revoke privileges from roles

```
REVOKE UPDATE
ON invoice_line_items
FROM invoice_entry
```

## How to remove users from roles

### The syntax of the REVOKE statement for removing users from roles

```
REVOKE [IF EXISTS] role1[, role2]...
FROM username1[, username2]...
[IGNORE UNKNOWN USER]
```

### A statement that removes a user from the new role

```
REVOKE IF EXISTS invoice_entry FROM john
IGNORE UNKNOWN USER
```

## How to drop roles

### The syntax of the DROP ROLE statement

```
DROP ROLE [IF EXISTS] role1 [, role2]...
```

### A statement that deletes the new role

```
DROP ROLE invoice_entry
```

## Description

- You use the SET DEFAULT ROLE statement to name the default roles for a user. These roles are activated by default when the user connects to the server. To set the default role for another user, you must have the CREATE USER privilege.
- A user can use the SET ROLE statement to change the active role for a session.
- You use the REVOKE statement to revoke privileges from a role or to remove users from a role.
- You use the DROP ROLE statement to delete one or more roles. To use this statement, you must have the DROP ROLE or CREATE USER privilege.

Figure 18-11 How to create, manage, and drop roles (part 2 of 2)

## A script that creates users and roles

Figure 18-12 presents a script that creates users and roles and grants privileges to the roles for the AP database. Unlike the script you saw in figure 18-10, this script doesn't start with statements that drop the users. Instead, it includes the IF NOT EXISTS clause on each CREATE USER statement so a user is only created if they don't already exist. Since this script works with roles, it's written to work with MySQL 8.0 or later.

The CREATE USER statements create users named john, jane, jim, and joel. Then, the script uses a CREATE ROLE statement to create roles named developer, manager, and user. Like the CREATE USER statements, this statement includes an IF NOT EXISTS clause so the script will continue if any of the roles already exist.

The statements that follow grant privileges to the new roles. The first statement grants all privileges to all databases and tables to the developer role. In addition, the role is given the GRANT OPTION privilege. As a result, any user assigned to this role will be able to grant their privileges to other users.

The next statement grants SELECT, INSERT, UPDATE, and DELETE privileges to all tables in the AP database to the manager role. Like the developer role, this role is also given the GRANT OPTION privilege.

The next five statements grant privileges to the user role. The first three statements grant SELECT, INSERT, UPDATE, and DELETE privileges on the Vendors, Invoices, and Invoice_Line_Items tables. Then, the fourth and fifth statements grant the SELECT privilege on the General_Ledger_Accounts and Terms tables.

The next three statements assign the users that were created at the beginning of the script to the new roles. Here, the user named joel is assigned to the developer role, the user named jim is assigned to the manager role, and the users named john and jane are assigned to the user role.

Finally, this script sets the default role for each user. As you can see, the default role for each user is set to the role that the user is assigned to by the GRANT statement for that user. That way, the users won't have to set the role after connecting to the server.

Now that you've seen this script, you might want to compare it to the one in figure 18-10. If you do, you'll see that it grants the same privileges to the same users. Because it uses roles, though, it's easier to modify. If you wanted to change the privileges that are assigned to a group of users, for example, you would just need to change the privileges for the role that those users are assigned to. Or, if you wanted to add users with the same privileges as existing users, you would just need to assign that user to the same role.

## A script that sets up the users and roles for a database

```
-- create the users
CREATE USER IF NOT EXISTS john PASSWORD EXPIRE;
CREATE USER IF NOT EXISTS jane PASSWORD EXPIRE;
CREATE USER IF NOT EXISTS jim PASSWORD EXPIRE;
CREATE USER IF NOT EXISTS joel@localhost PASSWORD EXPIRE;

-- create the roles
CREATE ROLE IF NOT EXISTS developer, manager, user;

-- grant privileges to the developer role
GRANT ALL ON *.* TO developer WITH GRANT OPTION;

-- grant privileges to the manager role
GRANT SELECT, INSERT, UPDATE, DELETE ON ap.* TO manager WITH GRANT OPTION;

-- grant privileges to user role
GRANT SELECT, INSERT, UPDATE, DELETE ON ap.vendors TO user;
GRANT SELECT, INSERT, UPDATE, DELETE ON ap.invoices TO user;
GRANT SELECT, INSERT, UPDATE, DELETE ON ap.invoice_line_items TO user;
GRANT SELECT ON ap.general_ledger_accounts TO user;
GRANT SELECT ON ap.terms TO user;

-- assign users to roles
GRANT developer TO joel@localhost;
GRANT manager TO jim;
GRANT user TO john, jane;

-- set default roles for users
SET DEFAULT ROLE developer TO joel@localhost;
SET DEFAULT ROLE manager TO jim;
SET DEFAULT ROLE user TO john, jane;
```

Figure 18-12 A script that creates users and roles

# How to use MySQL Workbench

Since you often use SQL statements to set up the users for a database or to view the privileges that have been granted to a user, it's important to understand the SQL statements presented in this chapter. Once you understand them, you can use MySQL Workbench to work with security. For example, you can use MySQL Workbench to drop or alter an existing user or to grant or revoke the privileges for a user.

## How to work with users and privileges

Figure 18-13 shows how you can work with users using MySQL Workbench. Here, you can see the Users and Privileges window that's displayed when you select Users and Privileges from the Navigator window. To do that, you may need to click the Administration tab to display this item as shown in this figure.

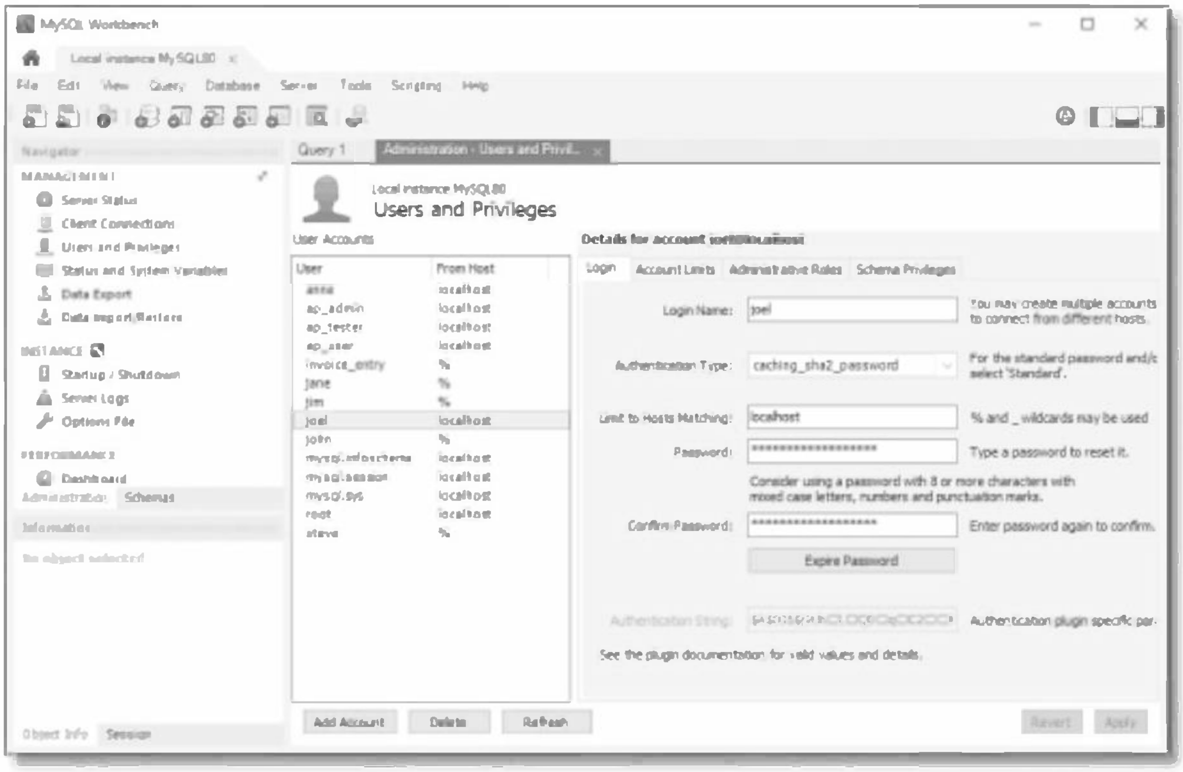
To work with the login information for a user, display the Login tab within the Users and Privileges window as shown in the first screen. Then, you can select a user to display or change the login information for that user. You can click the Expire Password button to cause the user's password to expire immediately. And you can click the Delete button to remove the user.

You can also add an account from the Login tab. To do that, just click the Add Account button, enter the login information, and click the Apply button.

To view the database privileges for a user, display the Schema Privileges tab, select the user, and select a schema as shown in the second screen. Then, you can use the check boxes at the bottom of the tab to change the privileges. You can revoke all privileges from the user by clicking the Revoke All Privileges button. You can revoke all privileges from the selected schema by clicking the Delete Entry button. And you can add a new schema by clicking the Add Entry button. Note that only the privileges that are granted directly to the user are displayed on this tab, not privileges that are granted through roles.

As you learned earlier in this chapter, you can also assign privileges to specific tables and columns. However, MySQL Workbench doesn't currently provide a way to view or change privileges at these levels.

## The Login tab




## The Schema Privileges tab

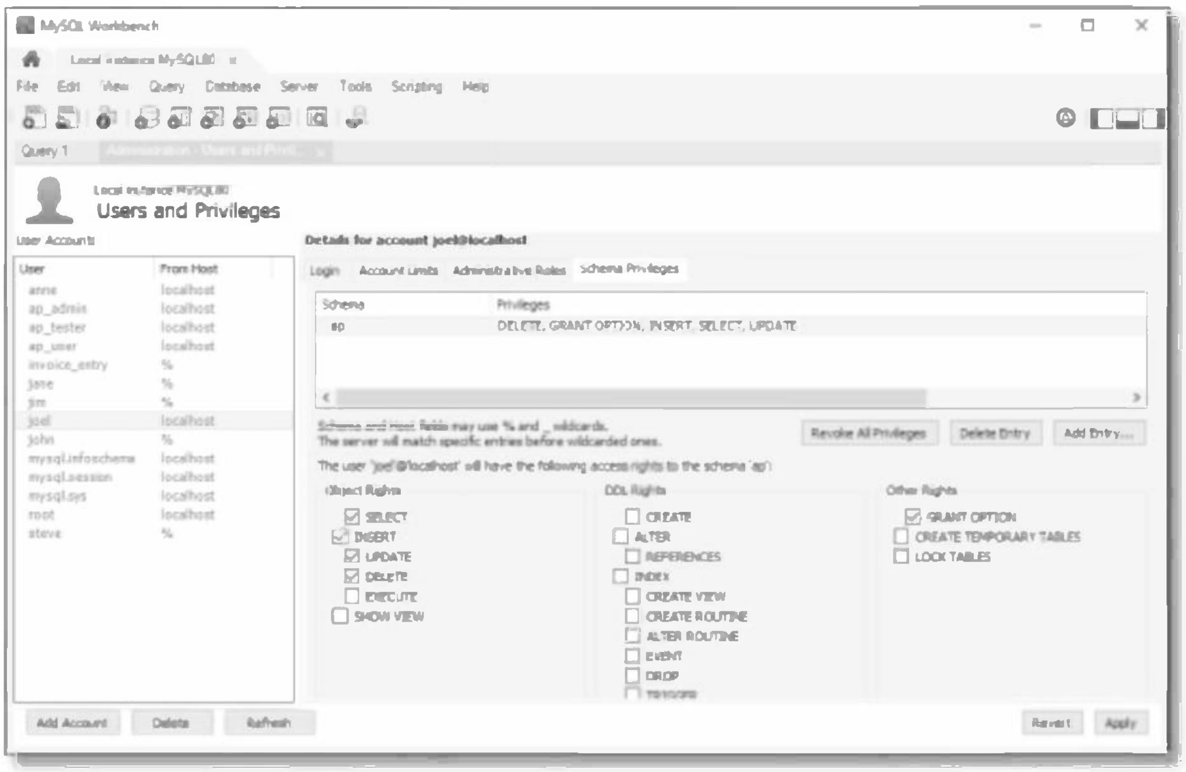
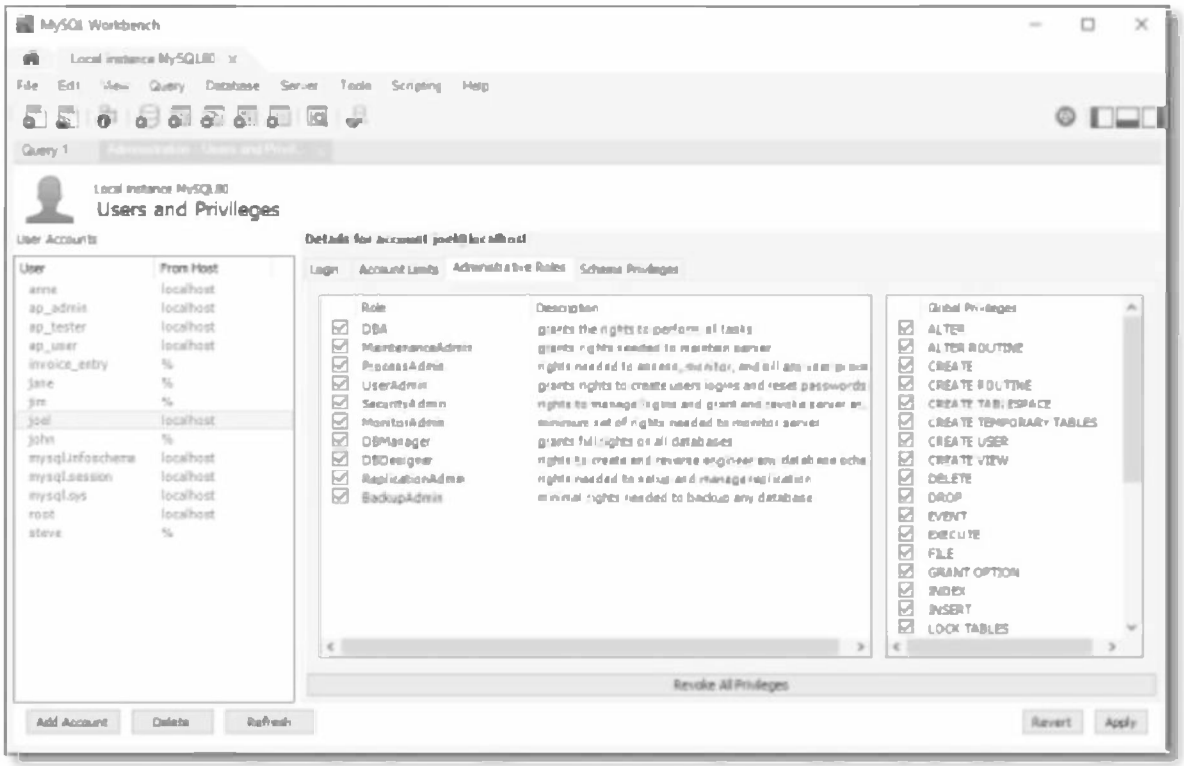



Figure 18-13 How to work with users and privileges (part 1 of 2)

Workbench provides some predefined administrative roles that you can use to quickly set up privileges for database administrators, managers, and designers. Before you begin working with these roles, you should know that they are not the same as the roles that you learned how to create with SQL statements earlier in this chapter. In other words, they aren't roles that are stored in the mysql database, and they can't be manipulated using SQL statements. Instead, they are a Workbench feature that allows you to quickly assign privileges to users.

To view the Workbench roles for a user, you select the user from the Administrative Roles tab of the Users and Privileges window as shown in the screen in part 2 of figure 18-13. Then, you can select the roles that you want to assign the user to, and the privileges assigned by those roles will be selected at the right side of the tab. Note that these are global privileges, so they apply to all databases on the server. Because of that, you'll want to be careful who you assign to these roles.

## The Administrative Roles tab




## Description

- To display the Users and Privileges window, select Users and Privileges from the Navigator window. If necessary, click the Administration tab to display this item.
- To change a user's name, password, or host access options, use the Login tab. You can also use this tab to add or remove a user account, to expire a user's password, or to revoke all privileges for a user.
- To view the database privileges for a user, use the Schema Privileges tab. You can also use this tab to change privileges and to add and remove host/schema access options.
- To view the administrative roles that a user is assigned to and the global privileges granted to those roles, use the Administrative Roles tab. You can also use the check boxes on this tab to assign or revoke the privileges of the administrative roles. These roles are defined by Workbench and are not stored as roles in the mysql database.

Figure 18-13 How to work with users and privileges (part 2 of 2)

## How to connect as a user for testing

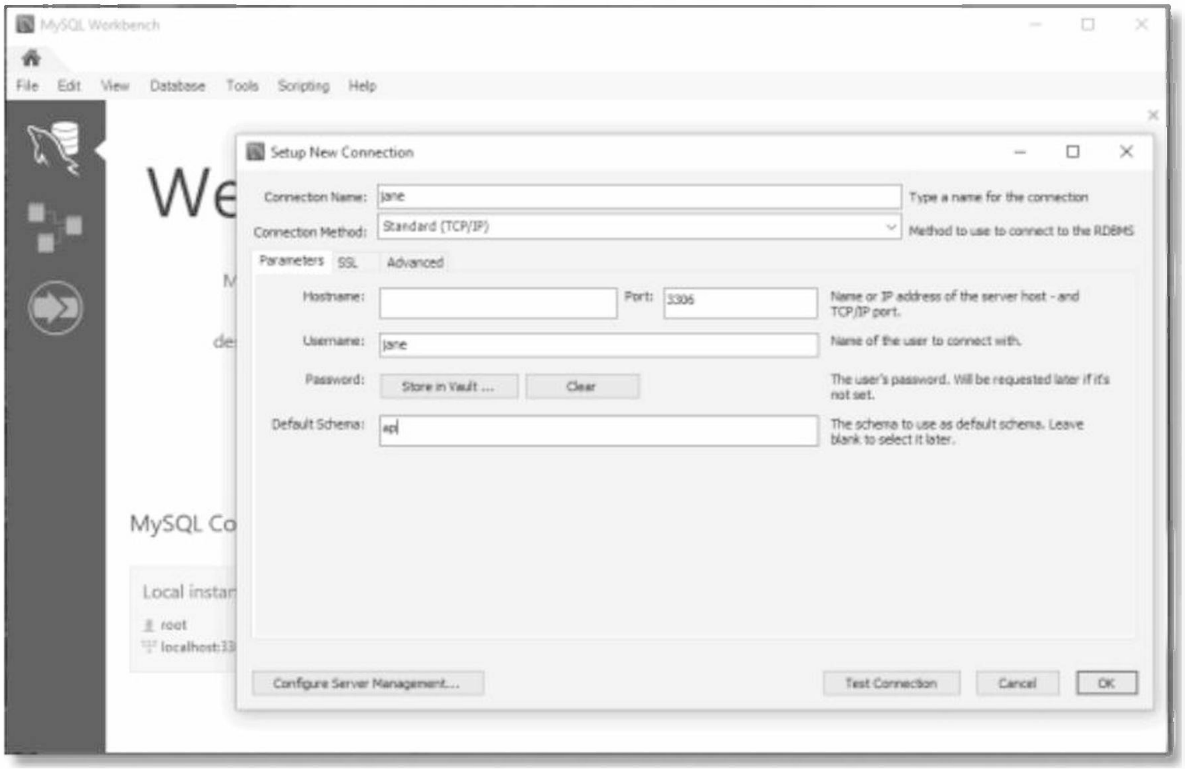
To test the username, password, and privileges for a user, you can connect as that user. To do that, you create a new connection for the user as described in figure 18-14.

To start, you display the Home tab and click on the ⊕ icon next to MySQL Connections. Then, you enter the connection information in the resulting dialog box, including a connection name and a username. In this figure, for example, I'm creating a connection named jane for the user with the same name. Here, no hostname is specified because the user can connect from any host. Also, a default schema of AP is specified, so the AP database is used if no other database is selected.

After you create a connection for a user, the connection is added to the list of connections on the Home tab. Then, you can connect as that user by clicking on the connection and entering the user's password if necessary.

When you connect as a user, you can only use that connection to view the databases and tables that the user has privileges to view. In addition, you can only modify the databases and tables that the user has privileges to modify. To make sure that the user's privileges are working correctly, you can run SQL statements. For example, if a user only has the SELECT privilege on a table, you can try inserting, updating or deleting a row. In that case, MySQL Workbench will display an error indicating that the statement was denied.

## The Setup New Connection dialog box




## Description

- To create a connection for testing a specific user's privileges and roles, display the Home tab, click the ⊕ icon to the right of MySQL Connections, and enter the connection information in the resulting dialog box. This includes a name for the connection and a name for the user.
- To connect as a user, click on the connection for the user in the list of connections, and enter the password for the user if necessary.
- When you connect as a user, you can only view the databases and tables that the user has privileges to view, and you can only modify the databases and tables that the user has privileges to modify.

Figure 18-14 How to connect as a user for testing

# Perspective

Although managing security can be complex, MySQL provides tools to simplify the job. In this chapter, you learned how to manage security by writing SQL statements, and you learned how to use MySQL Workbench to work with users and manage privileges. Once you're familiar with both of these techniques, you can use the one that's easiest for the security task at hand.

In addition to the skills presented in this chapter, you may also need to secure MySQL's file system if the server is running on a computer that has multiple users. That way, other users who log in on that computer can't access any of the MySQL files that may contain sensitive data. That includes the data, log, and configuration files you learned about in chapter 17. Because the procedure for securing the file system varies depending on the operating system, this information isn't presented in this book.

You may also need to use SSL to secure the usernames and passwords of users who are allowed to connect remotely. In most cases, users connect locally. For example, a web server often runs on the same machine as the MySQL server. As a result, users of the website use a local connection to connect to MySQL. If the MySQL server is on a different machine, though, you can learn about providing secure connections by looking up "Using Encrypted Connections" in the MySQL Reference Manual.

## Terms

privilege
object privileges
administrative privileges
global privileges
database privileges
table privileges
column privileges
grant tables
role

## Exercise

In this exercise, you will create two users and a role. You will grant privileges directly to the first user, and you will grant privileges to the second user through a role. In addition, you will use MySQL Workbench to connect as the two users and test their privileges.

1. Use MySQL Workbench to connect as the root user.
2. Write a script that creates a user named ray@localhost with a password that expires immediately. This user should have SELECT, INSERT, and UPDATE privileges for the Vendors table of the AP database; SELECT, INSERT, and UPDATE privileges for the Invoices table; and SELECT and INSERT privileges for the Invoice_Line_Items table. This user should also have the right to grant privileges to other users. Run the script in MySQL Workbench.
3. Check the privileges for ray@localhost by using the Users and Privileges window of MySQL Workbench.
4. Use MySQL Workbench to create a connection for the user named ray@localhost and connect as that user. To do that, you can leave the old password blank and enter a new password. Use the Navigator window to see which databases and tables this user can view.
5. Run a SELECT statement that selects the vendor_id column for all rows in the Vendors table. This statement should succeed.
6. Write a DELETE statement that attempts to delete one of the rows in the Vendors table. This statement should fail due to insufficient privileges.
7. Switch back to the tab for the connection for the root user.
8. Grant the UPDATE privilege for the Invoice_Line_Items table to ray@localhost, and give the user the right to grant the same privilege to other users.
9. Write a script that creates a user named dorothy with a password of "sesame". Then, create a role named ap_user, and grant this role privileges to select, insert, and update data from any table in the AP database. However, don't grant this role privileges to delete any data from the database. Assign the user named dorothy to this role.
10. Check the privileges for dorothy by using the SHOW GRANTS statement.
11. Use MySQL Workbench to create another connection for the user named dorothy and then connect as that user.
12. Run a SELECT statement that displays the active roles for the current user. This should display NONE.
13. Close the tab for the connection for the user named dorothy, and switch back to the tab for the connection for the root user.
14. Set the default role for the user named dorothy to ap_user.
15. Connect as dorothy again and then display the active roles using the same statement as in exercise 12. This time, the ap_user role should be displayed.

# 19

# How to back up and restore a database

When you work with a database that stores important data, you should have a plan for backing up that database regularly. Then, you need to execute that plan. That way, if something bad happens to the database, you can restore it and minimize the amount of data that's lost.

In this chapter, you'll learn how to back up and restore a database. You'll also learn some skills that are related to backing up and restoring a database. Specifically, you'll learn how to export data to a file and how to import data from a file.

# How to back up and restore a database

One important task of a database administrator is to regularly *back up* the database. Then, if the database ever becomes corrupted, the database administrator can use the backup files to *restore* the database.

## Strategies for backing up and restoring databases

Figure 19-1 starts by presenting strategies for backing up and restoring databases. MySQL provides for two types of backups. A *full backup* includes the structure and data of a database. This creates one or more SQL script files that can be used to recreate the database. You should create a full backup at regular intervals. For a medium-size database for a website, for example, you might want to create a full backup once a week.

When you create a full backup, it locks all tables so other users can't update the database while it's being backed up. As a result, it's a good practice to schedule this backup at a time of low traffic for the database.

An *incremental backup* contains changes that have been made to a database since the last full backup. To implement incremental backups, the binary log must be enabled as described in chapter 17. That's because the binary log files store the changes to the database.

When you use this backup strategy, you shouldn't store your backup files (SQL scripts or log files) on the same hard drive where the MySQL server is running. If you do, those files will be lost if that hard drive fails. As a result, it's a good practice to configure the binary log so it writes to a directory on a different hard drive. This has the added benefit of balancing the load between two hard drives.

When you create a backup strategy, don't forget that the database named mysql stores information about the users and privileges for all databases on the server. As a result, you typically want to include this database in your backups.

The goal of backing up your databases is to allow you to restore them to their exact state at any specified point in time. This is known as a *point-in-time recovery* (*PITR*). To restore a database to a point in time, you can use the last full backup to restore the database. Then, you can use the binary log to restore the database from the time of the last full backup to the specified point in time.

## A strategy for backing up databases

1. Use Workbench to create full backups of each database. These backups should be stored in one or more SQL script files.
2. Enable the binary log as described in chapter 17 to create incremental backups.

## A strategy for restoring databases

1. Use Workbench to restore the database from the last full backup.
2. Use the mysqlbinlog program to execute all statements in the binary log that occurred after the last full backup.

## Description

- It's important for the database administrator to regularly *back up* the database. Then, if the database becomes corrupted, the database administrator can use the backup to *restore* the database.
- A *full backup* includes the structure and content of a database. You should perform full backups according to a regular schedule.
- An *incremental backup* only contains changes that have been made to the structure and content of a database since the last full backup.
- You often want to include the database named mysql in your backups, since this database stores information about the users and privileges for all databases on the server.
- You shouldn't store your backup files (SQL scripts or log files) on the same hard drive where the MySQL server is running. If you do, those backup files will be lost along with the databases if that hard drive fails.
- A *point-in-time recovery* (PITR) allows you to restore the data up to any specified point in time.

Figure 19-1 Strategies for backing up and restoring databases

## How to use Workbench to create a full backup

Figure 19-2 shows how to use MySQL Workbench to create a full backup, or *dump*, of a database. By default, Workbench backs up the structure and data for the database into multiple SQL scripts with one script per database object. This gives you the flexibility to restore all or part of a database, and it works well for most scenarios.

To create a full backup, you display the Data Export window. Then, you can click on any database to display the tables and views it contains, and you can select a database to select all of its tables and views. In the example shown here, all of the tables for the AP, EX, and OM databases for this book are selected. (These databases don't contain views.)

In most cases, you'll leave all other settings at their default values. Then, Workbench backs up the structure and the data for all of the selected tables, and it stores the SQL scripts in a folder with a name of "Dump" followed by eight digits that represent the date of the backup in the YYYYMMDD format.

You can also use the Data Export window to modify the basic options. For example, you can back up the objects for stored procedures, functions, events, and triggers by selecting the appropriate options in the Objects to Export section. Similarly, you can back up all selected objects into a single SQL script file by selecting Export to Self-Contained File in the Export Options section. Because this doesn't give you as much flexibility when restoring the database, however, it's not the approach we recommend.

If you think you might need to restore a database that doesn't exist, you can select Include Create Schema. This option adds a CREATE DATABASE statement at the beginning of each script that creates the database if it doesn't exist. You may need to do that if the database has been accidentally deleted or if the hard drive has failed and you need to restore the database to a new hard drive.

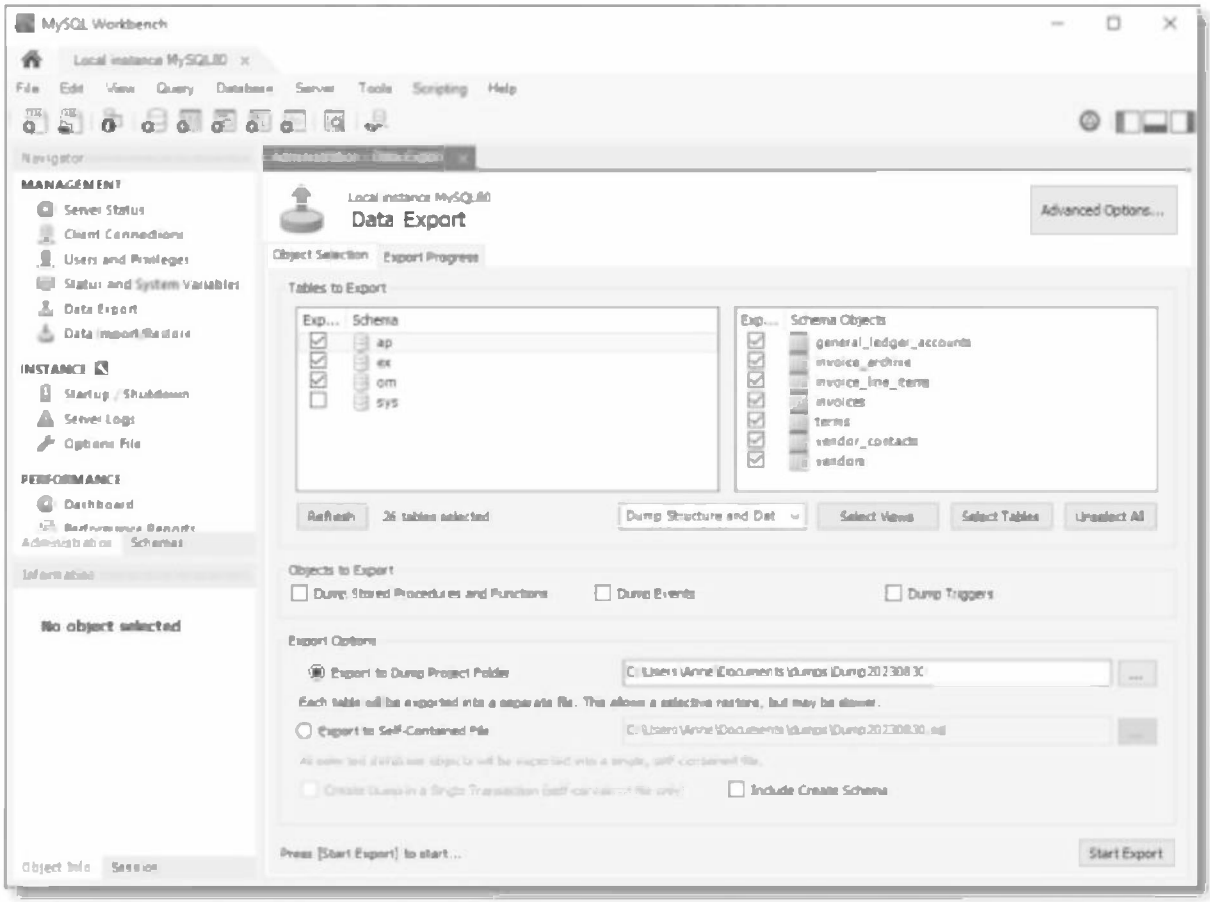
If the basic options in the Data Export window don't give you enough control over the backup operation, you can click the Advanced Options button to display additional options. For example, by default, the Data Export window doesn't include internal databases like the mysql database. As a result, if you want to use Workbench to back up this database, you need to select Show Internal Schemas so the mysql database is listed in the Data Export window.

In addition, you may want to select "flush-logs" so the server starts a new binary log file when you back up the databases. This makes it easier to find the binary log file or files that you will need to restore the database later.

After you set the options for your backup, you can click the Start Export button to back up your database objects. If you don't see this button in the lower-right corner of the Data Export window, you may need to enlarge the window.

Under the hood, Workbench uses the mysqldump command-line program to back up a database. In general, Workbench is easier to use than the mysqldump program, which is why it's presented in this chapter. However, the mysqldump program makes it possible to automate your backups. Although the details for doing this vary depending on the operating system, the same principles apply to all operating systems. To start, you create a script file that uses the mysqldump

### Workbench after selecting the data to back up




### How to back up one or more databases

1. Use Workbench to connect to the local server.
2. Display the Administration tab in the Navigator window, and then select Data Export from the Management category.
3. Click on any database name to display its objects, and select the databases and objects you want to back up.
4. Click the Start Export button.

### Description

- You can use Workbench to back up, or *dump*, one or more databases into one or more SQL script files.
- By default, Workbench backs up the structure and data for the database into multiple scripts with one script per database object.
- By default, Workbench doesn't show internal databases like the mysql database in the list of databases. To change that, click the Advanced Options button and select Show Internal Schemas.
- By default, Workbench doesn't start a new binary log file when you create a full backup. To change that, click the Advanced Options button and select "flush-logs".

Figure 19-2 How to use Workbench to create a full backup program to back up one or more databases. Then, you use the operating system's task scheduler to execute that script file at a specified interval.

## How to use Workbench to restore a full backup

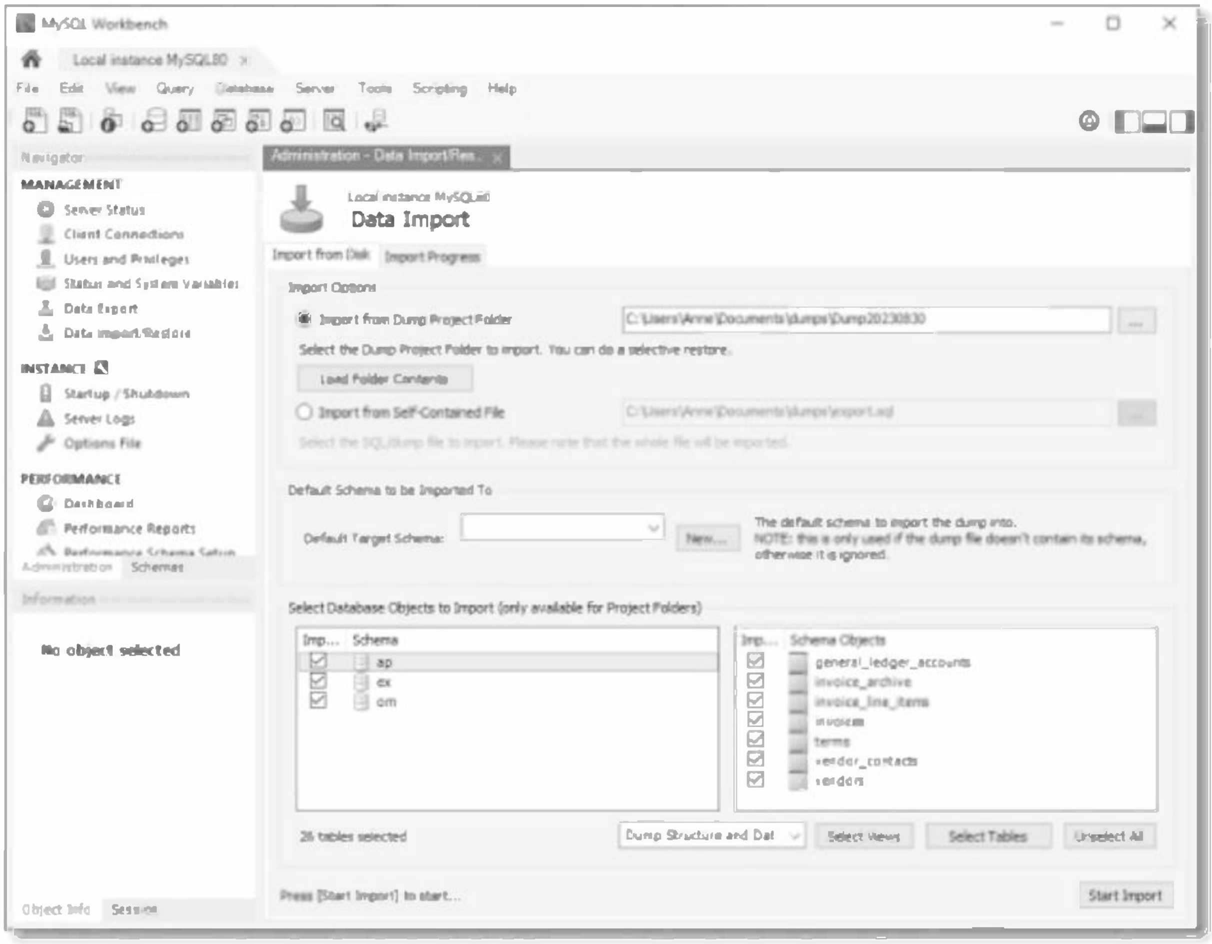
Figure 19-3 shows how to use Workbench to restore a full backup of one or more databases. To start, you display the Data Import window. Then, you select the folder that contains the full backup you want to restore. Here, the folder is the one that contains the full backup that was created in the previous figure.

After you select the backup folder, Workbench lists and selects all of the databases and database objects that were included in the backup. At this point, you can click the Start Import button to restore everything that was included in the backup. Or, you can deselect any databases or objects that you don't want to restore.

To be able to restore a database, the database must exist on the MySQL server. If it doesn't and you didn't select Include Create Schema when you backed up the database, you can create the database before you start the import. One way to do that is to click the New button in the Data Import window and then enter the database's name.

Before you restore a database, it's often a good idea to back up the existing database. That way, if the restore operation doesn't work correctly, you have a backup of the database that existed before the restore operation.

### Workbench after selecting the data to restore




### How to restore one or more databases from a full backup

1. Use Workbench to connect to the local server.
2. Display the Administration tab in the Navigator window, and then select Data Import/Restore from the Management category.
3. Select the folder that contains the backup scripts.
4. Deselect any databases and objects that you don't want to restore.
5. Click the Start Import button.

### Description

- You can use Workbench to restore one or more databases by running the appropriate SQL script files generated by a previous backup.

Figure 19-3 How to use Workbench to restore a full backup

## How to execute statements in the binary log

The first example in figure 19-4 shows the file names for a binary log named bin-log located in the murach/mysql directory. MySQL created these after the binary log was enabled as described in chapter 17. The bin-log.index file is a text file. It contains a list of all of the numbered files that store the binary log. The numbered log files (bin-log.000001, bin-log.000002, etc.) are binary files. If you open them in a text editor, most of the contents will be unreadable. However, they contain a record of each statement made to the database while binary logging was enabled for your server.

To execute statements in the binary log file, you begin by displaying the command line for your operating system. For Windows, you can start the Command Prompt program. For macOS, you can start the Terminal program.

Once you've started a command line, you use the cd command to change to MySQL's bin directory as shown in the second example. This is the directory that stores the various MySQL command-line programs, including the mysqlbinlog and mysql programs described in this figure. In this figure, front slashes are used to separate the directory and file names because they work on all operating systems. However, it's common to use backslashes on Windows.

The third example shows how to use the mysqlbinlog program to execute statements recorded in the binary log. This allows you to recreate the state of your database from the time when the log was started.

The first command shows how to execute all statements stored in a single binary log file. To start, this command uses the mysqlbinlog program to identify the binary log file you want to use. Then, it uses a pipe character ( | ) followed by mysql to indicate that the mysqlbinlog program should use the mysql program to execute the statements in the binary log. Finally, the -u option identifies the user (root), and the -p option specifies that the program should prompt for a password.

When you restore data using a binary log as shown by the first command, every statement in the log file is executed by default. But what if you only need to restore one database from the binary log? In that case, you can use the database option to specify the name of that database. This is shown in the second command. Or, if you want to only execute statements that fall within a specified date/time range, you can use one or both of the date/time options to specify a start and end point as shown by the third command.

If your binary log has been split across multiple files, you can specify a list of binary log files as shown in the fourth and fifth commands. In the fourth command, the names of the log files are separated by a space. This works for Windows, macOS, and Unix/Linux. For macOS and Unix/Linux, you can also use a regular expression to select all binary log files as shown in the fifth command.

### The files for a binary log named bin-log

```
bin-log.index
bin-log.000001
bin-log.000002
bin-log.000003
...
```

### How to change to MySQL's bin directory

#### Using Windows

```
cd /program files/mysql/mysql server 8.0/bin
```

#### Using macOS or Unix/Linux

```
cd /usr/local/mysql/bin
```

### How to use the mysqlbinlog program to execute statements

#### For all databases

```
mysqlbinlog /murach/mysql/bin-log.000001 | mysql -u root -p
```

#### For a specific database

```
mysqlbinlog --database=ap /murach/mysql/bin-log.000001 | mysql -u root -p
```

#### For a specific time range

```
mysqlbinlog --start-datetime="2023-01-10 00:00:00"
--end-datetime="2023-01-10 04:30:00" /murach/mysql/bin-log.000001 |
mysql -u root -p
```

#### For all databases using multiple binary log files

```
mysqlbinlog /murach/mysql/bin-log.000001 /murach/mysql/bin-log.000002 |
mysql -u root -p
```

#### For all databases using multiple binary log files (macOS and Unix/Linux only)

```
mysqlbinlog /murach/mysql/bin-log.[0-9]* | mysql -u root -p
```

### Description

- You can use the mysqlbinlog program to execute statements in the log file.
- If the statements you want to execute are stored in multiple binary logs, you should specify all of them on the command line in sequence from the lowest numbered log file to the highest numbered log file.
- On macOS, you typically need to begin by coding the sudo command, code a dot and slash before the name of the mysqlbinlog program and the mysql program, and specify a path to the data directory. For example, you can execute the first example shown above like this:

```
sudo ./mysqlbinlog ../data/binlog.000001 | ./mysql -u root -p
```

Figure 19-4 How to execute statements in the binary log

# How to use Workbench to export and import data

In addition to backing up and restoring an entire database, you may sometimes need to export selected data from a database to a file. For example, you might need to export data for someone who needs to use a spreadsheet program to work with that data or for someone who wants to use other software to analyze the data. Conversely, you may need to import data from a file into a database. For example, you may need to import updated shipping rates that are stored in a file into a table. Fortunately, MySQL Workbench makes it easy to export and import data.

## How to export data to a file

Figure 19-5 shows how to export data to a file. To do that, you begin by using Workbench to run a SELECT statement that retrieves the data you want to export. This SELECT statement can retrieve data from a single table or from multiple tables that have been joined. In this figure, the SELECT statement joins the Vendors and Invoices tables and retrieves four columns.

After selecting the data, you click the Export button that's displayed above the result set. Then, you use the resulting Export dialog box to specify a name and type for the file. This dialog box allows you to select many different types of data formats, but this chapter focuses on two of the most common: CSV and JSON. Those formats are also the ones that you can most easily import.

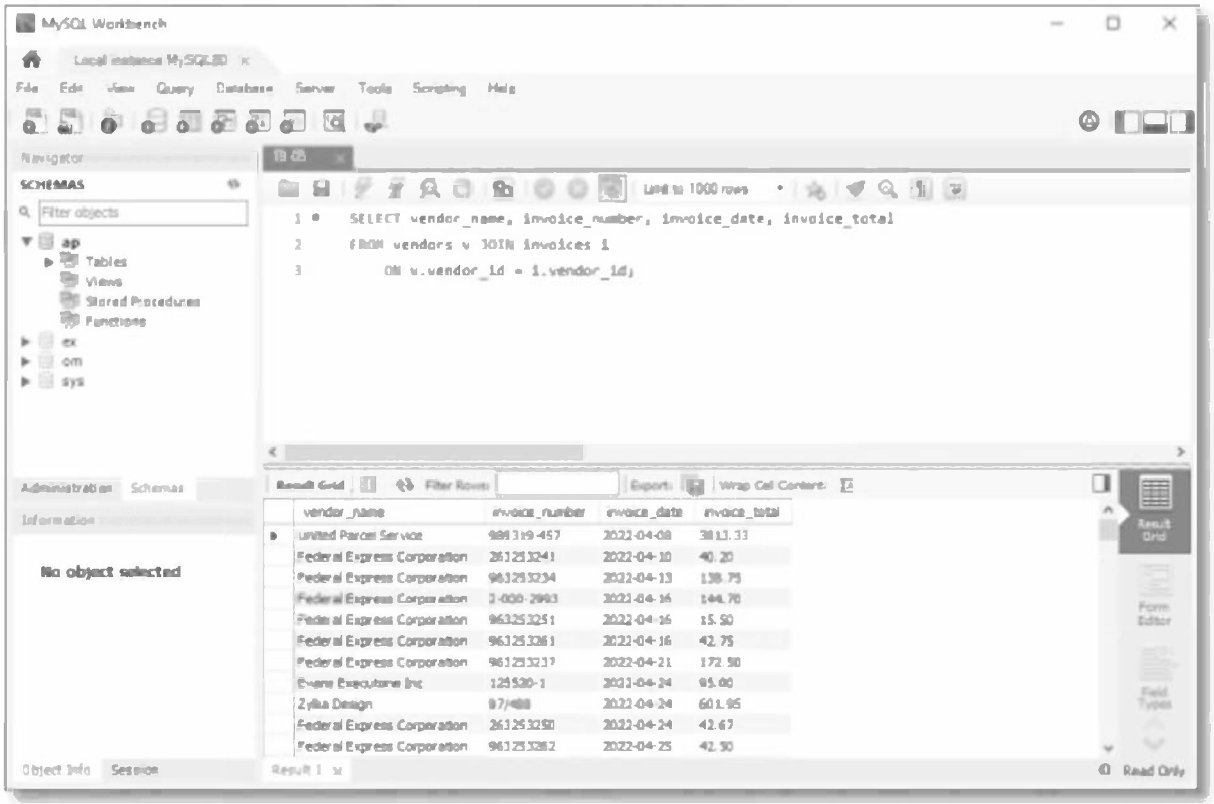
Since it's easy to export data to a CSV file, and since this format can be read by most other programs including spreadsheet programs, this is the type of file that you usually want to use. A *CSV (comma-separated values)* file uses a comma to separate each column and stores each row on its own line.

In addition, a CSV file encloses some strings in double quotes. In this figure, the CSV file encloses the vendor names in double quotes because these names include spaces. However, a string would also be enclosed in double quotes if it stored a comma.

Typically, a CSV file includes the column names on its first line as shown in this figure. This makes it easier to import the data that's stored in a CSV file.

Although you typically export data from a database into a CSV file, you can also export data into other formats, such as a JSON file. *JSON (JavaScript Object Notation)* is a data interchange format that was originally used by the JavaScript language but is now used by many modern programming languages. It's typically used to export data that has multiple levels, not the tabular data that's typically exported by a database. However, it's easy enough to export tabular data to JSON if you ever need to do that.

## Workbench after selecting the data to export




## How to export selected data to a file

1. Use Workbench to run the statement that selects the data.
2. Click the Export button that's displayed above the result set.
3. Use the Export dialog box to specify a name and type for the file.

## A CSV (comma-separated values) file

```
vendor_name,invoice_number,invoice_date,invoice_total
"United Parcel Service",989319-457,2022-04-08,3813.33
"Federal Express Corporation",263253241,2022-04-10,40.20
"Federal Express Corporation",963253234,2022-04-13,138.75
...
```

## Description

- You can use Workbench to export data to different types of files including CSV and JSON files.
- A *CSV (comma-separated values)* file uses commas to separate each column, stores each row on its own line, and typically includes the column names on its first line.
- *JSON (JavaScript Object Notation)* is a data interchange format that was originally used by the JavaScript language but is now used by many modern programming languages.

Figure 19-5 How to export data to a file

## How to import data from a file

Figure 19-6 shows one way to use Workbench to import data from a file into a table. Specifically, it shows how to import the data stored in the CSV file at the top of this figure into the Vendor_Contacts table that's in the AP database. However, if the same data was stored in a JSON file, you could use a similar procedure to import it.

To start, you use Workbench to run a statement that selects all rows and columns from the Vendor_Contacts table. When you do that, Workbench displays an Import button above the result set. Then, you can click that button to start a series of dialog boxes that let you control how the import works.

The dialog boxes that are displayed vary depending on the type of file that you're importing. For example, the first dialog box lets you select a CSV or JSON file. Then, you can click on the Next button and use the resulting dialog boxes to set other options.

The first screen in this figure shows the options you can set for the destination table. Here, these options import the data by adding it to the data in the Vendor_Contacts table that already exists in the AP database. However, if you want to delete the existing data before importing the data, you can select "Truncate table before import". Similarly, if you want to create a new table to store the data, you can select "Create new table".

You can use the second screen to map the columns of the source file to the columns of the destination table. In this figure, Workbench has detected that the source file is a CSV file and has used its first line to get the names of its columns. In this case, the columns have the same names in both the source file and the destination table. As a result, it's easy to map them. However, this would work even if the columns had different names.

When you import data into an existing table, the columns in the source file must match the columns in the table for the import to work successfully. For example, the Vendor_Contacts table has three required columns: an INT column followed by two VARCHAR(50) columns. As a result, MySQL must be able to convert the data that's stored in the source file to the data types specified by the Vendor_Contacts table.

In addition, the data in the source file must not conflict with the values of any unique keys that are already stored in the rows of the table. If that happens, you'll get an error that indicates that you were attempting to make a duplicate entry. Usually, that's what you want. If it isn't, you can delete any duplicate entries that you don't want from the source file or the destination table.

If you import data into a new table, the columns in that table are given the same names as the columns in the source file. In addition, Workbench determines the data type of each column in the new table based on the data in the columns of the source file. However, Workbench displays the data type for each column in a drop-down list so you can change the type if you need to.

### A CSV file that contains vendor contacts

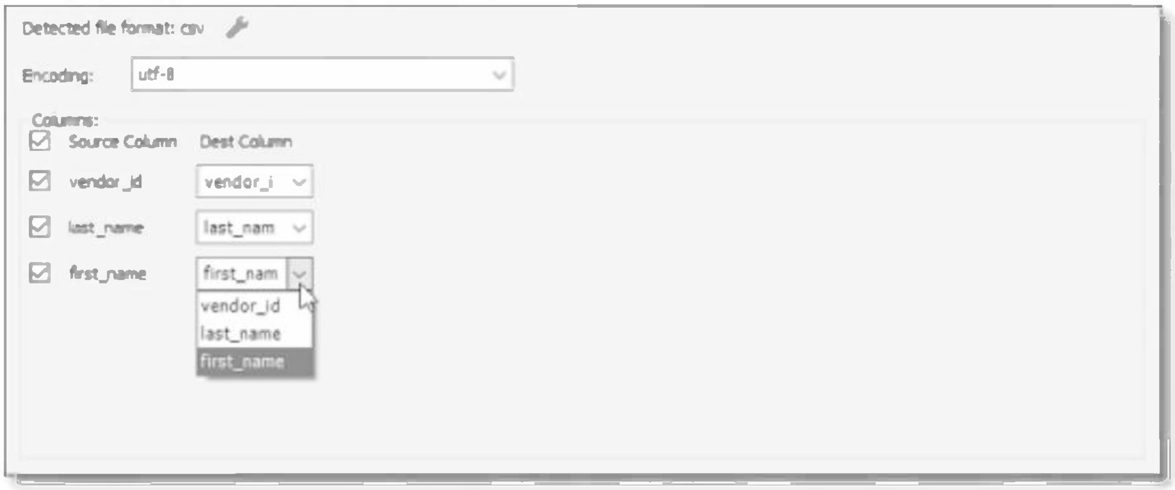
```
vendor_id,last_name,first_name
19,Strummer,Joe
77,Jones,Mick
85,Simonon,Paul
```

### A procedure for importing data from a CSV or JSON file

1. Use Workbench to run a statement that selects all rows and columns from the destination table.
2. Click the Import button that's displayed above the result set.
3. Use the Import dialog box to select the file that contains the data and click the Next button.
4. Continue clicking the Next button and setting the options until the import finishes.

### The destination table options


### The import options for a CSV file




### Description

- You can use Workbench to import CSV files or JSON files.
- If you import data into an existing table, Workbench adds the data to the table by default. However, if you want to delete the existing data before the import, you can select "Truncate table before import".

Figure 19-6 How to import data from a file

# Perspective

In this chapter, you learned how to back up your databases and how to restore them if necessary. If you combine these skills with the skills you learned in the previous chapter for securing a database and working with user accounts, you are on your way to becoming a successful database administrator.

## Terms

back up a database
restore a database
full backup
incremental backup
point-in-time recovery (PITR)
dump a database
CSV (comma-separated values)
JSON (JavaScript Object Notation)

## Excercise

In this exercise, you will back up a database. Then, you'll make some changes to the database. Finally, you'll restore the database.

### Back up a database

1. Make sure binary logging is enabled as described in chapter 17.
2. Use Workbench to connect to the local server, and then create a full backup of the AP database. This backup should include the structure and data for the database, as well as any stored routines, functions, events, and triggers for the database.
3. Execute an INSERT statement that inserts one row into the Vendors table of the AP database, and note the time on your computer that this statement is executed.
4. Wait until the time on your computer changes to at least the next minute.
5. Execute a DELETE statement that deletes the row you just added.

### Restore a database

6. Use Workbench to restore the entire AP database.
7. Identify the highest numbered file for the binary log.
8. Open a command line and use the mysqlbinlog program to add the row to the Vendors table that you inserted in step 3. To do that, you'll need to include start and end times that include the INSERT statement but omit the DELETE statement you executed in step 5.

# 20

# How to host a database with AWS

For years now, the tech industry has been moving away from using local servers to host databases and websites, preferring instead to use servers in the cloud. In other words, instead of using physical servers located on the same premises, many organizations are now using virtual servers hosted at server farms running at one or more remote locations. This is known as *cloud computing*. There are many reasons for this trend including increased affordability, flexibility, and scalability.

In this chapter, you'll learn how to use Amazon's cloud computing platform, Amazon Web Services (AWS), to host a database in the cloud. In particular, you'll learn how to use Amazon's Relational Database Service (RDS) to host MySQL databases.

# How to create and configure a MySQL RDS instance

In this topic, you'll learn how to use *Amazon Web Services (AWS)* to create and configure a *Relational Database Service (RDS)* instance for hosting MySQL databases in the cloud. But first, you'll learn how to access these services.

## The AWS Management Console

Before you can use any of Amazon's web services, you must first create an AWS account. To do that, you go to the URL for the AWS portal shown in figure 20-1. This account is separate from any other Amazon accounts you might already have.

When you create a new account, you will need to provide a credit card. However, many introductory services are available for free, at a very low cost, or as free trials. This means that you can learn and experiment with AWS before committing to any services.

Once you've created your account and logged in, you'll see the AWS Management Console shown in the first screen. From this page, you can click the Services icon or use the search bar to navigate to any of the services that AWS provides.

## The Amazon RDS Databases page

This chapter shows you how to use Amazon RDS. RDS is a managed database service, which means that it handles most aspects of server and database maintenance, including creating backups and allocating compute and storage. It allows you to create and work with cloud-hosted relational database (DB) instances. In RDS, an *instance* is an isolated database environment that can contain one or more databases.

To create and interact with an RDS database, you navigate to the RDS Databases page from the AWS portal as described in figure 20-1. This page is shown in the second screen. You can use it to create new database instances and work with existing instances.

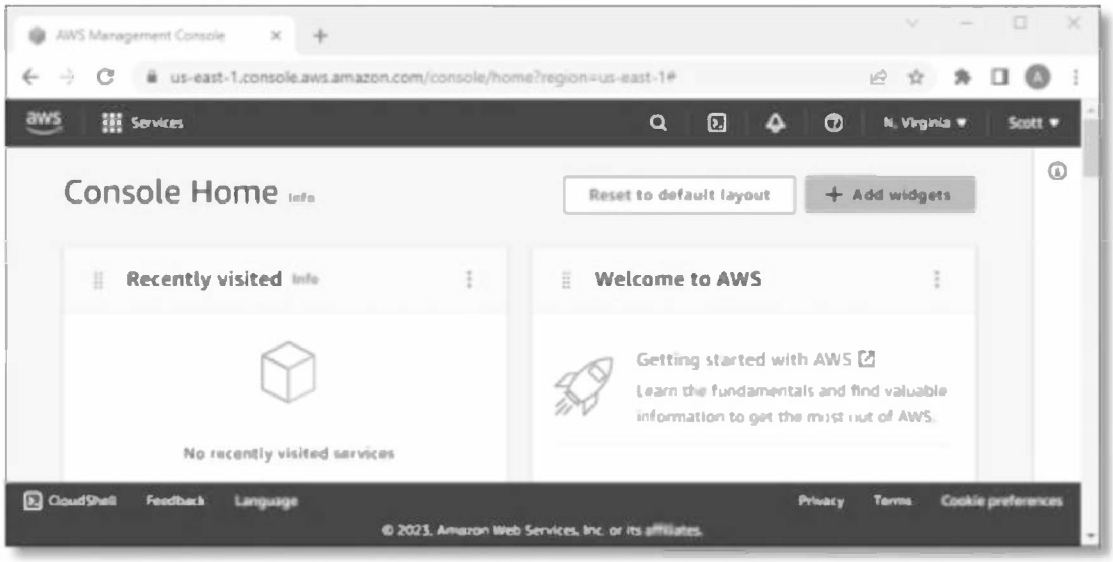
As you work with RDS, you'll notice that it often refers to a database instance as simply a database. For example, as you'll learn in the next figure, you use the "Create database" button on the Databases page to create a database instance, not a database. This can be confusing at first, so you'll want to keep it in mind as you work with RDS.

Because RDS is a managed database service, I recommend using it for your first cloud-hosted databases. However, if you want more control over the server that hosts your databases, you may want to use *Amazon Elastic Compute Cloud (EC2)* instead. Keep in mind that when you use EC2, you must set up everything your database requires, including installing an operating system. So, you should be sure that having more control over the server warrants this extra work.

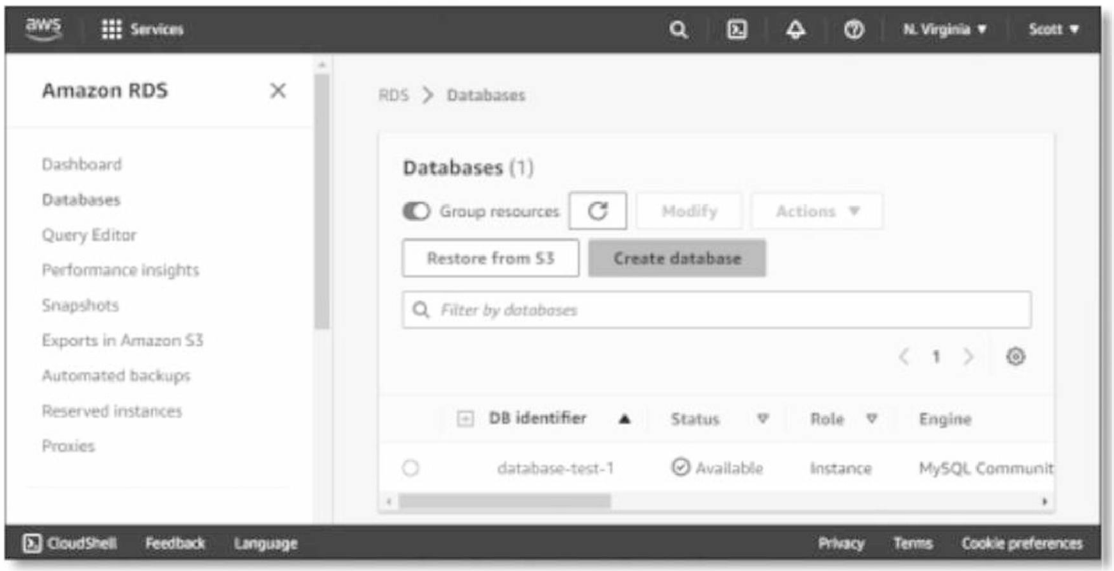
### The AWS portal

`aws.amazon.com`

### The AWS Management Console




### The Amazon RDS Databases page




### Description

- The *Amazon Web Services (AWS) portal* provides a way to manage all types of Amazon services, including database services.
- Amazon *Relational Database Service (RDS)* is a managed database service. That means that Amazon handles most of the server and database maintenance for you.
- To work with MySQL *database (DB) instances* in the Amazon cloud, you use the Amazon RDS Databases page. To display this page from the AWS portal, use the search bar to search for and select RDS, or click the Services icon and select Database→RDS from the lists that are displayed. Then, click Databases in the left sidebar.

Figure 20-1 The AWS Management Console and the RDS Databases page

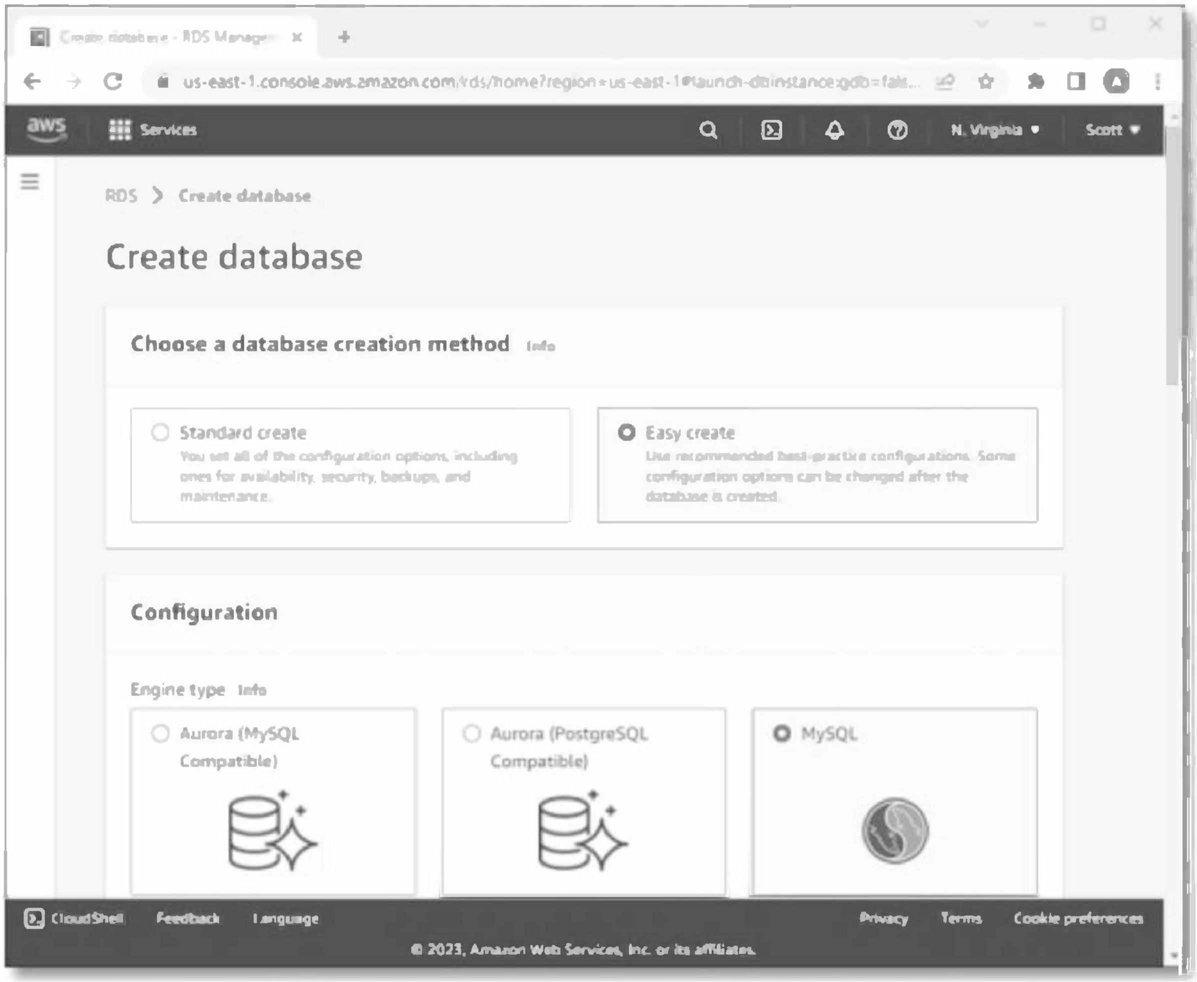
## How to create a MySQL RDS instance

Before you can create a database that's hosted by RDS, you need to create an RDS instance. An RDS instance provides the *compute and storage* that are used to physically host your database. Compute and storage is the common way to refer to the physical aspects of the server: memory, processing power, and disk storage. With RDS, Amazon handles allocating compute and storage for you, but you can modify the instance configuration to change compute and storage if you need to.

Figure 20-2 presents a procedure for creating a free MySQL RDS instance from the RDS Databases page. As you follow these steps, you'll see additional options that you may want to explore later. For example, you can create an RDS instance with a different RDBMS. That includes Aurora for MySQL or PostgreSQL, which are optimized for the cloud environment, as well as MariaDB, PostgreSQL, Oracle, and MS SQL Server.

In step 5 of this procedure, you're asked to select an instance size. The option you choose determines the number of CPUs that are available to you, the RAM and storage that are available, as well as what you will be charged if you exceed these limits. For the purposes of this book, the free tier should be adequate, and it will cost only 20 cents an hour if you exceed the limits.

### The page for creating a MySQL RDS instance




### How to create a free MySQL RDS instance

1. Log in to the AWS Management Console, and navigate to the RDS Databases page.
2. Click the "Create database" button to display the page shown above.
3. Select "Easy create" for the database creation method.
4. Select MySQL for the engine type.
5. Select "Free tier" for the DB instance size.
6. Enter a name such as "database-test-1" for the DB instance identifier.
7. Enter a master password you can easily remember.
8. Click the "Create database" button to create the DB instance and return to the RDS Databases page.

### Description

- As you follow the procedure above, you can skip any additional options that Amazon presents for now. Then, you can change these options later when you have a better idea of how you want to use AWS.

Figure 20-2 How to create a MySQL RDS instance

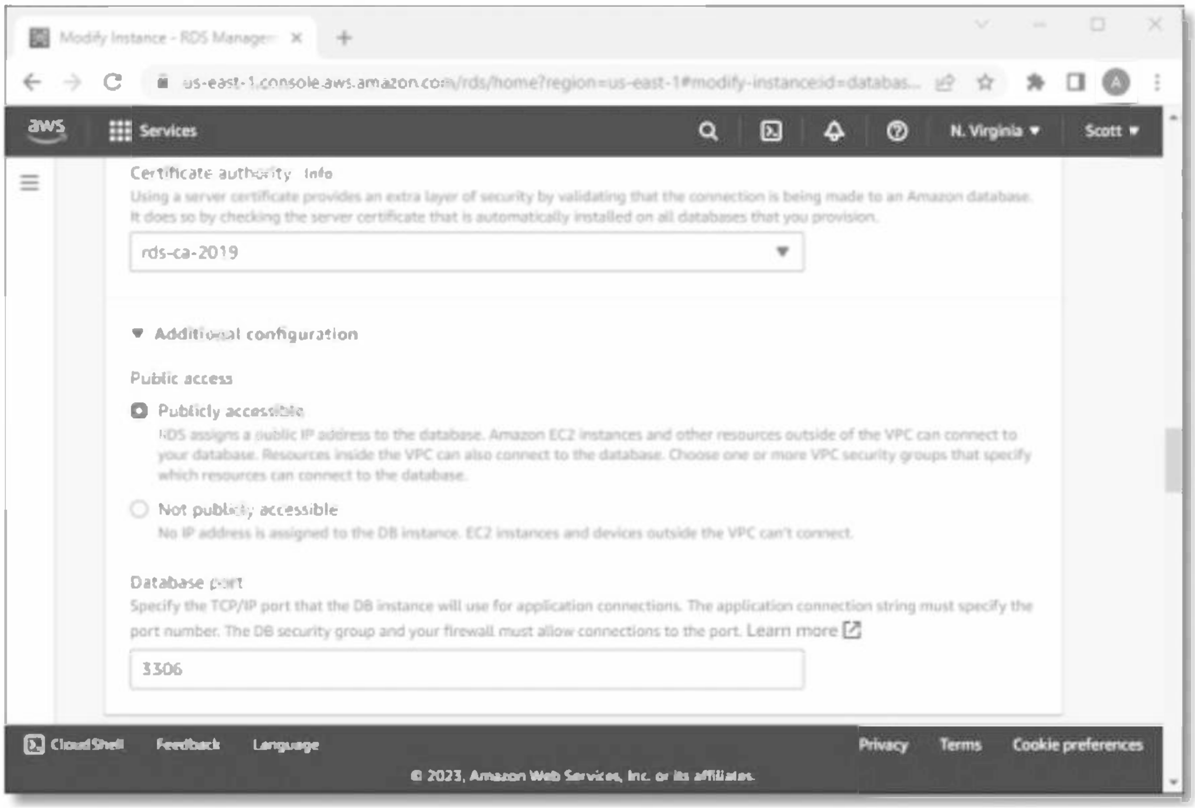
## How to modify an RDS instance so it's publicly accessible

When you create your AWS account, Amazon creates a default *VPC* (*virtual private cloud*) for you. A VPC is just what its name implies: a private environment hosted in a cloud. It is "virtual" because although the network mimics physical connections, it is entirely contained in Amazon's cloud. Unless you specify otherwise, all databases you create will be associated with your default VPC.

Before you can connect to your RDS instance from outside of the VPC, you need to modify the instance so it's publicly accessible. To do that, you can use the procedure shown in figure 20-3. Then, Amazon assigns a public identifier, called an IP (Internet Protocol) address, to the instance so it can be found by outside networks. That way, you'll be able to use client tools such as MySQL Workbench to connect to and work with the instance as shown later in this chapter.

Although it's okay for an RDS instance for a test database to be publicly accessible for a short period of time, Amazon recommends against making your RDS instances publicly accessible for production databases. That's because public accessibility can lead to security issues. Although you can use firewall rules as shown in the next figure to control access to RDS instance, there's a lot more to securing networked resources than that. However, those details are beyond the scope of this book.

## The page for configuring an RDS instance




## How to modify an RDS instance so it's publicly accessible

1. Navigate to the RDS Databases page and make sure that the status of your instance is "Available".
2. Click the name of the instance to display detailed information about that instance.
3. Click the Modify button to display the modifiable settings.
4. Expand the "Additional configuration" heading in the Connectivity section.
5. Select "Publicly Accessible" for the "Public access" option.
6. Scroll to the bottom of the page and click the Continue button.
7. Confirm the changes on the screen that's displayed, select "Apply immediately", and click the "Modify DB instance" button.

## Description

- By default, an RDS instance you create isn't publicly accessible. To work with the instance from outside of the *VPC* (*virtual private cloud*) associated with the instance, you need to change the instance so it is publicly accessible.
- In the real world, your instance shouldn't be publicly accessible unless you properly configure the inbound firewall rules.

Figure 20-3 How to modify an RDS instance so it's publicly accessible

## How to add a firewall rule for your IP address

In addition to making an RDS instance publicly accessible, to access it from outside the VPC, you must be sure that the instance includes a firewall rule for your IP address. *Firewall rules* are used to implement access control for a networked resource. The two main types of rules are inbound rules and outbound rules. *Inbound rules* control the traffic that can go into a resource, and *outbound rules* control the traffic that can go out from a resource. In this topic, you'll learn how to configure inbound rules so you have access to your resources, and you can configure outbound rules similarly.

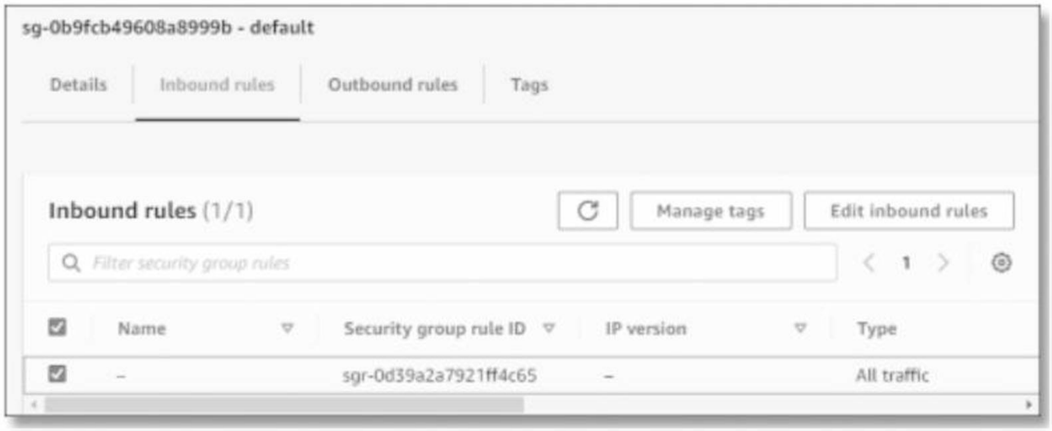
Figure 20-4 starts by showing the inbound rule that's created by default when you create an RDS instance. This rule is part of a security group, in this case, the default group. A *security group* is used to combine the rules for different types of traffic. An instance can be assigned to one or more security groups that control the types of traffic that the instance can create or receive. By default, security groups deny all inbound traffic and allow all outbound traffic.

In this figure, you can see that the default rule applies to all traffic. This rule allows all inbound traffic within the VPC. In addition, a second inbound rule that applies to MySQL/Aurora may also be created. This rule provides access to the database instance from the IP address you used to create your AWS account. If this rule isn't created automatically, however, you will need to add a firewall rule for your IP address as shown in this figure.

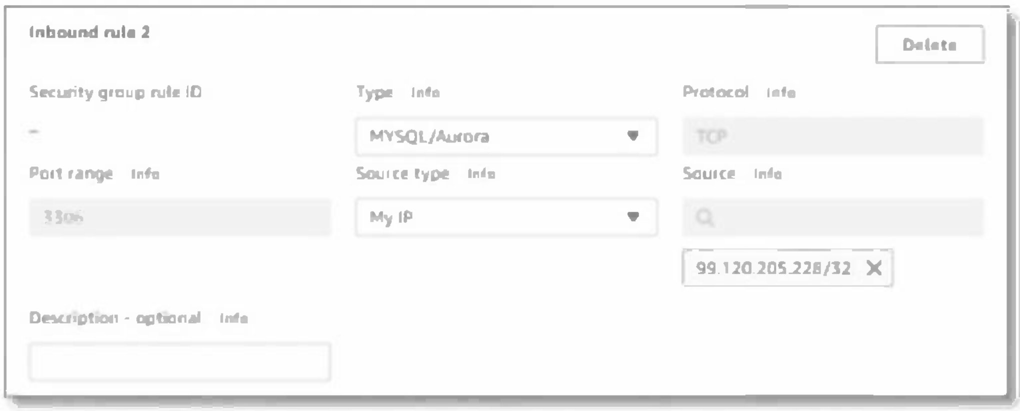
Although it's not shown here, you should know that you can also edit and delete existing firewall rules. To do that, you follow the first four steps of the procedure in this figure to display the "Edit inbound rules" page. Then, to edit a rule, you make the appropriate changes and click the "Save rules" button. And to delete a rule, you just click the Delete button for the rule. In most cases, however, you won't need to edit or delete rules.

Cloud security groups make network security easier to manage than the security for traditional local servers. In a traditional architecture, for example, a company might host their application and database servers on a single machine. Then, the machine would, at a minimum, need to keep ports 80 and 443 (http and https respectively) and port 3306 (MySQL) open. You would also need to do additional server configuration to ensure that only the web apps that should have access to a database can access it. To implement this with a security group, however, you just need to add a rule to the appropriate security group to allow connections.

### The default firewall rule for an instance




### The controls for adding a new rule




### How to add a firewall rule for your IP address

1. Navigate to the RDS Databases page and click the name of your instance.
2. Scroll down to the "Security group rules" section, and click the security group with "Inbound" in the Type column to display information about that group.
3. Click the "Inbound rules" tab for the security group to display the default inbound rule.
4. Click the "Edit inbound rules" button, and click the "Add rule" button in the "Edit inbound rules" page that's displayed.
5. Click the "Add rule" button to display controls for adding a new rule.
6. Select MYSQL/Aurora from the Type dropdown.
7. Select "My IP" from the "Source type" dropdown.
8. Click the "Save rules" button.

### Description

- AWS uses *firewall rules* to control access to RDS instances. *Security groups* are used to combine rules for different types of traffic.
- Before you can connect to you RDS instance from outside of the VPC, you need to add a firewall rule for your IP address if it isn't automatically added.

Figure 20-4 How to add a firewall rule for your IP address

# How to use MySQL Workbench with an RDS instance

Once you've created your RDS instance, made it publicly accessible, and made sure that it includes a firewall rule for your IP address, you're ready to connect to it from MySQL Workbench. After that, interacting with your RDS database is similar to interacting with a locally hosted database.

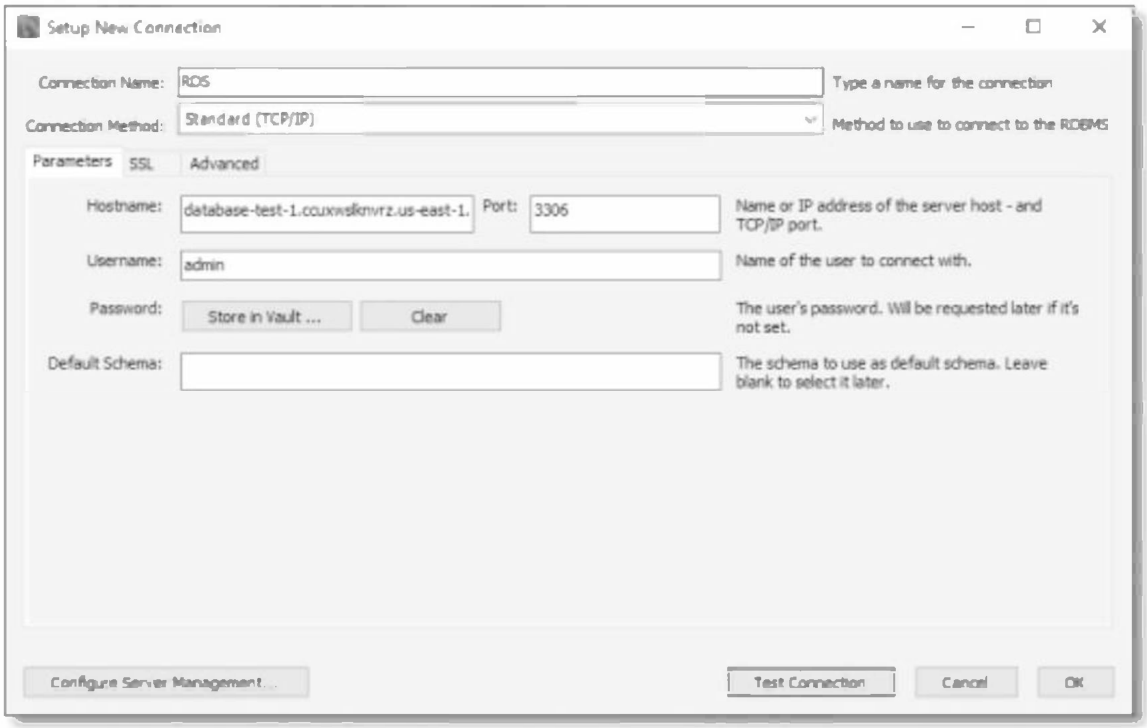
## How to connect to an RDS instance

Figure 20-5 shows the steps for connecting to your RDS instance from MySQL Workbench. Here, the most important thing to note is that you must use the endpoint string for your RDS instance as the hostname for the connection. In addition, you must assign a name to the connection, and you should store the password for the admin user in the vault. If you don't store the password, you will have to enter it each time you connect to the instance.

Once you enter the appropriate information, you can click the Test Connection button to verify that you're able to connect to the instance. If it is, a confirmation message is displayed. If an error message is displayed, however, you should start by checking that you completed the steps in figure 20-3 correctly so the instance is publicly accessible.

If the instance is publicly accessible but you're unable to connect, it usually means that the firewall for your instance is blocking your connection. In that case, you can follow the procedure in figure 20-4 to add a firewall rule for your IP address. Note that if the firewall blocks your connection, an error won't be displayed when you click the Test Connection button. However, an error message will be displayed if you try to connect to the instance from the Connections tab of MySQL Workbench.

## The settings for an RDS connection




## How to connect to an RDS instance

1. Navigate to the RDS Databases page, and click the name of the instance you want to connect to.
2. Copy the complete endpoint string in the Connectivity & Security section.
3. Open MySQL Workbench, display the Home tab, and click the ⊕ button to the right of MySQL Connections to display the Setup New Connection dialog box shown above.
4. Enter a descriptive connection name such as "RDS".
5. Replace the hostname with the endpoint string you copied in step 2.
6. Change the username to "admin".
7. Click the "Store in Vault..." button and enter your AWS password when prompted.
8. Click the Test Connection button to be sure the connection works.

## Description

- If the connection is successful, a confirmation message is displayed. If the connection isn't successful, an error message is displayed unless the error is due to the lack of a firewall rule for your IP address.
- An unsuccessful connection may indicate that the RDS instance isn't publicly accessible. It may also indicate that you're using an IP address that's different from the one you used when you created your AWS account.

Figure 20-5 How to connect to an RDS instance

## How to run scripts and SQL statements against an RDS database

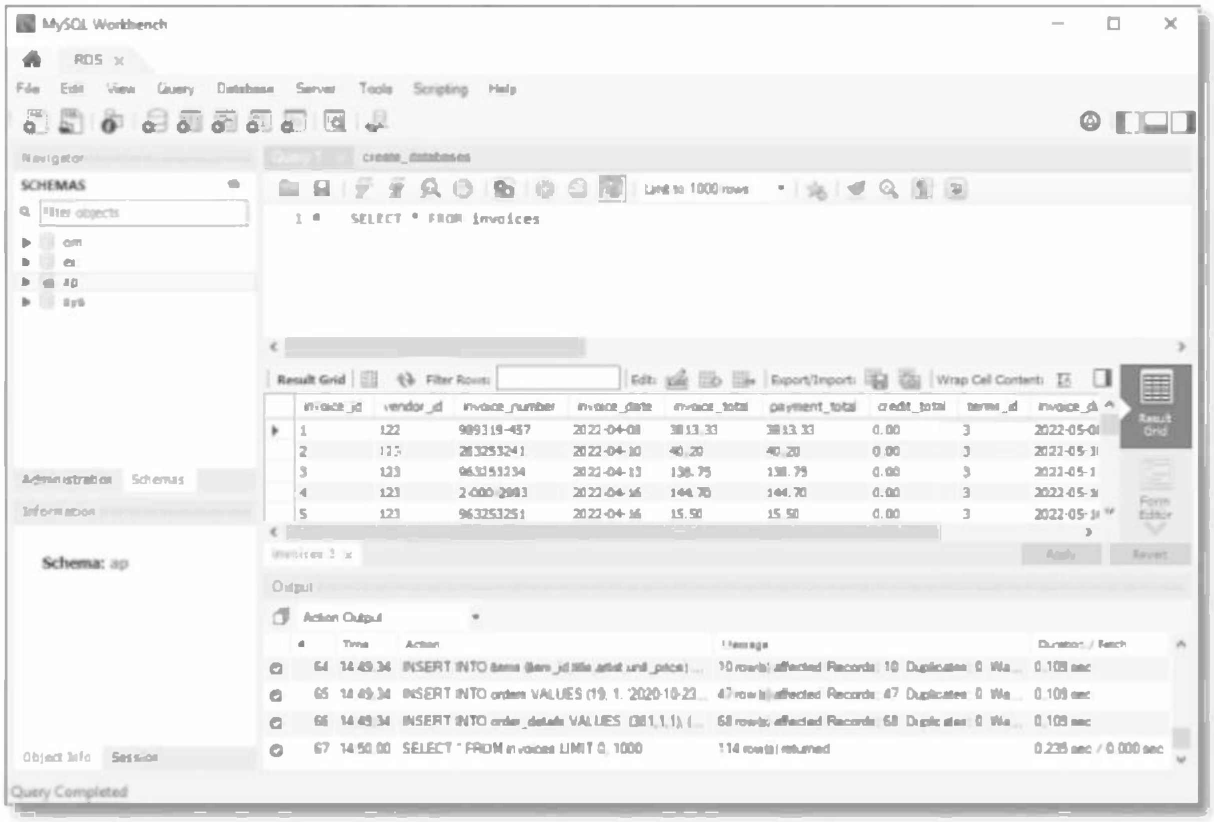
Once you've established a connection to your RDS instance, you can work with the instance from MySQL Workbench using the same techniques you use to work with a local instance. To start, you can create databases on the RDS instance. In figure 20-6, for example, you can see that the create_databases script that's used to create the databases for this book is open in a SQL Editor tab. The Output tab also shows that the last three statements in this script executed successfully, and the Schemas tab shows that three databases have been created.

This figure also shows a SQL Editor tab with a SELECT statement. The results of that statement are shown in the Result grids, and the Output tab shows that the statement executed successfully and that it returned 114 rows. Although I chose to show a SELECT statement in this figure, most SQL statements will work with AWS as well.

You should know, however, that you shouldn't execute statements from Workbench that attempt to change configurations that are managed by RDS. This includes privileges and permissions, backups, software patching, compute and storage scaling, and monitoring. You should change these configurations from the AWS portal.

You should also know that MySQL extensions and plugins may not work because of discrepancies between the supported versions of MySQL. This is particularly true if you're using Aurora MySQL rather than regular MySQL.

## Workbench after running a script and a SQL statement




## Description

- Once you've created a connection to an RDS instance from MySQL Workbench, you can use that connection to interact with the instance just like you would a local instance.
- Most of the SQL statements that work on a local database will work on a database hosted by RDS. However, some statements used to configure a database may conflict with the RDS instance. Because of that, you should use the RDS Databases page for database configuration.
- Some MySQL extensions and plugins may not work with RDS, particularly if they are specific to certain versions of MySQL.

Figure 20-6 How to run scripts and SQL statements against an RDS instance

# How to backup and restore a database instance

When you use AWS, you can use three techniques to *back up* your database instance. You'll learn about all three of these techniques in this topic. In addition, you'll learn how to *restore* your database instance from a backup.

## How to work with the built-in backup

By default, AWS creates a backup of each RDS instance every day. To display the settings for this *built-in backup*, you can follow the first procedure in figure 20-7. These settings are shown at the top of this figure. They indicate that backups will take place between 06:23 and 06:53 UTC (Coordinated Universal Time) and will be retained for seven days.

If you want to modify the default backup settings, you can do that as described in the second procedure. You can modify the default backup by changing when the backups will start and how long they will be retained. If you change the backup retention period to 0 days, the backups will be disabled.

## How to create a backup plan

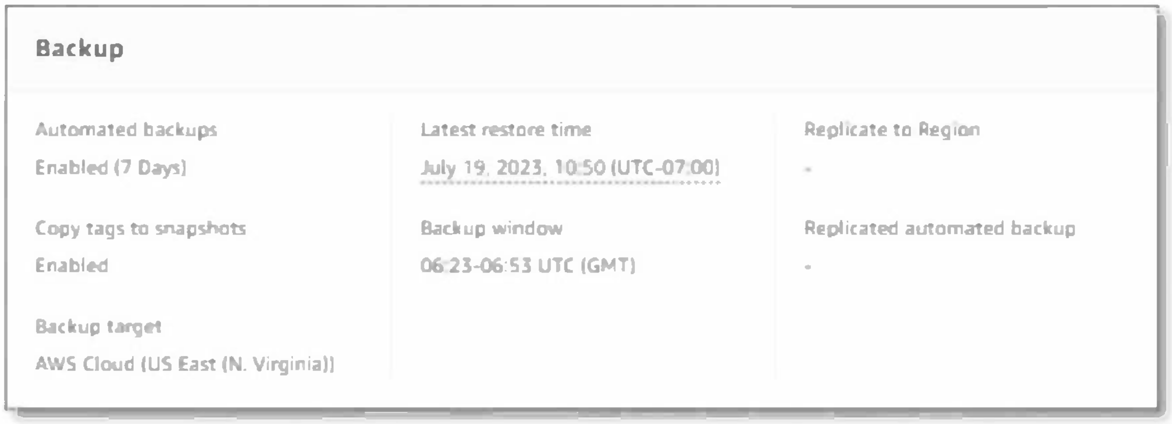
In many cases, the daily built-in backups are all you'll need. However, you can also define your own backups by creating one or more *backup plans*. A backup plan runs on a schedule like the built-in backup, but it provides additional options. For example, backup plans are often used to back up groups of related resources, such as an RDS instance and the EC2 instance that runs an associated web server.

The third procedure in figure 20-7 shows how to create a backup plan for an RDS instance. Note in step 2 that I recommend starting a backup plan from a template. Although you can also create a backup plan from scratch, the backup templates usually provide all the options you'll need. They determine how often the backups will be created and how long they will be retained.

In steps 5 through 8, you assign the resources that you want to include in the backup. In this example, only the RDS instance used in this chapter is included. However, if you're working with multiple resources, you can select each type of resource and then select to include all or selected resources of each type.

If you ever need to delete a backup plan, you should know that you first have to delete any resource assignments for the plan. To do that, you navigate to the AWS Backup page, click "Backup plans" in the sidebar, and click the plan you want to delete. Then, you scroll down to the "Resource assignments" section and delete each resource by selecting its option and clicking the Delete button. When you're done, you can scroll back to the top of the page and click the Delete button for the plan.

## The built-in backup settings for an instance




## How to display the built-in backup settings for an instance

1. Navigate to the RDS Databases page, and click the name of the instance.
2. Click the "Maintenance & backups" tab, and scroll down to the Backup section.

## How to modify the built-in backup settings

1. Navigate to the RDS Databases page, and click the name of the instance.
2. Click the Modify button on the page that's displayed.
3. Scroll down to the "Additional configuration" section, and change the backup settings as necessary.
4. Click the Continue button, confirm the changes on the page that's displayed, and click the "Modify DB instance" button.

## How to create a backup plan

1. Use the search bar to navigate to the AWS Backup page, and click the "Create Backup plan" button.
2. In the Start options section, select the "Start with a template" backup plan option, select a template plan, and enter a unique, descriptive name for the backup plan.
3. Click the "Create plan" button at the bottom of the page.
4. Click "Backup plans" in the sidebar, and click the plan you just created.
5. Scroll down to the "Resource assignments" section of the page that's displayed, and click the "Assign resources" button.
6. In the General section, enter a unique, descriptive name for the resource assignment.
7. In the "Resource selection" section, select the "Include specific resource types" radio button, select RDS as the resource type, and select your RDS instance.
8. Click the "Assign resources" button.

## Description

- You can use the built-in backup settings for your automatic backups, you can modify those settings, and you can create one or more custom *backup plans*.

Figure 20-7 How to configure automatic backups

## How to work with snapshots

In addition to the scheduled backups that are created using the built-in backup and backup plans, you can manually create a backup of a database instance at any time. To do that, you take a *snapshot* of the instance. A snapshot is just like any other backup, except it's retained until you delete it.

Snapshots are useful when you want to create a backup without disrupting your regular scheduled backups. For example, before you do a mass update to a database instance, you may want to take a snapshot of the instance in case something goes wrong.

To create a snapshot of a database instance, you can use the first procedure in figure 20-8. When you display the Snapshots section in step 3, a list of all the existing snapshots and backups is displayed as shown at the top of this figure. Then, you can click the "Take snapshot" button to take another snapshot.

When the snapshot completes, it's displayed in the Manual tab of the RDS Snapshots page. Although this page isn't shown here, you can display it at any time by navigating to RDS and clicking Snapshots in the sidebar. In addition to the snapshots, the built-in backups are listed on the System tab of the Snapshots page, and the backups created from any backup plans are listed on the "Backup service" tab.

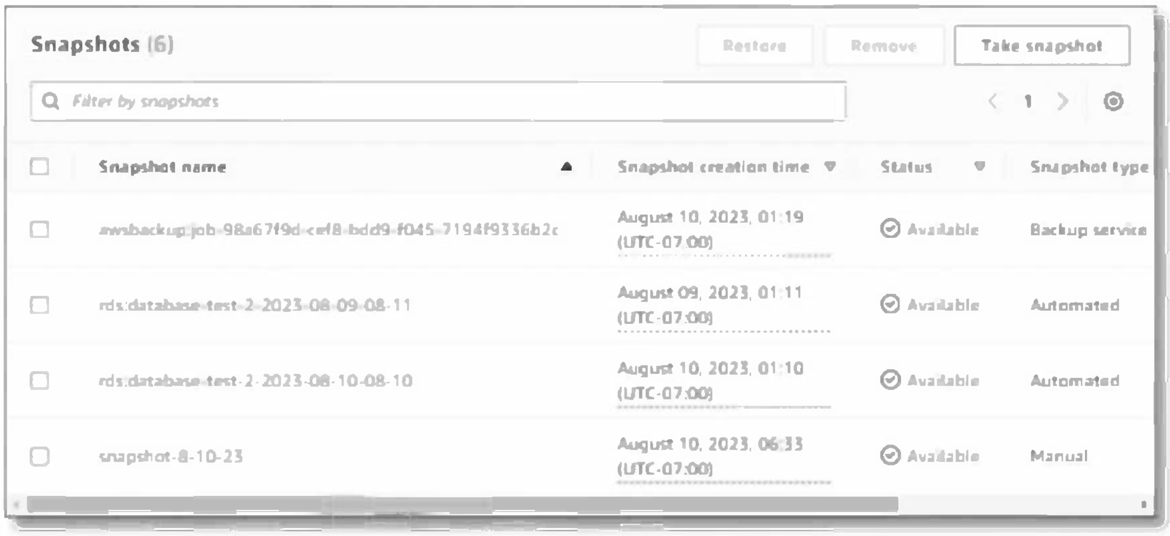
Because snapshots are retained indefinitely, you typically delete them when they're no longer needed. To do that, you can use the second procedure in this figure. Note that because the built-in backups and backups created by backup plans are deleted on a predetermined schedule, they can't be deleted manually.

## How to restore a database instance

If a problem occurs with one of your databases, you can use a backup to restore the instance that contains that database. For example, human error can cause rows in a database to be updated incorrectly or deleted inadvertently. Hardware failures and natural disasters can also cause data to be destroyed.

To restore a database instance from a backup, you can use the third procedure in figure 20-8. When you use this procedure, you should realize that you are creating a new database instance with a new name rather than overwriting an existing database instance. Then, when you're sure that the new instance corrects the problem that was encountered, you can rename or delete the original instance. At that point, you can rename the new instance so it's the same as the original instance. That way, you'll be able to access the instance from outside the VPC without changing the connection you're using.

### The backups and snapshots for an instance




### How to take a snapshot of a database instance

1. Navigate to the RDS Databases page and click the name of the database instance you want to take a snapshot of.
2. Click the "Maintenance & backups" tab below the Summary section.
3. Scroll to the Snapshots section of the page and click the "Take snapshot" button.
4. Enter a unique, descriptive name for the snapshot and click the Take Snapshot button.

### How to delete one or more snapshots

1. Navigate to the "Maintenance & backups" tab on the page for the database instance that has snapshots you want to delete.
2. Scroll to the Snapshots section, select the check boxes for the snapshots you want to delete, and click the Remove button.
3. Click the Delete button in the dialog box that's displayed.

### How to restore a database instance from a backup or snapshot

1. Navigate to the "Maintenance & backups" tab on the page for the database instance you want to restore.
2. Scroll to the Snapshots section, and select the checkbox for the snapshot or backup you want to restore.
3. Click the Restore button to display the Restore Snapshot page.
4. Enter the name of the database instance in the Settings section, select Yes for the "Public access" option in the Connectivity section, and click the "Restore DB instance" button.

### Description

- You can manually back up a database at any time by taking a *snapshot* of it.
- You can manually restore a database from any backup or snapshot.

Figure 20-8 How to work with snapshots and restore a database instance

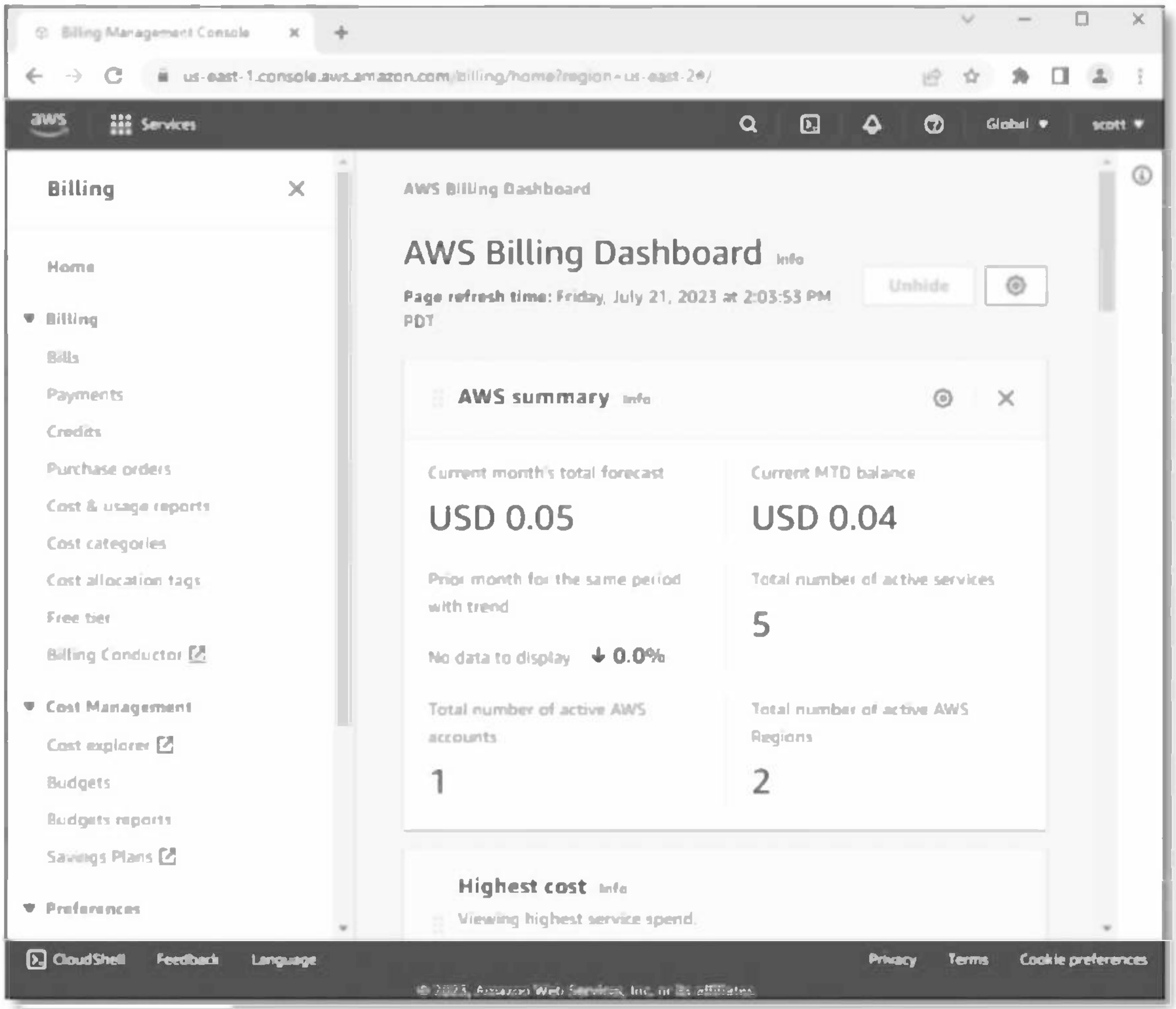
# More skills for working with RDS

The rest of this chapter presents two additional skills for working with RDS. Here, you'll learn how to use the AWS Billing Dashboard and how to delete an RDS instance.

## How to check the AWS Billing Dashboard

Figure 20-9 shows the AWS Billing Dashboard. This dashboard shows your forecasted charges for the month, as well as the current month-to-date charges for the month. It also includes information about the costs for each service you're using. And it provides options for making payments and generating cost and usage reports. These reports can help you make decisions about whether you are purchasing too much or too little compute and storage.

### The AWS Billing Dashboard




### Description

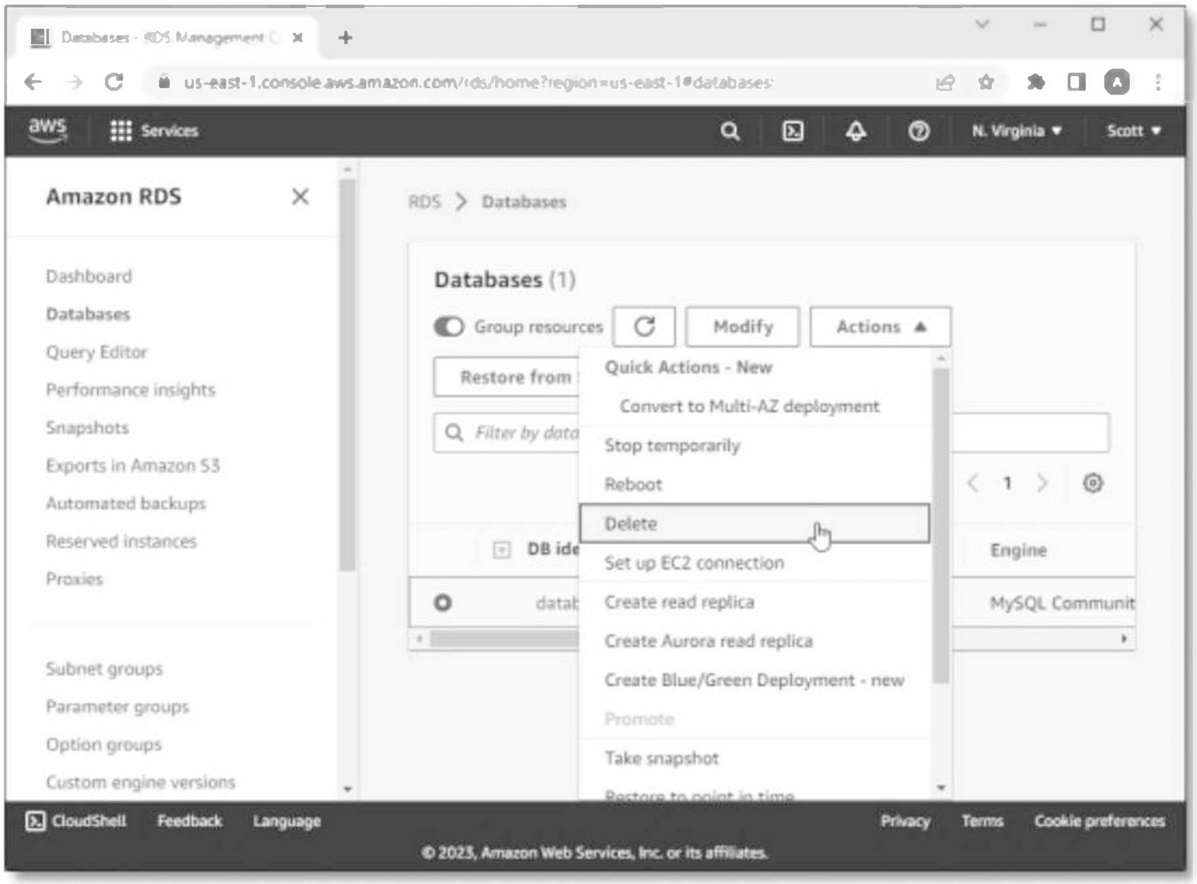
- To display the AWS Billing Dashboard, enter "Billing" in the AWS search bar and select Billing from the list that's displayed.
- The Billing Dashboard shows your current and projected charges for the month, as well as analytics on which services are costing you the most.
- You can also use this dashboard to make payments and generate cost and usage reports.

Figure 20-9 How to check the AWS Billing Dashboard

## How to delete an RDS database

If you've been following along with this chapter, you'll probably want to delete the resources that you've created when you're done experimenting with them. This will ensure that you aren't charged for a resource that you aren't using. Figure 20-10 shows how to delete an RDS database.

### The menu for deleting a database




### How to delete an RDS database

1. Navigate to the RDS Databases page, and select the instance you want to delete by clicking the circle to the left of its name.
2. Click the Actions button and select Delete from the drop-down menu that's displayed to display a Delete dialog box.
3. Uncheck the "Create final snapshot" and "Retain automated backups" options if you are certain you won't need the data in the database again.
4. Check the "I acknowledge…" option, type "delete me" into the text box at the bottom of the dialog box, and click the Delete button.

### Description

- When you are finished experimenting with the database, you should delete it so you won't incur any charges.
- It is usually a good idea to keep backups of a database prior to deleting it.

Figure 20-10 How to delete an RDS database

# Perspective

The world is moving away from locally hosted databases and towards cloud-hosted databases. Although this chapter showed you the steps for hosting a database using Amazon Web Services, most cloud providers offer similar services.

## Terms

AWS (Amazon Web Service)
RDS (relational database service)
Database (DB) instance
EC2 (elastic compute cloud)
Compute and storage
VPC (virtual private cloud)
Firewall rule
Inbound rule
Outbound rule
Security group
Back up a database
Restore a database
Built-in backup
Backup plan
Snapshot

## Exercises

1. Create an AWS account and sign in.
2. Navigate to the RDS Databases page and create a MySQL RDS instance.
3. Configure the instance to be publicly accessible.
4. Check if the instance includes an inbound firewall rule for your IP address, and create one if it doesn't.
5. Create a connection to the RDS instance in MySQL Workbench, and open that connection.
6. Open and run the create_databases.sql script to create the three databases used by this book.
7. Enter and run a SELECT statement against one of the databases.
8. Create a backup plan that creates a weekly backup of the database instance.
9. Take a snapshot of the database instance.
10. Use MySQL Workbench to make a change to a database in that instance.
11. Restore the snapshot and confirm that the change to the database was reversed.
12. Delete the RDS instance.

# Appendix A

## How to set up Windows for this book

Before you begin reading this book, we recommend that you install MySQL Community Server and MySQL Workbench. Both of these software products are available for free from the MySQL website, and you can install them on your computer as described in this appendix.

After you install these products, we recommend that you download the files for this book that are available from the Murach website (www.murach.com). Then, we recommend that you run the SQL script that creates the databases that are used throughout this book.

Once you create these databases, you're ready to gain valuable hands-on experience by running the SQL scripts for the examples presented in this book. In addition, you can get more practice by doing the exercises that are at the end of each chapter, starting with chapter 2.

## How to install MySQL Community Server

MySQL Community Server is a database server that's free and easy to use. Since it's designed to run on most modern computers, it's ideal for developers who want to install it on their computer so they can learn how to work with a MySQL database. That's why this book assumes that you have installed the Community Server on your computer.

In July 2023, Oracle announced a new versioning model for MySQL that provides two different release tracks. The releases that contain new features and improvements will be known as *Innovation versions*, and the releases that will only be updated with bug fixes after the initial release will be known as *Long Term Support (LTS) versions*. Oracle also released the first Innovation version, MySQL 8.1 Innovation. In addition, Oracle announced that MySQL 8.0.34 and later will only be updated with bug fixes, not with new features or improvements. As a result, MySQL 8.0 is now essentially an LTS version.

So, which version should you install? If you want to make sure the MySQL server works exactly as described in this book, we recommend installing MySQL 8.0. That's because all of the SQL statements presented in this book have been tested against MySQL 8.0.

On the other hand, if you want the latest features and improvements as they become available, you should install the newest Innovation version of MySQL. Or, if you only want access to the features included in an LTS version, you should install the newest LTS version. Oracle plans to release the first LTS version in 2024. Since MySQL is backwards compatible, the SQL statements presented in this book should also work with these releases of MySQL. For example, we tested all of the SQL statements in this book against MySQL 8.1, and they all worked correctly.

Once you decide on a version of the MySQL server, you can install it as described in figure A-1. This procedure varies depending on whether you're installing MySQL 8.0 or a later version, but regardless of the version, it installs only the MySQL server using the typical configuration options. As part of this procedure, you need to specify a password for the root user. When you do, *make sure to remember the password that you enter.*

## How to start and stop the MySQL sever

To make sure the MySQL server has been installed correctly, you can start the Services app and check whether the service for the MySQL server is running. By default, this service has a name that begins with MySQL and ends with the first two digits of the version number. For instance, the service for MySQL 8.0 is named MySQL80.

By default, the MySQL service starts automatically when you start your computer. However, there are times when you may want to stop this service. For example, you can stop this service if you aren't going to be using it and you want to free the resources on your computer. To do that, you can use the procedure

### The MySQL Community Server downloads page

`http://dev.mysql.com/downloads/mysql/`

### How to install MySQL Community Server

1. Go to the MySQL Community Server downloads page. If necessary, you can find this page by searching the internet for "MySQL community server download".
2. Select the version of MySQL that you want to install and select Windows as the operating system. If you select version 8.0, click the MySQL Installer link to go to that page.
3. Download the installer (MSI) file by clicking its Download button. For MySQL 8.0, you download the MSI file for the MySQL Installer for all MySQL products. For MySQL 8.1 and later, you download a MSI file that's only for the MySQL server.
4. Find the downloaded MSI file and double-click it. This should start the installer.
5. Respond to the resulting dialogs to install MySQL and configure it. You can accept most of the default options.
    - For the setup type, if you're installing MySQL 8.0, leave the setup type at its default setting of Server Only. If you're installing 8.1 or later, select Typical.
    - Make sure to enter a password for the root user, and *make sure to remember the password that you enter.*

### How to start and stop the MySQL server

1. Click the Windows Start button, type "services", and select the Services app.
2. Scroll down to view the MySQL service. By default, the service for MySQL 8.0 is named MySQL80, the service for MySQL 8.1 is named MySQL81, and so on.
3. Right-click the MySQL service and select Start or Stop. Or, if you want to control whether MySQL starts automatically when you start your computer, select Properties.

### Description

- In July 2023, Oracle announced a new versioning model for MySQL that provides two different release tracks. The releases that contain new features and improvements will be known as *Innovation versions*, and the releases that will only be updated with bug fixes after the initial release will be known as *Long Term Support (LTS) versions.*
- Since July 2023, Oracle is only updating MySQL 8.0 with bug fixes, not new features or improvements. As a result, MySQL 8.0 is now essentially an LTS version.
- If you want to make sure that the MySQL server works exactly as described in this book, you should use the 8.0 version.
- If you want access to the latest features as they become available, you should use an Innovation version. The first Innovation version is 8.1.
- If you only want access to the features included in an LTS version, you can use that version. The first LTS version will become available in 2024.
- You can use the Services app to start and stop the MySQL service and to control whether the MySQL server starts automatically when you start your computer.

Figure A-1    How to install MySQL Community Server shown in figure A-1. Then, when you're ready to start the service again, you can use this procedure to do that too.

## How to install MySQL Workbench

MySQL Workbench is a free program that makes it easy to work with MySQL databases. To install MySQL Workbench, you can use the procedure shown in figure A-2. When you download the installer file, make sure it is the installer file for MySQL Workbench only, not the installer file for all MySQL products.

If you install a newer version of MySQL server such as 8.1 Innovation, you may need to install an older version of Workbench such as 8.0. That's because a version of Workbench that corresponds to your version of the MySQL server may not yet be available. In that case, you can install the older version of Workbench and use it until a new version becomes available.

All of the skills for working with MySQL Workbench presented in this book were tested against version 8.0. As a result, if you're using this version of MySQL Workbench, these skills should work exactly as described. If you're using a later version of MySQL Workbench, these skills may not work exactly as described, but they should work similarly.

### The MySQL Workbench downloads page

`http://dev.mysql.com/downloads/workbench/`

### How to install MySQL Workbench

1. Go to the MySQL Workbench downloads page. If necessary, you can find this page by searching the internet for "MySQL Workbench community download".
2. Select Windows as the operating system.
3. Click the Download button to download the installer (MSI) file for the latest version of MySQL Workbench. This file should be named something like mysql-workbench-community-8.x.xx-winx64.msi. Make sure you download this installer file, not the MySQL Installer for all MySQL products.
4. Find the installer file and double-click it to start the installer.
5. Respond to the resulting dialog boxes. You can accept all defaults.

### Notes

- If you install a newer version of MySQL server such as 8.1 Innovation, you may need to install an older version of Workbench such as 8.0. That's because there may not yet be a newer version of Workbench available.
- To make it easy to start MySQL Workbench, you can pin it to the taskbar.

Figure A-2 How to install MySQL Workbench

## How to download the files for this book

Figure A-3 shows how to download the files for this book. This download includes a SQL script that you can use to create the databases that are used throughout this book. It includes SQL scripts for all of the examples in this book. And it includes SQL scripts for the solutions to the exercises that are at the end of each chapter.

The files for this book are in a zip file that you can download from www.murach.com. When you download this file, it contains a directory named mysql that stores the SQL script files for this book. Within this directory, you can find the subdirectories that contain the files shown in this figure.

After double-clicking on the zip file to view the mysql directory, we recommend moving this directory into a directory named murach that you can create directly on your hard disk. That way, the directories and files on your system will match the directories and files shown in this book.

## The recommended directory for the files

```
C:\murach\mysql
```

## The files for this book

| Directory | Contains |
|---|---|
| `db_setup` | The SQL script that creates the three databases for this book. |
| `book_scripts` | The SQL scripts for all of the examples presented in this book. |
| `ex_solutions` | The SQL scripts for the solutions to the exercises at the end of each chapter. |
| `diagrams` | The MySQL Workbench file for the diagram that's presented in chapter 10. |

## The databases for this book

| Database | Description |
|---|---|
| `ap` | The AP (Accounts Payable) database. This database is used by most examples in this book. |
| `om` | The OM (Order Management) database. This database is used by a few examples in this book. |
| `ex` | The EX (Examples) database. This database contains several tables that are used for short examples. |

## How to download the files

1. Go to www.murach.com.
2. Find the page for *Murach's MySQL (4th Edition)*.
3. Scroll down to the "FREE downloads" tab and click it.
4. Click the Download Now button for the zip file to download a setup file named msq4_allfiles.zip.
5. Find the downloaded zip file and double-click it. This should display a directory named mysql.
6. Use File Explorer to create a directory named murach in the root directory of your hard disk.
7. Use File Explorer to move the mysql directory into the murach directory.

## Description

- All of the files described in this book are contained in a zip file that can be downloaded from www.murach.com.

Figure A-3 How to download the files for this book

## How to create the databases for this book

Before you can run the SQL statements presented in this book, you need to create the three databases used by this book. To do that, you can use MySQL Workbench to run the SQL script that's stored in the create_databases.sql file as described in figure A-4.

To determine if the SQL script ran successfully, you can review the results in the Output window. In this figure, for example, the Output window shows a series of statements that have executed successfully. In addition, the Schemas tab of the Navigator window shows that the three databases have been created. The other database, named sys, is a database that comes with MySQL.

If the script encounters problems, MySQL Workbench displays one or more errors in the Output window. Then, you can read these errors to figure out why the script isn't executing correctly.

Before you can run the create_databases.sql script, the database server must be running. By default, the database server starts automatically when you start your computer, so this usually isn't a problem. However, if it isn't running on your system, you can start it as described in figure A-1.

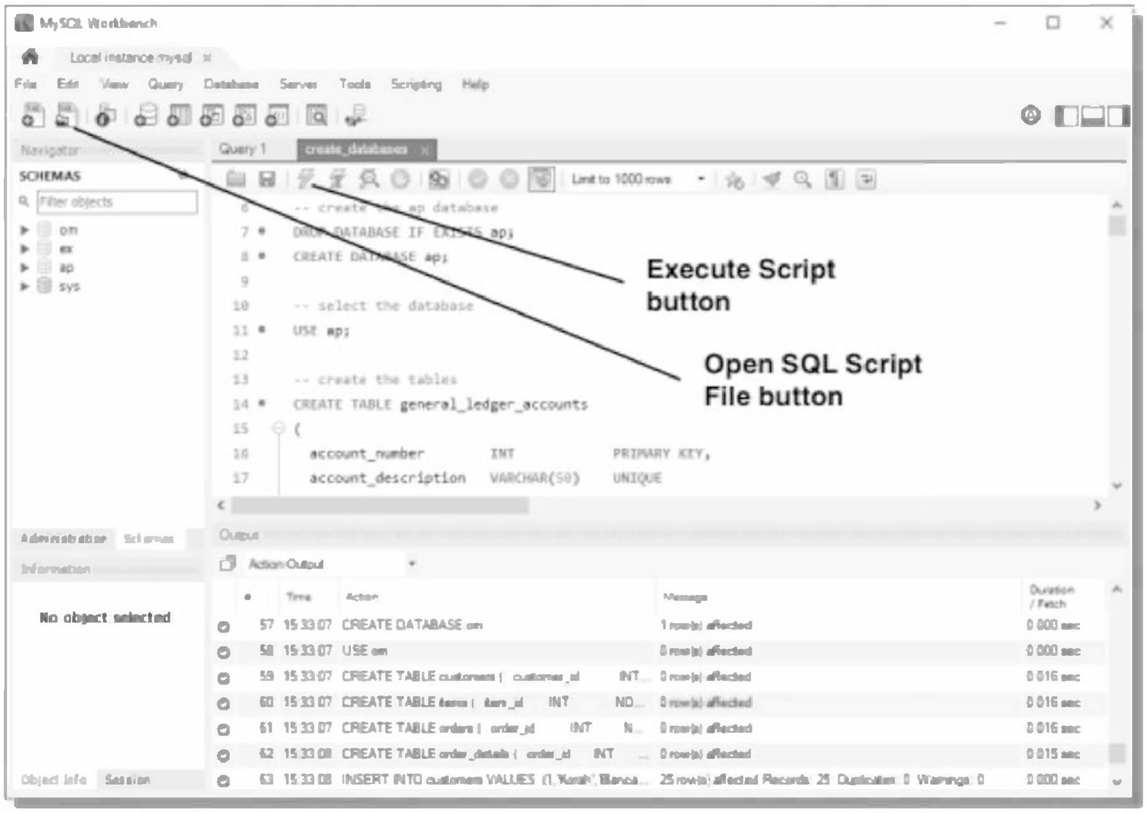
## How to restore the databases

As you work with the code that's presented in this book, you may make changes to the databases that you don't intend to make. In that case, you may want to restore the databases to their original state so your results match the results shown in this book. To do that, you can run the create_databases.sql file again. This deletes the three databases described in this appendix and recreates them.

### The directory that contains the create_databases.sql file

```
C:\murach\mysql\db_setup
```

### MySQL Workbench after executing the create_databases.sql file




### How to create the databases

1. Start MySQL Workbench.
2. Click on the stored connection named "Local instance MySQL" and enter the password for the root user if prompted. *This is the password that you created when installing the MySQL server in figure A-1.* This connects you as the root user to the local instance of MySQL.
3. If you get a warning that MySQL Workbench is incompatible with the server version and that some features may not work properly, don't be alarmed. You can click Continue Anyway and the features described in this book should still work.
4. Open the create_databases.sql file by clicking the Open SQL Script File button. Then, use the resulting dialog box to locate and open the file. When you do, MySQL Workbench displays this script in a SQL Editor tab.
5. Execute the script by clicking the Execute Script button. When you do, the Output window displays messages that indicate whether the script executed successfully.

### How to restore the databases

- Run the create_databases.sql script again to delete the databases and recreate them.

Figure A-4    How to create and restore the databases for this book

# Appendix B

## How to set up macOS for this book

Before you begin reading this book, we recommend that you install MySQL Community Server and MySQL Workbench. Both of these software products are available for free from the MySQL website, and you can install them on your computer as described in this appendix.

After you install these products, we recommend that you download the files for this book that are available from the Murach website (www.murach.com). Then, we recommend that you run the SQL script that creates the databases that are used throughout this book.

Once you create these databases, you're ready to gain valuable hands-on experience by running the SQL scripts for the examples presented in this book. In addition, you can get more practice by doing the exercises that are at the end of each chapter, starting with chapter 2.

## How to install MySQL Community Server

MySQL Community Server is a database server that's free and easy to use. Since it's designed to run on most modern computers, it's ideal for developers who want to install it on their computer so they can learn how to work with a MySQL database. That's why this book assumes that you have installed the Community Server on your computer.

In July 2023, Oracle announced a new versioning model for MySQL that provides two different release tracks. The releases that contain new features and improvements will be known as *Innovation versions*, and the releases that will only be updated with bug fixes after the initial release will be known as *Long Term Support (LTS) versions*. Oracle also released the first Innovation version, MySQL 8.1 Innovation. In addition, Oracle announced that MySQL 8.0.34 and later will only be updated with bug fixes, not with new features or improvements. As a result, MySQL 8.0 is now essentially an LTS version.

So, which version should you install? If you want to make sure the MySQL server works exactly as described in this book, we recommend installing MySQL 8.0. That's because all of the SQL statements presented in this book have been tested against MySQL 8.0.

On the other hand, if you want the latest features and improvements as they become available, you should install the newest Innovation version of MySQL. Or, if you only want access to the features included in an LTS version, you should install the newest LTS version. Oracle plans to release the first LTS version in 2024. Since MySQL is backwards compatible, the SQL statements presented in this book should also work with these releases of MySQL. For example, we tested all of the SQL statements in this book against MySQL 8.1, and they all worked correctly.

Once you decide on a version of the MySQL server, you can install it as described in figure B-1. As part of this procedure, you need to specify a password for the root user. When you do, *make sure to remember the password that you enter*.

## How to start and stop the MySQL sever

To make sure the MySQL server has been installed correctly, you can start the MySQL preference pane and check whether the MySQL server is running. By default, the MySQL server starts automatically when you start your computer. However, there are times when you may want to stop this server. For example, you can stop this server if you aren't going to be using it and you want to free the resources on your computer. To do that, you can use the procedure shown in figure B-1. Then, when you're ready to start the server again, you can use this procedure to do that too.

### The MySQL Community Server downloads page

`http://dev.mysql.com/downloads/mysql/`

### How to install MySQL Community Server

1. Go to the MySQL Community Server downloads page. If necessary, you can find this page by searching the internet for "MySQL community server download".
2. Select the version of the MySQL server, select macOS as the operating system, and select the operating system version for your processor (x86 or ARM).
3. Download the disk image (DMG) file by clicking on its Download button.
4. Find the downloaded DMG file and double-click it. This opens a window with a package (PKG) file.
5. Double-click the PKG file for MySQL, and respond to the resulting dialog boxes to install it. You can accept most of the default options and specify a password for the root user. *Make sure to remember the password that you enter.*

### How to start and stop the MySQL server

1. Use the Apple menu to select System Preferences.
2. Click the MySQL icon.
3. Use the buttons on the MySQL preference pane to start or stop the MySQL server. Or, use the check box on that page to control whether the MySQL server starts automatically when you start your computer.

### Description

- In July 2023, Oracle announced a new versioning model for MySQL that provides two different release tracks. The releases that contain new features and improvements will be known as *Innovation versions*, and the releases that will only be updated with bug fixes after the initial release will be known as *Long Term Support (LTS) versions*.
- Since July 2023, Oracle is only updating MySQL 8.0 with bug fixes, not new features or improvements. As a result, MySQL 8.0 is now essentially an LTS version.
- If you want to make sure that the MySQL server works exactly as described in this book, you should use the 8.0 version.
- If you want access to the latest features as they become available, you should use an Innovation version. The first Innovation version is 8.1.
- If you only want access to the features included in an LTS version, you can use that version. The first LTS version will become available in 2024.
- You can use the MySQL preference pane to start and stop the MySQL server and to control whether the MySQL server starts automatically when you start your computer.

Figure B-1 How to install MySQL Community Server

## How to install MySQL Workbench

MySQL Workbench is a free program that makes it easy to work with MySQL databases. To install MySQL Workbench, you can use the procedure shown in figure B-2.

If you install a newer version of MySQL server such as 8.1 Innovation, you may still need to install an older version of Workbench such as 8.0. That's because there may not yet be a newer version of Workbench that corresponds to your version of the MySQL server. In that case, you can install the older version of Workbench and use it until a new version becomes available.

All of the skills for working with MySQL Workbench presented in this book were tested against version 8.0. As a result, if you're using this version of MySQL Workbench, these skills should work exactly as described. If you're using a later version of MySQL Workbench, these skills may not work exactly as described, but they should work similarly.

### The MySQL Workbench downloads page

`http://dev.mysql.com/downloads/workbench/`

### How to install MySQL Workbench

1. Go to the MySQL Workbench downloads page. If necessary, you can find this page by searching the internet for "MySQL Workbench community download".
2. Select macOS as the operating system.
3. Click the Download button to download the disk image (DMG) file for the latest version of MySQL Workbench that matches your processor (x86 or ARM).
4. Find the DMG file on your hard disk and double-click on it.
5. Respond to the resulting dialog boxes.

### Notes

- If you install a newer version of MySQL server such as 8.1 Innovation, you may need to install an older version of Workbench such as 8.0. That's because there may not yet be a newer version of Workbench available.
- To make it easy to start MySQL Workbench, you may want to keep this application in your dock.

Figure B-2 How to install MySQL Workbench

## How to download the files for this book

Figure B-3 shows how to download the files for this book. This download includes a SQL script that you can use to create the databases that are used throughout this book. It includes SQL scripts for all of the examples in this book. And it includes SQL scripts for the solutions to the exercises that are at the end of each chapter.

The files for this book are in a zip file that you can download from www.murach.com. When you download this file, it contains a directory named mysql that stores the SQL script files for this book. Within this directory, you can find the subdirectories that contain the files shown in this figure.

After double-clicking on the zip file to unzip the mysql directory, we recommend moving this directory into a directory named murach that you can create in your Documents directory. That way, your system will store the files for this book in the directory shown at the top of this figure.

In this book, there are two figures (17-10 and 19-4) that show how to use the command line to work with files. To keep the path to the files short, these figures use a path of

```
/murach/mysql
```

However, to get these figures to work correctly on macOS, you need to substitute the following path:

```
/Users/yourname/Documents/murach/mysql
```

Here, you need to substitute your macOS username for *yourname*. For example, for a username of johndoe, you could use this path:

```
/Users/johndoe/Documents/murach/mysql
```

### The recommended directory for the files

`Documents/murach/mysql`

### The files for this book

| Directory | Contains |
|---|---|
| `db_setup` | The SQL script that creates the three databases for this book. |
| `book_scripts` | The SQL scripts for all of the examples presented in this book. |
| `ex_solutions` | The SQL scripts for the solutions to the exercises at the end of each chapter. |
| `diagrams` | The MySQL Workbench file for the diagram that's presented in chapter 10. |

### The databases for this book

| Database | Description |
|---|---|
| `ap` | The AP (Accounts Payable) database. This database is used by most examples in this book. |
| `om` | The OM (Order Management) database. This database is used by a few examples in this book. |
| `ex` | The EX (Examples) database. This database contains several tables that are used for short examples. |

### How to download the files

1. Go to www.murach.com.
2. Find the page for *Murach's MySQL (4th Edition)*.
3. Scroll down to the "FREE downloads" tab and click it.
4. Click the Download Now button for the zip file to download a setup file named msq4_allfiles.zip.
5. Find the downloaded zip file and double-click on it to unzip it. This creates the mysql directory and its subdirectories.
6. If necessary, use the Finder to create the murach directory in the Documents directory.
7. Use the Finder to move the mysql directory into the murach directory.

### Description

- All of the source files described in this book are in a zip file that can be downloaded from www.murach.com.

### A note about right-clicking

- This book often instructs you to right-click, because that's common in Windows. On macOS, right-clicking is not enabled by default. Instead, you can use Ctrl-click instead of right-click. Or, if you prefer, you can enable right-clicking by editing the system preferences for your mouse.

Figure B-3 How to download the files for this book

## How to create the databases for this book

Before you can run the SQL statements presented in this book, you need to create the three databases used by this book. To do that, you can use MySQL Workbench to run the SQL script that's stored in the create_databases.sql file as described in figure B-4.

To determine if the SQL script ran successfully, you can review the results in the Output window. In this figure, for example, the Output window shows a series of statements that have executed successfully. In addition, the Schemas tab of the Navigator window shows that the three databases have been created. The other database, named sys, is a database that comes with MySQL.

If the script encounters problems, MySQL Workbench displays one or more errors in the Output window. Then, you can read these errors to figure out why the script isn't executing correctly.

Before you can run the create_databases.sql script, the database server must be running. By default, the database server starts automatically when you start your computer, so this usually isn't a problem. However, if it isn't running on your system, you can start it as described in figure B-1.

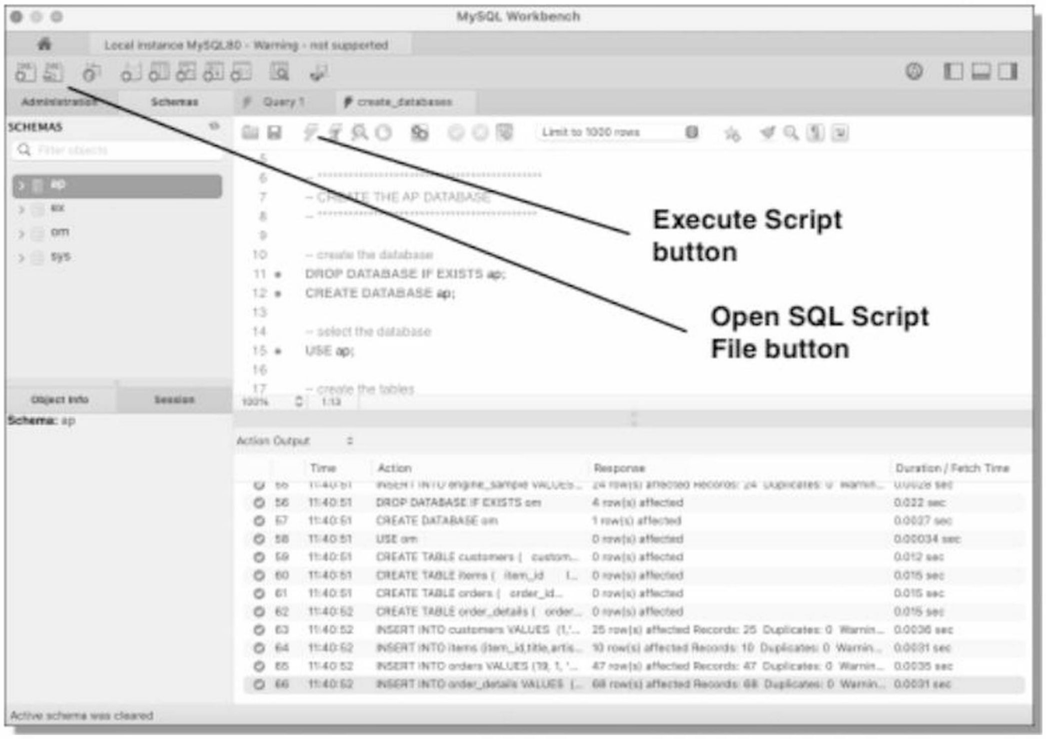
## How to restore the databases

As you work with the code that's presented in this book, you may make changes to the databases that you don't intend to make. In that case, you may want to restore the databases to their original state so your results match the results shown in this book. To do that, you can run the create_databases.sql file again. This deletes the three databases described in this appendix and recreates them.

### The directory that contains the create_databases.sql file

`Documents/murach/mysql/db_setup`

### MySQL Workbench after executing the create_databases.sql file




### How to create the databases

1. Start MySQL Workbench.
2. Click on the stored connection named “Local instance MySQL” and enter the password for the root user if prompted. *This is the password that you created when installing the MySQL server in figure B-1.* This connects you as the root user to the local instance of MySQL.
3. If Workbench doesn’t display a connection, you can create one. To do that, click the ⊕ icon to the right of MySQL Connections, enter “Local instance MySQL” for the connection name, and click the OK button.
4. If you get a warning that MySQL Workbench is incompatible with the server version and that some features may not work properly, don’t be alarmed. You can click Continue Anyway and the features described in this book should still work.
5. Open the create_databases.sql file by clicking the Open SQL Script File button. Then, use the resulting dialog box to locate and open the file. When you do, MySQL Workbench displays this script in a SQL Editor tab.
6. Execute the script by clicking the Execute Script button. When you do, the Output window displays messages that indicate whether the script executed successfully.

### How to restore the databases

- Run the create_databases.sql script again to drop the databases and recreate them.

Figure B-4    How to create and restore the databases for this book

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## V



## W

## XYZ

## What software you need

- MySQL Community Server
- MySQL Workbench

This software is available for free, and appendixes A (Windows) and B (macOS) show how to install it.

## What the download contains

- The script file that creates the three databases for this book
- Scripts for the SQL statements presented throughout this book
- Solutions to the exercises that are at the end of each chapter

## How to download the files

1. Go to www.murach.com.
2. Find the page for *Murach's MySQL (4th Edition)*.
3. Scroll down to the FREE Downloads tab and click it.
4. Click the Download Now button to download the zip file.
5. Find the downloaded zip file and double-click it. This should display a directory named mysql.
6. Create a directory named murach.
7. Move the mysql directory into the murach directory.

For more detailed instructions, please see appendix A (Windows) or B (macOS).

## How to create the databases

1. Start MySQL Workbench and connect to the local instance of the MySQL server as the root user.
2. Click the Open SQL Script File button and use the resulting dialog box to open this script:
   `murach/mysql/db_setup/create_databases.sql`
3. Click the Execute Script button to run the script.

For more detailed instructions, please see appendix A (Windows) or B (macOS).

## What makes Murach books the best

During the last 50 years, many customers have asked me how it is that a small publisher in Fresno can make the best programming books. The short answer is that no other publisher works the way we do.

Instead of using freelance writers who get no training, we use a small staff of programmers who are trained in our proven writing and teaching methods. Instead of publishing 40+ books each year, we focus on just a few. Instead of showing pieces of code, we provide complete applications that have been checked and re-checked for accuracy. And instead of rushing books to market, we refuse to let schedule or budget interfere with quality. As I see it, that's the only way to make sure that every book we publish is the best one on its subject.

That's why people often tell me that our books are the ones that they look for *first* whenever they need to learn a new subject. Why not try this book and see for yourself!

Mike Murach
*Publisher*

## MySQL contents

### Get started fast

- The concepts and terms you need for working with relational databases and SQL
- Use MySQL Workbench to work more efficiently with a MySQL database

### Master the SQL that you'll use every day

- Write SQL statements that retrieve data from a database
- Write SQL statements that insert, update, and delete the data in a database
- Work with joins, summary queries, subqueries, data types, and functions

### Learn how to design and create a database

- Design a database from start to finish, the first step toward becoming a database administrator (DBA)
- Use an EER (enhanced entity-relationship) model and its related diagrams to create or modify the design for a database
- Maintain referential integrity with foreign keys
- Speed data access with indexes
- Simplify data access with views

### Master stored programs

- Improve developer productivity with stored procedures and user-defined functions
- Maintain data integrity with transactions
- Automate data maintenance with triggers and events

### Get started as a database administrator

- Monitor a database
- Configure a database
- Secure a database
- Back up and restore a database
- Host a database in the cloud with AWS (Amazon Web Services)

### Download the examples and exercise solutions

*(see the last page of this book for details)*

## What developers have said about the previous editions

"If you ever wanted to learn to use MySQL, write SQL queries, create database elements, then this is the book to pick up. Rating: 10 Horseshoes."

Review by Mohamed Sanaulla, JavaRanch.com

"A great first book into SQL: From all the SQL books I looked over, this has by far the best division of chapters and the best order for learning."

Posted at an online bookseller

"As a developer with almost 10 years of MySQL experience, I still picked up a lot of new detail on things I thought I knew. Every development shop that works with MySQL should have a copy of this book."

David Bolton, C/C++/C# Guide, About.com

"This book was the text in my Database Concepts class, and I am so thankful that it was! It provided excellent explanations and examples of database syntax, queries, subqueries, design, etc. I aced the class and decided to take more database classes because of this book."

Posted at an online bookseller

"This book is not just up-to-date with the latest information on MySQL, but it is extremely easy to read and learn from. It only took me a couple weeks to rip through it!"

Posted at an online bookseller

"I was amazed at how much information was packed into this book. I learned a lot of new MySQL ideas, and I will be using it frequently as a reference."

Paul Turpin, Southeastern Inter-Relational Database Users Group

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