

# Table of Contents

[Preface](#Preface__Programming_languages_c_2)

[Why Learn SQL?](#Why_Learn_SQL_____Whether_you_wi)

[Why Use This Book to Do It?](#Why_Use_This_Book_to_Do_It___The)

[Structure of This Book](#Structure_of_This_Book__This_boo)

[Conventions Used in This Book](#Conventions_Used_in_This_Book)

[Using the Examples in This Book](#Using_the_Examples_in_This_Book)

[O’Reilly Online Learning](#O_Reilly_Online_Learning_Note_Fo)

[How to Contact Us](#How_to_Contact_Us_Please_address)

[Acknowledgments](#Acknowledgments_I_would_like_to)

[1. A Little Background](#Chapter_1__A_Little_Background_2)

[Introduction to Databases](#Introduction_to_Databases____A_d)

[Nonrelational Database Systems](#Nonrelational_Database_Systems)

[The Relational Model](#The_Relational_Model________In_1)

[Some Terminology](#Some_Terminology__I_introduced_s)

[What Is SQL?](#What_Is_SQL________________Along)

[SQL Statement Classes](#SQL_Statement_Classes__________T)

[SQL: A Nonprocedural Language](#SQL__A_Nonprocedural_Language)

[SQL Examples](#SQL_Examples___Earlier_in_this_c)

[What Is MySQL?](#What_Is_MySQL_______Relational_d)

[SQL Unplugged](#SQL_Unplugged_____A_great_deal_h)

[What’s in Store](#What_s_in_Store__The_overall_goa)

[2. Creating and Populating a Database](#Chapter_2__Creating_and_Populati_2)

[Creating a MySQL Database](#Creating_a_MySQL_Database)

[Using the mysql Command-Line Tool](#Using_the_mysql_Command_Line_Too)

[MySQL Data Types](#MySQL_Data_Types______In_general)

[Character Data](#Character_Data___________Charact)

[Numeric Data](#Numeric_Data_____Although_it_mig)

[Temporal Data](#Temporal_Data_____Along_with_str)

[Table Creation](#Table_Creation_____Now_that_you)

[Step 1: Design](#Step_1__Design__A_good_way_to_st)

[Step 2: Refinement](#Step_2__Refinement_____In_Chapte)

[Step 3: Building SQL Schema Statements](#Step_3__Building_SQL_Schema_Stat)

[Populating and Modifying Tables](#Populating_and_Modifying_Tables)

[Inserting Data](#Inserting_Data____Since_there_is)

[Updating Data](#Updating_Data_____When_the_data)

[Deleting Data](#Deleting_Data_____It_seems_that)

[When Good Statements Go Bad](#When_Good_Statements_Go_Bad__So)

[Nonunique Primary Key](#Nonunique_Primary_Key_____Becaus)

[Nonexistent Foreign Key](#Nonexistent_Foreign_Key_____The)

[Column Value Violations](#Column_Value_Violations______The)

[Invalid Date Conversions](#Invalid_Date_Conversions_______I)

[The Sakila Database](#The_Sakila_Database_____For_the)

[3. Query Primer](#Chapter_3__Query_Primer__So_far_2)

[Query Mechanics](#Query_Mechanics_________Before_d)

[Query Clauses](#Query_Clauses____Several_compone)

[The select Clause](#The_select_Clause_____Even_thoug)

[Column Aliases](#Column_Aliases______Although_the)

[Removing Duplicates](#Removing_Duplicates______In_some)

[The from Clause](#The_from_Clause____Thus_far__you)

[Tables](#Tables_____When_confronted_with)

[Table Links](#Table_Links______The_second_devi)

[Defining Table Aliases](#Defining_Table_Aliases_____When)

[The where Clause](#The_where_Clause____In_some_case)

[The group by and having Clauses](#The_group_by_and_having_Clauses)

[The order by Clause](#The_order_by_Clause_____In_gener)

[Ascending Versus Descending Sort Order](#Ascending_Versus_Descending_Sort)

[Sorting via Numeric Placeholders](#Sorting_via_Numeric_Placeholders)

[Test Your Knowledge](#Test_Your_Knowledge__The_followi)

[Exercise 3-1](#Exercise_3_1__Retrieve_the_actor)

[Exercise 3-2](#Exercise_3_2__Retrieve_the_actor)

[Exercise 3-3](#Exercise_3_3__Write_a_query_agai)

[Exercise 3-4](#Exercise_3_4__Fill_in_the_blanks)

[4. Filtering](#Chapter_4__Filtering__Sometimes_2)

[Condition Evaluation](#Condition_Evaluation_______A_whe)

[Using Parentheses](#Using_Parentheses______If_your_w)

[Using the not Operator](#Using_the_not_Operator_____Hopef)

[Building a Condition](#Building_a_Condition_____Now_tha)

[Condition Types](#Condition_Types___There_are_many)

[Equality Conditions](#Equality_Conditions_____A_large)

[Range Conditions](#Range_Conditions_____Along_with)

[Membership Conditions](#Membership_Conditions_____In_som)

[Matching Conditions](#Matching_Conditions_____So_far)

[Null: That Four-Letter Word](#Null__That_Four_Letter_Word)

[Test Your Knowledge](#Test_Your_Knowledge__The_followi_1)

[Exercise 4-1](#Exercise_4_1__Which_of_the_payme)

[Exercise 4-2](#Exercise_4_2__Which_of_the_payme)

[Exercise 4-3](#Exercise_4_3__Construct_a_query)

[Exercise 4-4](#Exercise_4_4__Construct_a_query)

[5. Querying Multiple Tables](#Chapter_5__Querying_Multiple_Tab_2)

[What Is a Join?](#What_Is_a_Join___Queries_against)

[Cartesian Product](#Cartesian_Product____The_easiest)

[Inner Joins](#Inner_Joins_____To_modify_the_pr)

[The ANSI Join Syntax](#The_ANSI_Join_Syntax______The_no)

[Joining Three or More Tables](#Joining_Three_or_More_Tables)

[Using Subqueries as Tables](#Using_Subqueries_as_Tables_____Y)

[Using the Same Table Twice](#Using_the_Same_Table_Twice____If)

[Self-Joins](#Self_Joins_______Not_only_can_yo)

[Test Your Knowledge](#Test_Your_Knowledge__The_followi_2)

[Exercise 5-1](#Exercise_5_1__Fill_in_the_blanks)

[Exercise 5-2](#Exercise_5_2__Write_a_query_that)

[Exercise 5-3](#Exercise_5_3__Construct_a_query)

[6. Working with Sets](#Chapter_6__Working_with_Sets__Al_2)

[Set Theory Primer](#Set_Theory_Primer____In_many_par)

[Set Theory in Practice](#Set_Theory_in_Practice__The_circ)

[Set Operators](#Set_Operators__The_SQL_language)

[The union Operator](#The_union_Operator_____The_union)

[The intersect Operator](#The_intersect_Operator______The)

[The except Operator](#The_except_Operator______The_ANS)

[Set Operation Rules](#Set_Operation_Rules__The_followi)

[Sorting Compound Query Results](#Sorting_Compound_Query_Results)

[Set Operation Precedence](#Set_Operation_Precedence_____If)

[Test Your Knowledge](#Test_Your_Knowledge__The_followi_3)

[Exercise 6-1](#Exercise_6_1__If_set_A____L_M_N)

[Exercise 6-2](#Exercise_6_2__Write_a_compound_q)

[Exercise 6-3](#Exercise_6_3__Sort_the_results_f)

[7. Data Generation, Manipulation, and Conversion](#Chapter_7__Data_Generation__Mani_2)

[Working with String Data](#Working_with_String_Data_____Whe)

[String Generation](#String_Generation________The_sim)

[String Manipulation](#String_Manipulation_____Each_dat)

[Working with Numeric Data](#Working_with_Numeric_Data_____Un)

[Performing Arithmetic Functions](#Performing_Arithmetic_Functions)

[Controlling Number Precision](#Controlling_Number_Precision)

[Handling Signed Data](#Handling_Signed_Data____If_you_a)

[Working with Temporal Data](#Working_with_Temporal_Data____Of)

[Dealing with Time Zones](#Dealing_with_Time_Zones_____Beca)

[Generating Temporal Data](#Generating_Temporal_Data_______Y)

[Manipulating Temporal Data](#Manipulating_Temporal_Data__This)

[Conversion Functions](#Conversion_Functions_______Earli)

[Test Your Knowledge](#Test_Your_Knowledge__These_exerc)

[Exercise 7-1](#Exercise_7_1__Write_a_query_that)

[Exercise 7-2](#Exercise_7_2__Write_a_query_that)

[Exercise 7-3](#Exercise_7_3__Write_a_query_to_r)

[8. Grouping and Aggregates](#Chapter_8__Grouping_and_Aggregat_2)

[Grouping Concepts](#Grouping_Concepts____Sometimes_y)

[Aggregate Functions](#Aggregate_Functions____Aggregate)

[Implicit Versus Explicit Groups](#Implicit_Versus_Explicit_Groups)

[Counting Distinct Values](#Counting_Distinct_Values_______W)

[Using Expressions](#Using_Expressions____Along_with)

[How Nulls Are Handled](#How_Nulls_Are_Handled_____When_p)

[Generating Groups](#Generating_Groups__People_are_ra)

[Single-Column Grouping](#Single_Column_Grouping_____Singl)

[Multicolumn Grouping](#Multicolumn_Grouping_____In_some)

[Grouping via Expressions](#Grouping_via_Expressions____Alon)

[Generating Rollups](#Generating_Rollups______In__Mult)

[Group Filter Conditions](#Group_Filter_Conditions_____In_C)

[Test Your Knowledge](#Test_Your_Knowledge__Work_throug)

[Exercise 8-1](#Exercise_8_1__Construct_a_query)

[Exercise 8-2](#Exercise_8_2__Modify_your_query)

[Exercise 8-3](#Exercise_8_3__Modify_your_query)

[9. Subqueries](#Chapter_9__Subqueries__Subquerie_2)

[What Is a Subquery?](#What_Is_a_Subquery_______A_subqu)

[Subquery Types](#Subquery_Types__Along_with_the_d)

[Noncorrelated Subqueries](#Noncorrelated_Subqueries_____The)

[Multiple-Row, Single-Column Subqueries](#Multiple_Row__Single_Column_Subq)

[Multicolumn Subqueries](#Multicolumn_Subqueries______So_f)

[Correlated Subqueries](#Correlated_Subqueries_____All_of)

[The exists Operator](#The_exists_Operator_____While_yo)

[Data Manipulation Using Correlated Subqueries](#Data_Manipulation_Using_Correlat)

[When to Use Subqueries](#When_to_Use_Subqueries__Now_that)

[Subqueries as Data Sources](#Subqueries_as_Data_Sources_____B)

[Subqueries as Expression Generators](#Subqueries_as_Expression_Generat)

[Subquery Wrap-Up](#Subquery_Wrap_Up__I_covered_a_lo)

[Test Your Knowledge](#Test_Your_Knowledge__These_exerc_1)

[Exercise 9-1](#Exercise_9_1__Construct_a_query)

[Exercise 9-2](#Exercise_9_2__Rework_the_query_f)

[Exercise 9-3](#Exercise_9_3__Join_the_following)

[10. Joins Revisited](#Chapter_10__Joins_Revisited__By_2)

[Outer Joins](#Outer_Joins_____In_all_the_examp)

[Left Versus Right Outer Joins](#Left_Versus_Right_Outer_Joins__I)

[Three-Way Outer Joins](#Three_Way_Outer_Joins_____In_som)

[Cross Joins](#Cross_Joins______Back_in_Chapter)

[Natural Joins](#Natural_Joins_____If_you_are_laz)

[Test Your Knowledge](#Test_Your_Knowledge__The_followi_4)

[Exercise 10-1](#Exercise_10_1__Using_the_followi)

[Exercise 10-2](#Exercise_10_2__Reformulate_your)

[Exercise 10-3 (Extra Credit)](#Exercise_10_3__Extra_Credit___De)

[11. Conditional Logic](#Chapter_11__Conditional_Logic__I_2)

[What Is Conditional Logic?](#What_Is_Conditional_Logic______C)

[The case Expression](#The_case_Expression_________All)

[Searched case Expressions](#Searched_case_Expressions_____Th)

[Simple case Expressions](#Simple_case_Expressions_____The)

[Examples of case Expressions](#Examples_of_case_Expressions__Th)

[Result Set Transformations](#Result_Set_Transformations)

[Checking for Existence](#Checking_for_Existence_____Somet)

[Division-by-Zero Errors](#Division_by_Zero_Errors______Whe)

[Conditional Updates](#Conditional_Updates_____When_upd)

[Handling Null Values](#Handling_Null_Values_____While_n)

[Test Your Knowledge](#Test_Your_Knowledge__Challenge_y)

[Exercise 11-1](#Exercise_11_1__Rewrite_the_follo)

[Exercise 11-2](#Exercise_11_2__Rewrite_the_follo)

[12. Transactions](#Chapter_12__Transactions__All_of_2)

[Multiuser Databases](#Multiuser_Databases____Database)

[Locking](#Locking_____Locks_are_the_mechan)

[Lock Granularities](#Lock_Granularities____There_are)

[What Is a Transaction?](#What_Is_a_Transaction______If_da)

[Starting a Transaction](#Starting_a_Transaction____Databa)

[Ending a Transaction](#Ending_a_Transaction_____Once_a)

[Transaction Savepoints](#Transaction_Savepoints_____In_so)

[Test Your Knowledge](#Test_Your_Knowledge__Test_your_u)

[Exercise 12-1](#Exercise_12_1__Generate_a_unit_o)

[13. Indexes and Constraints](#Chapter_13__Indexes_and_Constrai_2)

[Indexes](#Indexes____When_you_insert_a_row)

[Index Creation](#Index_Creation____Returning_to_t)

[Types of Indexes](#Types_of_Indexes__Indexing_is_a)

[How Indexes Are Used](#How_Indexes_Are_Used_____Indexes)

[The Downside of Indexes](#The_Downside_of_Indexes____If_in)

[Constraints](#Constraints_____A_constraint_is)

[Constraint Creation](#Constraint_Creation_____Constrai)

[Test Your Knowledge](#Test_Your_Knowledge__Work_throug_1)

[Exercise 13-1](#Exercise_13_1__Generate_an_alter)

[Exercise 13-2](#Exercise_13_2__Generate_a_multic)

[14. Views](#Chapter_14__Views__Well_designed_2)

[What Are Views?](#What_Are_Views_____A_view_is_sim)

[Why Use Views?](#Why_Use_Views_____In_the_previou)

[Data Security](#Data_Security_____If_you_create)

[Data Aggregation](#Data_Aggregation_____Reporting_a)

[Hiding Complexity](#Hiding_Complexity____One_of_the)

[Joining Partitioned Data](#Joining_Partitioned_Data_____Som)

[Updatable Views](#Updatable_Views_____If_you_provi)

[Updating Simple Views](#Updating_Simple_Views__The_view)

[Updating Complex Views](#Updating_Complex_Views__While_si)

[Test Your Knowledge](#Test_Your_Knowledge__Test_your_u_1)

[Exercise 14-1](#Exercise_14_1__Create_a_view_def)

[Exercise 14-2](#Exercise_14_2__The_film_rental_c)

[15. Metadata](#Chapter_15__Metadata__Along_with_2)

[Data About Data](#Data_About_Data____Metadata_is_e)

[information\_schema](#information_schema__All_of_the_o)

[Working with Metadata](#Working_with_Metadata__As_I_ment)

[Schema Generation Scripts](#Schema_Generation_Scripts_____Wh)

[Deployment Verification](#Deployment_Verification_____Many)

[Dynamic SQL Generation](#Dynamic_SQL_Generation______Some)

[Test Your Knowledge](#Test_Your_Knowledge__The_followi_5)

[Exercise 15-1](#Exercise_15_1__Write_a_query_tha)

[Exercise 15-2](#Exercise_15_2__Write_a_query_tha)

[16. Analytic Functions](#Chapter_16__Analytic_Functions_2)

[Analytic Function Concepts](#Analytic_Function_Concepts____Af)

[Data Windows](#Data_Windows______Let_s_say_you)

[Localized Sorting](#Localized_Sorting______Along_wit)

[Ranking](#Ranking_____People_love_to_rank)

[Ranking Functions](#Ranking_Functions__There_are_mul)

[Generating Multiple Rankings](#Generating_Multiple_Rankings__Th)

[Reporting Functions](#Reporting_Functions______Along_w)

[Window Frames](#Window_Frames______As_described)

[Lag and Lead](#Lag_and_Lead_____Along_with_comp)

[Column Value Concatenation](#Column_Value_Concatenation)

[Test Your Knowledge](#Test_Your_Knowledge__The_followi_6)

[Exercise 16-1](#Exercise_16_1__Write_a_query_tha)

[Exercise 16-2](#Exercise_16_2__Modify_the_query)

[Exercise 16-3](#Exercise_16_3__Write_a_query_tha)

[17. Working with Large Databases](#Chapter_17__Working_with_Large_D_2)

[Partitioning](#Partitioning_____When_exactly_do)

[Partitioning Concepts](#Partitioning_Concepts___Table_pa)

[Table Partitioning](#Table_Partitioning_______The_par)

[Index Partitioning](#Index_Partitioning_______If_your)

[Partitioning Methods](#Partitioning_Methods__While_each)

[Partitioning Benefits](#Partitioning_Benefits____One_maj)

[Clustering](#Clustering_____With_enough_stora)

[Sharding](#Sharding_____Let_s_say_you_have)

[Big Data](#Big_Data_____After_spending_some)

[Hadoop](#Hadoop_____Hadoop_is_best_descri)

[NoSQL and Document Databases](#NoSQL_and_Document_Databases)

[Cloud Computing](#Cloud_Computing_______Prior_to_t)

[Conclusion](#Conclusion__Databases_are_gettin)

[18. SQL and Big Data](#Chapter_18__SQL_and_Big_Data__Wh_2)

[Introduction to Apache Drill](#Introduction_to_Apache_Drill)

[Querying Files Using Drill](#Querying_Files_Using_Drill)

[Querying MySQL Using Drill](#Querying_MySQL_Using_Drill)

[Querying MongoDB Using Drill](#Querying_MongoDB_Using_Drill)

[Drill with Multiple Data Sources](#Drill_with_Multiple_Data_Sources)

[Future of SQL](#Future_of_SQL_______The_future_o)

[A. ER Diagram for Example Database](#Appendix_A__ER_Diagram_for_Examp_2)

[B. Solutions to Exercises](#Appendix_B__Solutions_to_Exercis_2)

[Chapter 3](#Chapter_3___Exercise_3_1__Retrie)

[Exercise 3-1](#Exercise_3_1__Retrieve_the_actor_1)

[Exercise 3-2](#Exercise_3_2__Retrieve_the_actor_1)

[Exercise 3-3](#Exercise_3_3__Write_a_query_agai_1)

[Exercise 3-4](#Exercise_3_4__Fill_in_the_blanks_1)

[Chapter 4](#Chapter_4__The_following_subset)

[Exercise 4-1](#Exercise_4_1__Which_of_the_payme_1)

[Exercise 4-2](#Exercise_4_2__Which_of_the_payme_1)

[Exercise 4-3](#Exercise_4_3__Construct_a_query_1)

[Exercise 4-4](#Exercise_4_4__Construct_a_query_1)

[Chapter 5](#Chapter_5___Exercise_5_1__Fill_i)

[Exercise 5-1](#Exercise_5_1__Fill_in_the_blanks_1)

[Exercise 5-2](#Exercise_5_2__Write_a_query_that_1)

[Exercise 5-3](#Exercise_5_3__Construct_a_query_1)

[Chapter 6](#Chapter_6___Exercise_6_1__If_set)

[Exercise 6-1](#Exercise_6_1__If_set_A____L_M_N_1)

[Exercise 6-2](#Exercise_6_2__Write_a_compound_q_1)

[Exercise 6-3](#Exercise_6_3__Sort_the_results_f_1)

[Chapter 7](#Chapter_7___Exercise_7_1__Write)

[Exercise 7-1](#Exercise_7_1__Write_a_query_that_1)

[Exercise 7-2](#Exercise_7_2__Write_a_query_that_1)

[Exercise 7-3](#Exercise_7_3__Write_a_query_to_r_1)

[Chapter 8](#Chapter_8___Exercise_8_1__Constr)

[Exercise 8-1](#Exercise_8_1__Construct_a_query_1)

[Exercise 8-2](#Exercise_8_2__Modify_your_query_1)

[Exercise 8-3](#Exercise_8_3__Modify_your_query_1)

[Chapter 9](#Chapter_9___Exercise_9_1__Constr)

[Exercise 9-1](#Exercise_9_1__Construct_a_query_1)

[Exercise 9-2](#Exercise_9_2__Rework_the_query_f_1)

[Exercise 9-3](#Exercise_9_3__Join_the_following_1)

[Chapter 10](#Chapter_10___Exercise_10_1__Usin)

[Exercise 10-1](#Exercise_10_1__Using_the_followi_1)

[Exercise 10-2](#Exercise_10_2__Reformulate_your_1)

[Exercise 10-3 (Extra Credit)](#Exercise_10_3__Extra_Credit___De_1)

[Chapter 11](#Chapter_11___Exercise_11_1__Rewr)

[Exercise 11-1](#Exercise_11_1__Rewrite_the_follo_1)

[Exercise 11-2](#Exercise_11_2__Rewrite_the_follo_1)

[Chapter 12](#Chapter_12___Exercise_12_1__Gene)

[Exercise 12-1](#Exercise_12_1__Generate_a_unit_o_1)

[Chapter 13](#Chapter_13___Exercise_13_1__Gene)

[Exercise 13-1](#Exercise_13_1__Generate_an_alter_1)

[Exercise 13-2](#Exercise_13_2__Generate_a_multic_1)

[Chapter 14](#Chapter_14___Exercise_14_1__Crea)

[Exercise 14-1](#Exercise_14_1__Create_a_view_def_1)

[Exercise 14-2](#Exercise_14_2__The_film_rental_c_1)

[Chapter 15](#Chapter_15___Exercise_15_1__Writ)

[Exercise 15-1](#Exercise_15_1__Write_a_query_tha_1)

[Exercise 15-2](#Exercise_15_2__Write_a_query_tha_1)

[Chapter 16](#Chapter_16__For_all_exercises_in)

[Exercise 16-1](#Exercise_16_1__Write_a_query_tha_1)

[Exercise 16-2](#Exercise_16_2__Modify_the_query_1)

[Exercise 16-3](#Exercise_16_3__Write_a_query_tha_1)

[Index](#IndexSymbols___asterisk_in_aggre_2)

[About the Author](#About_the_Author__Alan_Beaulieu_2)

# Learning SQL

Third Edition

Generate, Manipulate, and Retrieve Data

Alan Beaulieu

# Learning SQL

by Alan Beaulieu

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[LSI]

# Preface

Programming languages come and go constantly, and very few languages in use today have roots going back more than a decade or so. Some examples are COBOL, which is still used quite heavily in mainframe environments; Java, which was born in the mid-1990s and has become one of the most popular programming languages; and C, which is still quite popular for operating systems and server development and for embedded systems. In the database arena, we have SQL, whose roots go all the way back to the 1970s.

SQL was initially created to be the language for generating, manipulating, and retrieving data from relational databases, which have been around for more than 40 years. Over the past decade or so, however, other data platforms such as Hadoop, Spark, and NoSQL have gained a great deal of traction, eating away at the relational database market. As will be discussed in the last few chapters of this book, however, the SQL language has been evolving to facilitate the retrieval of data from various platforms, regardless of whether the data is stored in tables, documents, or flat files.

# Why Learn SQL?

Whether you will be using a relational database or not, if you are working in data science, business intelligence, or some other facet of data analysis, you will likely need to know SQL, along with other languages/platforms such as Python and R. Data is everywhere, in huge quantities, and arriving at a rapid pace, and people who can extract meaningful information from all this data are in big demand.

# Why Use This Book to Do It?

There are plenty of books out there that treat you like a dummy, idiot, or some other flavor of simpleton, but these books tend to just skim the surface. At the other end of the spectrum are reference guides that detail every permutation of every statement in a language, which can be useful if you already have a good idea of what you want to do but just need the syntax. This book strives to find the middle ground, starting with some background of the SQL language, moving through the basics, and then progressing into some of the more advanced features that will allow you to really shine. Additionally, this book ends with a chapter showing how to query data in nonrelational databases, which is a topic rarely covered in introductory books.

# Structure of This Book

This book is divided into 18 chapters and 2 appendixes:

[Chapter 1, “A Little Background”](#Chapter_1__A_Little_Background_2)

Explores the history of computerized databases, including the rise of the relational model and the SQL language.

[Chapter 2, “Creating and Populating a Database”](#Chapter_2__Creating_and_Populati_2)

Demonstrates how to create a MySQL database, create the tables used for the examples in this book, and populate the tables with data.

[Chapter 3, “Query Primer”](#Chapter_3__Query_Primer__So_far_2)

Introduces the select statement and further demonstrates the most common clauses (select, from, where).

[Chapter 4, “Filtering”](#Chapter_4__Filtering__Sometimes_2)

Demonstrates the different types of conditions that can be used in the where clause of a select, update, or delete statement.

[Chapter 5, “Querying Multiple Tables”](#Chapter_5__Querying_Multiple_Tab_2)

Shows how queries can utilize multiple tables via table joins.

[Chapter 6, “Working with Sets”](#Chapter_6__Working_with_Sets__Al_2)

This chapter is all about data sets and how they can interact within queries.

[Chapter 7, “Data Generation, Manipulation, and Conversion”](#Chapter_7__Data_Generation__Mani_2)

Demonstrates several built-in functions used for manipulating or converting data.

[Chapter 8, “Grouping and Aggregates”](#Chapter_8__Grouping_and_Aggregat_2)

Shows how data can be aggregated.

[Chapter 9, “Subqueries”](#Chapter_9__Subqueries__Subquerie_2)

Introduces subqueries (a personal favorite) and shows how and where they can be utilized.

[Chapter 10, “Joins Revisited”](#Chapter_10__Joins_Revisited__By_2)

Further explores the various types of table joins.

[Chapter 11, “Conditional Logic”](#Chapter_11__Conditional_Logic__I_2)

Explores how conditional logic (i.e., if-then-else) can be utilized in select, insert, update, and delete statements.

[Chapter 12, “Transactions”](#Chapter_12__Transactions__All_of_2)

Introduces transactions and shows how to use them.

[Chapter 13, “Indexes and Constraints”](#Chapter_13__Indexes_and_Constrai_2)

Explores indexes and constraints.

[Chapter 14, “Views”](#Chapter_14__Views__Well_designed_2)

Shows how to build an interface to shield users from data complexities.

[Chapter 15, “Metadata”](#Chapter_15__Metadata__Along_with_2)

Demonstrates the utility of the data dictionary.

[Chapter 16, “Analytic Functions”](#Chapter_16__Analytic_Functions_2)

Covers functionality used to generate rankings, subtotals, and other values used heavily in reporting and analysis.

[Chapter 17, “Working with Large Databases”](#Chapter_17__Working_with_Large_D_2)

Demonstrates techniques for making very large databases easier to manage and traverse.

[Chapter 18, “SQL and Big Data”](#Chapter_18__SQL_and_Big_Data__Wh_2)

Explores the transformation of the SQL language to allow retrieval of data from nonrelational data platforms.

[Appendix A, “ER Diagram for Example Database”](#Appendix_A__ER_Diagram_for_Examp_2)

Shows the database schema used for all examples in the book.

[Appendix B, “Solutions to Exercises”](#Appendix_B__Solutions_to_Exercis_2)

Shows solutions to the chapter exercises.

# Conventions Used in This Book

The following typographical conventions are used in this book:

Italic

Indicates new terms, URLs, email addresses, filenames, and file extensions.

Constant width

Used for program listings, as well as within paragraphs to refer to program elements such as variable or function names, databases, data types, environment variables, statements, and keywords.

Constant width italic

Shows text that should be replaced with user-supplied values or by values determined by context.

Constant width bold

Shows commands or other text that should be typed literally by the user.

##### Note

Indicates a tip, suggestion, or general note. For example, I use notes to point you to useful new features in Oracle9i.

Warning

Indicates a warning or caution. For example, I’ll tell you if a certain SQL clause might have unintended consequences if not used carefully.

# Using the Examples in This Book

To experiment with the data used for the examples in this book, you have two options:

* Download and install the MySQL server version 8.0 (or later) and load the Sakila example database from <https://dev.mysql.com/doc/index-other.html>.
* Go to <https://learning.oreilly.com/scenarios/mysql-sandbox/9781492079705> to access the MySQL Sandbox, which has the Sakila Sample database loaded in a MySQL instance. If you don’t have one already, you’ll have to set up an O’Reilly account. Then, click on the Start button and begin.

If you choose the second option, once you start the scenario, a MySQL server is installed and started, and then the Sakila schema and data are loaded. When it’s ready, a standard mysql> prompt appears, and you can then start querying the sample database. This is certainly the easiest option, and I anticipate that most readers will choose this option; if this sounds good to you, feel free to skip ahead to the next section.

If you prefer to have your own copy of the data and want any changes you have made to be permanent, or if you are just interested in installing the MySQL server on your own machine, you may prefer the first option. You may also opt to use a MySQL server hosted in an environment such as Amazon Web Services or Google Cloud. In either case, you will need to perform the installation/configuration yourself, as it is beyond the scope of this book. Once your database is available, you will need to follow a few steps to load the Sakila sample database.

First, you will need to launch the mysql command-line client and provide a password, and then perform the following steps:

Go to <https://dev.mysql.com/doc/index-other.html> and download the files for “sakila database” under the Example Databases section.

Put the files in a local directory such as C:\temp\sakila-db (used for the next two steps, but overwrite with your directory path).

Type source c:\temp\sakila-db\sakila-schema.sql; and press Enter.

Type source c:\temp\sakila-db\sakila-data.sql; and press Enter.

You should now have a working database populated with all the data needed for the examples in this book.

# O’Reilly Online Learning

##### Note

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# Chapter 1. A Little Background

Before we roll up our sleeves and get to work, it would be helpful to survey the history of database technology in order to better understand how relational databases and the SQL language evolved. Therefore, I’d like to start by introducing some basic database concepts and looking at the history of computerized data storage and retrieval.

##### Note

For those readers anxious to start writing queries, feel free to skip ahead to [Chapter 3](#Chapter_3__Query_Primer__So_far_2), but I recommend returning later to the first two chapters in order to better understand the history and utility of the SQL language.

# Introduction to Databases

A database is nothing more than a set of related information. A telephone book, for example, is a database of the names, phone numbers, and addresses of all people living in a particular region. While a telephone book is certainly a ubiquitous and frequently used database, it suffers from the following:

* Finding a person’s telephone number can be time consuming, especially if the telephone book contains a large number of entries.
* A telephone book is indexed only by last/first names, so finding the names of the people living at a particular address, while possible in theory, is not a practical use for this database.
* From the moment the telephone book is printed, the information becomes less and less accurate as people move into or out of a region, change their telephone numbers, or move to another location within the same region.

The same drawbacks attributed to telephone books can also apply to any manual data storage system, such as patient records stored in a filing cabinet. Because of the cumbersome nature of paper databases, some of the first computer applications developed were database systems, which are computerized data storage and retrieval mechanisms. Because a database system stores data electronically rather than on paper, a database system is able to retrieve data more quickly, index data in multiple ways, and deliver up-to-the-minute information to its user community.

Early database systems managed data stored on magnetic tapes. Because there were generally far more tapes than tape readers, technicians were tasked with loading and unloading tapes as specific data was requested. Because the computers of that era had very little memory, multiple requests for the same data generally required the data to be read from the tape multiple times. While these database systems were a significant improvement over paper databases, they are a far cry from what is possible with today’s technology. (Modern database systems can manage petabytes of data, accessed by clusters of servers each caching tens of gigabytes of that data in high-speed memory, but I’m getting a bit ahead of myself.)

## Nonrelational Database Systems

##### Note

This section contains some background information about pre-relational database systems. For those readers eager to dive into SQL, feel free to skip ahead a couple of pages to the next section.

Over the first several decades of computerized database systems, data was stored and represented to users in various ways. In a hierarchical database system, for example, data is represented as one or more tree structures. [Figure 1-1](#Figure_1_1__Hierarchical_view_of) shows how data relating to George Blake’s and Sue Smith’s bank accounts might be represented via tree structures.

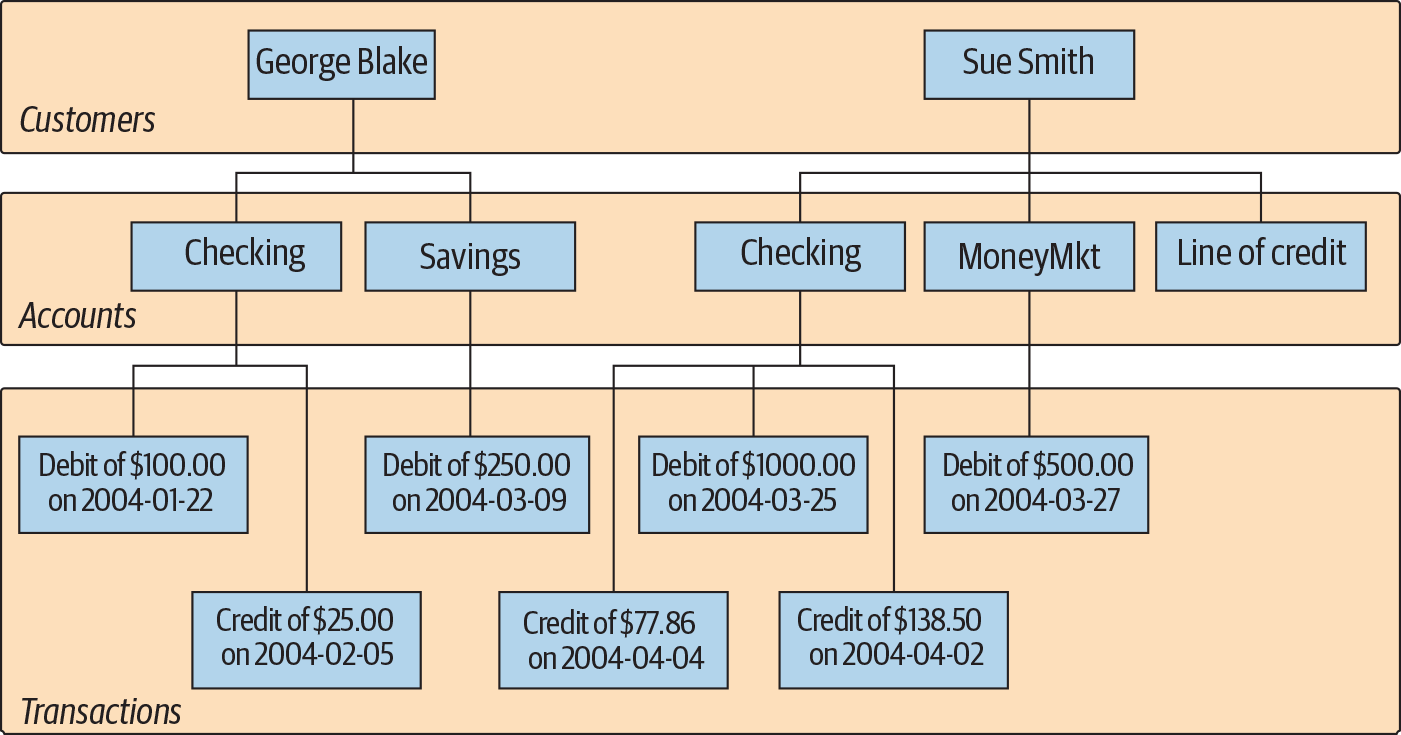


Figure 1-1. Hierarchical view of account data

George and Sue each have their own tree containing their accounts and the transactions on those accounts. The hierarchical database system provides tools for locating a particular customer’s tree and then traversing the tree to find the desired accounts and/or transactions. Each node in the tree may have either zero or one parent and zero, one, or many children. This configuration is known as a single-parent hierarchy.

Another common approach, called the network database system, exposes sets of records and sets of links that define relationships between different records. [Figure 1-2](#Figure_1_2__Network_view_of_acco) shows how George’s and Sue’s same accounts might look in such a system.

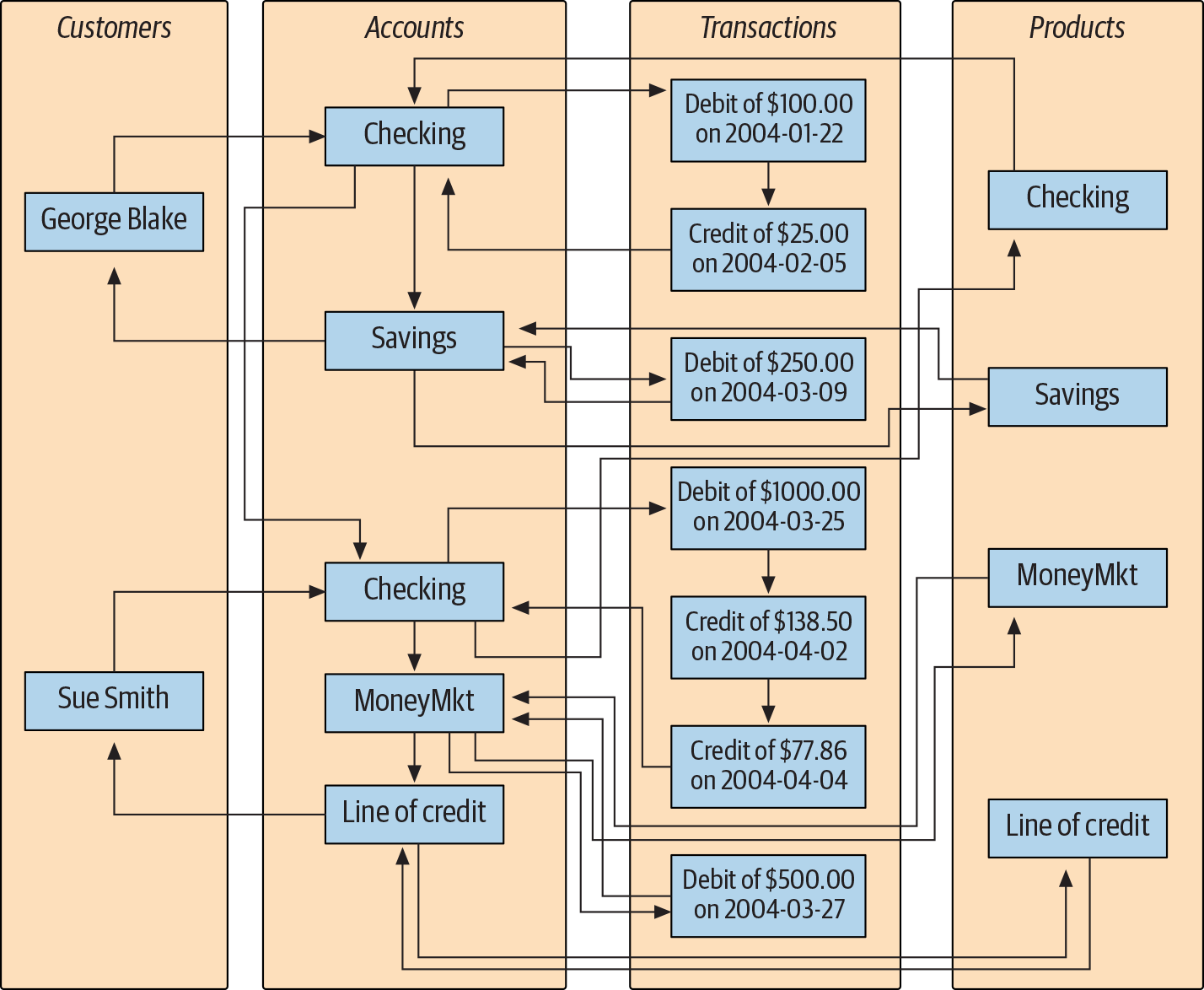


Figure 1-2. Network view of account data

In order to find the transactions posted to Sue’s money market account, you would need to perform the following steps:

Find the customer record for Sue Smith.

Follow the link from Sue Smith’s customer record to her list of accounts.

Traverse the chain of accounts until you find the money market account.

Follow the link from the money market record to its list of transactions.

One interesting feature of network database systems is demonstrated by the set of product records on the far right of [Figure 1-2](#Figure_1_2__Network_view_of_acco). Notice that each product record (Checking, Savings, etc.) points to a list of account records that are of that product type. Account records, therefore, can be accessed from multiple places (both customer records and product records), allowing a network database to act as a multiparent hierarchy.

Both hierarchical and network database systems are alive and well today, although generally in the mainframe world. Additionally, hierarchical database systems have enjoyed a rebirth in the directory services realm, such as Microsoft’s Active Directory and the open source Apache Directory Server. Beginning in the 1970s, however, a new way of representing data began to take root, one that was more rigorous yet easy to understand and implement.

## The Relational Model

In 1970, Dr. E. F. Codd of IBM’s research laboratory published a paper titled “A Relational Model of Data for Large Shared Data Banks” that proposed that data be represented as sets of tables. Rather than using pointers to navigate between related entities, redundant data is used to link records in different tables. [Figure 1-3](#Figure_1_3__Relational_view_of_a) shows how George’s and Sue’s account information would appear in this context.

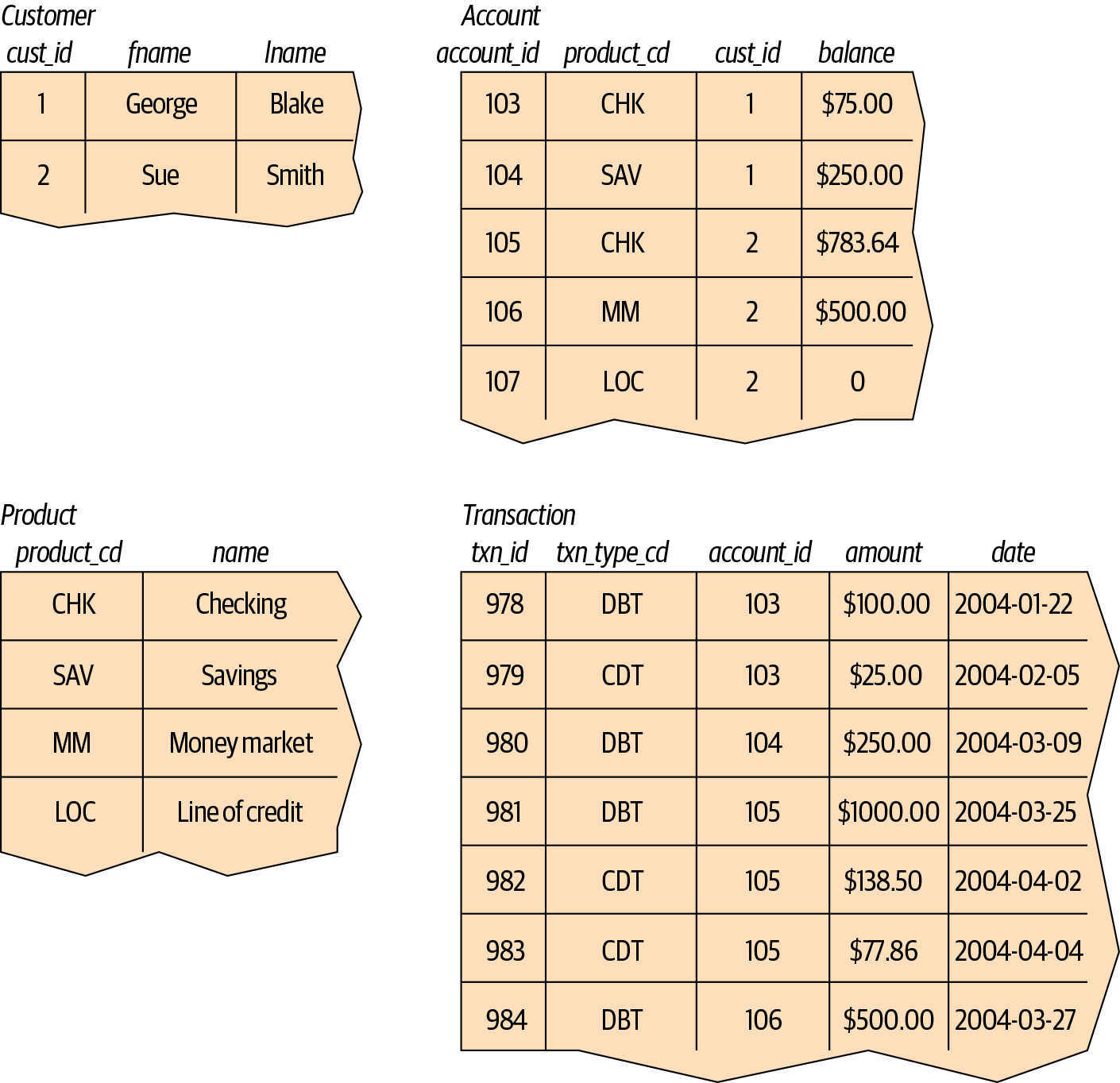


Figure 1-3. Relational view of account data

The four tables in [Figure 1-3](#Figure_1_3__Relational_view_of_a) represent the four entities discussed so far: customer, product, account, and transaction. Looking across the top of the customer table in [Figure 1-3](#Figure_1_3__Relational_view_of_a), you can see three columns: cust\_id (which contains the customer’s ID number), fname (which contains the customer’s first name), and lname (which contains the customer’s last name). Looking down the side of the customer table, you can see two rows, one containing George Blake’s data and the other containing Sue Smith’s data. The number of columns that a table may contain differs from server to server, but it is generally large enough not to be an issue (Microsoft SQL Server, for example, allows up to 1,024 columns per table). The number of rows that a table may contain is more a matter of physical limits (i.e., how much disk drive space is available) and maintainability (i.e., how large a table can get before it becomes difficult to work with) than of database server limitations.

Each table in a relational database includes information that uniquely identifies a row in that table (known as the primary key), along with additional information needed to describe the entity completely. Looking again at the customer table, the cust\_id column holds a different number for each customer; George Blake, for example, can be uniquely identified by customer ID 1. No other customer will ever be assigned that identifier, and no other information is needed to locate George Blake’s data in the customer table.

##### Note

Every database server provides a mechanism for generating unique sets of numbers to use as primary key values, so you won’t need to worry about keeping track of what numbers have been assigned.

While I might have chosen to use the combination of the fname and lname columns as the primary key (a primary key consisting of two or more columns is known as a compound key), there could easily be two or more people with the same first and last names who have accounts at the bank. Therefore, I chose to include the cust\_id column in the customer table specifically for use as a primary key column.

##### Note

In this example, choosing fname/lname as the primary key would be referred to as a natural key, whereas the choice of cust\_id would be referred to as a surrogate key. The decision whether to employ natural or surrogate keys is up to the database designer, but in this particular case the choice is clear, since a person’s last name may change (such as when a person adopts a spouse’s last name), and primary key columns should never be allowed to change once a value has been assigned.

Some of the tables also include information used to navigate to another table; this is where the “redundant data” mentioned earlier comes in. For example, the account table includes a column called cust\_id, which contains the unique identifier of the customer who opened the account, along with a column called product\_cd, which contains the unique identifier of the product to which the account will conform. These columns are known as foreign keys, and they serve the same purpose as the lines that connect the entities in the hierarchical and network versions of the account information. If you are looking at a particular account record and want to know more information about the customer who opened the account, you would take the value of the cust\_id column and use it to find the appropriate row in the customer table (this process is known, in relational database lingo, as a join; joins are introduced in [Chapter 3](#Chapter_3__Query_Primer__So_far_2) and probed deeply in Chapters [5](#Chapter_5__Querying_Multiple_Tab_2) and [10](#Chapter_10__Joins_Revisited__By_2)).

It might seem wasteful to store the same data many times, but the relational model is quite clear on what redundant data may be stored. For example, it is proper for the account table to include a column for the unique identifier of the customer who opened the account, but it is not proper to include the customer’s first and last names in the account table as well. If a customer were to change her name, for example, you want to make sure that there is only one place in the database that holds the customer’s name; otherwise, the data might be changed in one place but not another, causing the data in the database to be unreliable. The proper place for this data is the customer table, and only the cust\_id values should be included in other tables. It is also not proper for a single column to contain multiple pieces of information, such as a name column that contains both a person’s first and last names, or an address column that contains street, city, state, and zip code information. The process of refining a database design to ensure that each independent piece of information is in only one place (except for foreign keys) is known as normalization.

Getting back to the four tables in [Figure 1-3](#Figure_1_3__Relational_view_of_a), you may wonder how you would use these tables to find George Blake’s transactions against his checking account. First, you would find George Blake’s unique identifier in the customer table. Then, you would find the row in the account table whose cust\_id column contains George’s unique identifier and whose product\_cd column matches the row in the product table whose name column equals “Checking.” Finally, you would locate the rows in the transaction table whose account\_id column matches the unique identifier from the account table. This might sound complicated, but you can do it in a single command, using the SQL language, as you will see shortly.

## Some Terminology

I introduced some new terminology in the previous sections, so maybe it’s time for some formal definitions. [Table 1-1](#Table_1_1__Terms_and_definitions) shows the terms we use for the remainder of the book along with their definitions.

|  |  |
| --- | --- |
| Table 1-1. Terms and definitions  Term | Definition |

|  |  |
| --- | --- |
| Entity | Something of interest to the database user community. Examples include customers, parts, geographic locations, etc. |

|  |  |
| --- | --- |
| Column | An individual piece of data stored in a table. |

|  |  |
| --- | --- |
| Row | A set of columns that together completely describe an entity or some action on an entity. Also called a record. |

|  |  |
| --- | --- |
| Table | A set of rows, held either in memory (nonpersistent) or on permanent storage (persistent). |

|  |  |
| --- | --- |
| Result set | Another name for a nonpersistent table, generally the result of an SQL query. |

|  |  |
| --- | --- |
| Primary key | One or more columns that can be used as a unique identifier for each row in a table. |

|  |  |
| --- | --- |
| Foreign key | One or more columns that can be used together to identify a single row in another table. |

# What Is SQL?

Along with Codd’s definition of the relational model, he proposed a language called DSL/Alpha for manipulating the data in relational tables. Shortly after Codd’s paper was released, IBM commissioned a group to build a prototype based on Codd’s ideas. This group created a simplified version of DSL/Alpha that they called SQUARE. Refinements to SQUARE led to a language called SEQUEL, which was, finally, shortened to SQL. While SQL began as a language used to manipulate data in relational databases, it has evolved (as you will see toward the end of this book) to be a language for manipulating data across various database technologies.

SQL is now more than 40 years old, and it has undergone a great deal of change along the way. In the mid-1980s, the American National Standards Institute (ANSI) began working on the first standard for the SQL language, which was published in 1986. Subsequent refinements led to new releases of the SQL standard in 1989, 1992, 1999, 2003, 2006, 2008, 2011, and 2016. Along with refinements to the core language, new features have been added to the SQL language to incorporate object-oriented functionality, among other things. The later standards focus on the integration of related technologies, such as extensible markup language (XML) and JavaScript object notation (JSON).

SQL goes hand in hand with the relational model because the result of an SQL query is a table (also called, in this context, a result set). Thus, a new permanent table can be created in a relational database simply by storing the result set of a query. Similarly, a query can use both permanent tables and the result sets from other queries as inputs (we explore this in detail in [Chapter 9](#Chapter_9__Subqueries__Subquerie_2)).

One final note: SQL is not an acronym for anything (although many people will insist it stands for “Structured Query Language”). When referring to the language, it is equally acceptable to say the letters individually (i.e., S. Q. L.) or to use the word sequel.

## SQL Statement Classes

The SQL language is divided into several distinct parts: the parts that we explore in this book include SQL schema statements, which are used to define the data structures stored in the database; SQL data statements, which are used to manipulate the data structures previously defined using SQL schema statements; and SQL transaction statements, which are used to begin, end, and roll back transactions (concepts covered in [Chapter 12](#Chapter_12__Transactions__All_of_2)). For example, to create a new table in your database, you would use the SQL schema statement create table, whereas the process of populating your new table with data would require the SQL data statement insert.

To give you a taste of what these statements look like, here’s an SQL schema statement that creates a table called corporation:

CREATE TABLE corporation  
 (corp\_id SMALLINT,  
 name VARCHAR(30),  
 CONSTRAINT pk\_corporation PRIMARY KEY (corp\_id)  
 );

This statement creates a table with two columns, corp\_id and name, with the corp\_id column identified as the primary key for the table. We probe the finer details of this statement, such as the different data types available with MySQL, in [Chapter 2](#Chapter_2__Creating_and_Populati_2). Next, here’s an SQL data statement that inserts a row into the corporation table for Acme Paper Corporation:

INSERT INTO corporation (corp\_id, name)  
VALUES (27, 'Acme Paper Corporation');

This statement adds a row to the corporation table with a value of 27 for the corp\_id column and a value of Acme Paper Corporation for the name column.

Finally, here’s a simple select statement to retrieve the data that was just created:

mysql<   
SELECT name  
  
 ->   
FROM corporation  
  
 ->   
WHERE corp\_id = 27;  
  
+------------------------+  
| name |  
+------------------------+  
| Acme Paper Corporation |  
+------------------------+

All database elements created via SQL schema statements are stored in a special set of tables called the data dictionary. This “data about the database” is known collectively as metadata and is explored in [Chapter 15](#Chapter_15__Metadata__Along_with_2). Just like tables that you create yourself, data dictionary tables can be queried via a select statement, thereby allowing you to discover the current data structures deployed in the database at runtime. For example, if you are asked to write a report showing the new accounts created last month, you could either hardcode the names of the columns in the account table that were known to you when you wrote the report, or query the data dictionary to determine the current set of columns and dynamically generate the report each time it is executed.

Most of this book is concerned with the data portion of the SQL language, which consists of the select, update, insert, and delete commands. SQL schema statements are demonstrated in [Chapter 2](#Chapter_2__Creating_and_Populati_2), which will lead you through the design and creation of some simple tables. In general, SQL schema statements do not require much discussion apart from their syntax, whereas SQL data statements, while few in number, offer numerous opportunities for detailed study. Therefore, while I try to introduce you to many of the SQL schema statements, most chapters in this book concentrate on the SQL data statements.

## SQL: A Nonprocedural Language

If you have worked with programming languages in the past, you are used to defining variables and data structures, using conditional logic (i.e., if-then-else) and looping constructs (i.e., do while ... end), and breaking your code into small, reusable pieces (i.e., objects, functions, procedures). Your code is handed to a compiler, and the executable that results does exactly (well, not always exactly) what you programmed it to do. Whether you work with Java, Python, Scala, or some other procedural language, you are in complete control of what the program does.

##### Note

A procedural language defines both the desired results and the mechanism, or process, by which the results are generated. Nonprocedural languages also define the desired results, but the process by which the results are generated is left to an external agent.

With SQL, however, you will need to give up some of the control you are used to, because SQL statements define the necessary inputs and outputs, but the manner in which a statement is executed is left to a component of your database engine known as the optimizer. The optimizer’s job is to look at your SQL statements and, taking into account how your tables are configured and what indexes are available, decide the most efficient execution path (well, not always the most efficient). Most database engines will allow you to influence the optimizer’s decisions by specifying optimizer hints, such as suggesting that a particular index be used; most SQL users, however, will never get to this level of sophistication and will leave such tweaking to their database administrator or performance expert.

Therefore, with SQL, you will not be able to write complete applications. Unless you are writing a simple script to manipulate certain data, you will need to integrate SQL with your favorite programming language. Some database vendors have done this for you, such as Oracle’s PL/SQL language, MySQL’s stored procedure language, and Microsoft’s Transact-SQL language. With these languages, the SQL data statements are part of the language’s grammar, allowing you to seamlessly integrate database queries with procedural commands. If you are using a non-database-specific language such as Java or Python, however, you will need to use a toolkit/API to execute SQL statements from your code. Some of these toolkits are provided by your database vendor, whereas others have been created by third-party vendors or by open source providers. [Table 1-2](#Table_1_2__SQL_integration_toolk) shows some of the available options for integrating SQL into a specific language.

|  |  |
| --- | --- |
| Table 1-2. SQL integration toolkits  Language | Toolkit |

|  |  |
| --- | --- |
| Java | JDBC (Java Database Connectivity) |

|  |  |
| --- | --- |
| C# | ADO.NET (Microsoft) |

|  |  |
| --- | --- |
| Ruby | Ruby DBI |

|  |  |
| --- | --- |
| Python | Python DB |

|  |  |
| --- | --- |
| Go | Package database/sql |

If you only need to execute SQL commands interactively, every database vendor provides at least a simple command-line tool for submitting SQL commands to the database engine and inspecting the results. Most vendors provide a graphical tool as well that includes one window showing your SQL commands and another window showing the results from your SQL commands. Additionally, there are third-party tools such as SQuirrel, which will connect via a JDBC connection to many different database servers. Since the examples in this book are executed against a MySQL database, I use the mysql command-line tool that is included as part of the MySQL installation to run the examples and format the results.

## SQL Examples

Earlier in this chapter, I promised to show you an SQL statement that would return all the transactions against George Blake’s checking account. Without further ado, here it is:

SELECT t.txn\_id, t.txn\_type\_cd, t.txn\_date, t.amount  
FROM individual i  
 INNER JOIN account a ON i.cust\_id = a.cust\_id  
 INNER JOIN product p ON p.product\_cd = a.product\_cd  
 INNER JOIN transaction t ON t.account\_id = a.account\_id  
WHERE i.fname = 'George' AND i.lname = 'Blake'  
 AND p.name = 'checking account';  
  
+--------+-------------+---------------------+--------+  
| txn\_id | txn\_type\_cd | txn\_date | amount |  
+--------+-------------+---------------------+--------+  
| 11 | DBT | 2008-01-05 00:00:00 | 100.00 |  
+--------+-------------+---------------------+--------+  
1 row in set (0.00 sec)

Without going into too much detail at this point, this query identifies the row in the individual table for George Blake and the row in the product table for the “checking” product, finds the row in the account table for this individual/product combination, and returns four columns from the transaction table for all transactions posted to this account. If you happen to know that George Blake’s customer ID is 8 and that checking accounts are designated by the code 'CHK', then you can simply find George Blake’s checking account in the account table based on the customer ID and use the account ID to find the appropriate transactions:

SELECT t.txn\_id, t.txn\_type\_cd, t.txn\_date, t.amount  
FROM account a  
 INNER JOIN transaction t ON t.account\_id = a.account\_id  
WHERE a.cust\_id = 8 AND a.product\_cd = 'CHK';

I cover all of the concepts in these queries (plus a lot more) in the following chapters, but I wanted to at least show what they would look like.

The previous queries contain three different clauses: select, from, and where. Almost every query that you encounter will include at least these three clauses, although there are several more that can be used for more specialized purposes. The role of each of these three clauses is demonstrated by the following:

SELECT /\* one or more things \*/ ...  
FROM /\* one or more places \*/ ...  
WHERE /\* one or more conditions apply \*/ ...

##### Note

Most SQL implementations treat any text between the /\* and \*/ tags as comments.

When constructing your query, your first task is generally to determine which table or tables will be needed and then add them to your from clause. Next, you will need to add conditions to your where clause to filter out the data from these tables that you aren’t interested in. Finally, you will decide which columns from the different tables need to be retrieved and add them to your select clause. Here’s a simple example that shows how you would find all customers with the last name “Smith”:

SELECT cust\_id, fname  
FROM individual  
WHERE lname = 'Smith';

This query searches the individual table for all rows whose lname column matches the string 'Smith' and returns the cust\_id and fname columns from those rows.

Along with querying your database, you will most likely be involved with populating and modifying the data in your database. Here’s a simple example of how you would insert a new row into the product table:

INSERT INTO product (product\_cd, name)  
VALUES ('CD', 'Certificate of Depysit')

Whoops, looks like you misspelled “Deposit.” No problem. You can clean that up with an update statement:

UPDATE product  
SET name = 'Certificate of Deposit'  
WHERE product\_cd = 'CD';

Notice that the update statement also contains a where clause, just like the select statement. This is because an update statement must identify the rows to be modified; in this case, you are specifying that only those rows whose product\_cd column matches the string 'CD' should be modified. Since the product\_cd column is the primary key for the product table, you should expect your update statement to modify exactly one row (or zero, if the value doesn’t exist in the table). Whenever you execute an SQL data statement, you will receive feedback from the database engine as to how many rows were affected by your statement. If you are using an interactive tool such as the mysql command-line tool mentioned earlier, then you will receive feedback concerning how many rows were either:

* Returned by your select statement
* Created by your insert statement
* Modified by your update statement
* Removed by your delete statement

If you are using a procedural language with one of the toolkits mentioned earlier, the toolkit will include a call to ask for this information after your SQL data statement has executed. In general, it’s a good idea to check this info to make sure your statement didn’t do something unexpected (like when you forget to put a where clause on your delete statement and delete every row in the table!).

# What Is MySQL?

Relational databases have been available commercially for more than three decades. Some of the most mature and popular commercial products include:

* Oracle Database from Oracle Corporation
* SQL Server from Microsoft
* DB2 Universal Database from IBM

All these database servers do approximately the same thing, although some are better equipped to run very large or very high throughput databases. Others are better at handling objects or very large files or XML documents, and so on. Additionally, all these servers do a pretty good job of complying with the latest ANSI SQL standard. This is a good thing, and I make it a point to show you how to write SQL statements that will run on any of these platforms with little or no modification.

Along with the commercial database servers, there has been quite a bit of activity in the open source community in the past two decades with the goal of creating a viable alternative. Two of the most commonly used open source database servers are PostgreSQL and MySQL. The MySQL server is available for free, and I have found it to be extremely simple to download and install. For these reasons, I have decided that all examples for this book be run against a MySQL (version 8.0) database, and that the mysql command-line tool be used to format query results. Even if you are already using another server and never plan to use MySQL, I urge you to install the latest MySQL server, load the sample schema and data, and experiment with the data and examples in this book.

However, keep in mind the following caveat:

This is not a book about MySQL’s SQL implementation.

Rather, this book is designed to teach you how to craft SQL statements that will run on MySQL with no modifications, and will run on recent releases of Oracle Database, DB2, and SQL Server with few or no modifications.

# SQL Unplugged

A great deal has happened in the database world during the decade between the second and third editions of this book. While relational databases are still heavily used and will continue to be for some time, new database technologies have emerged to meet the needs of companies like Amazon and Google. These technologies include Hadoop, Spark, NoSQL, and NewSQL, which are distributed, scalable systems typically deployed on clusters of commodity servers. While it is beyond the scope of this book to explore these technologies in detail, they do all share something in common with relational databases: SQL.

Since organizations frequently store data using multiple technologies, there is a need to unplug SQL from a particular database server and provide a service that can span multiple databases. For example, a report may need to bring together data stored in Oracle, Hadoop, JSON files, CSV files, and Unix log files. A new generation of tools have been built to meet this type of challenge, and one of the most promising is Apache Drill, which is an open source query engine that allows users to write queries that can access data stored in most any database or filesystem. We will explore Apache Drill in [Chapter 18](#Chapter_18__SQL_and_Big_Data__Wh_2).

# What’s in Store

The overall goal of the next four chapters is to introduce the SQL data statements, with a special emphasis on the three main clauses of the select statement. Additionally, you will see many examples that use the Sakila schema (introduced in the next chapter), which will be used for all examples in the book. It is my hope that familiarity with a single database will allow you to get to the crux of an example without having to stop and examine the tables being used each time. If it becomes a bit tedious working with the same set of tables, feel free to augment the sample database with additional tables or to invent your own database with which to experiment.

After you have a solid grasp on the basics, the remaining chapters will drill deep into additional concepts, most of which are independent of each other. Thus, if you find yourself getting confused, you can always move ahead and come back later to revisit a chapter. When you have finished the book and worked through all of the examples, you will be well on your way to becoming a seasoned SQL practitioner.

For readers interested in learning more about relational databases, the history of computerized database systems, or the SQL language than was covered in this short introduction, here are a few resources worth checking out:

* [Database in Depth: Relational Theory for Practitioners](http://oreilly.com/catalog/9780596100124/) by C. J. Date (O’Reilly)
* An Introduction to Database Systems, Eighth Edition, by C. J. Date (Addison-Wesley)
* The Database Relational Model: A Retrospective Review and Analysis, by C. J. Date (Addison-Wesley)
* [Wikipedia subarticle on definition of “Database Management System”](https://oreil.ly/sj2xR)

# Chapter 2. Creating and Populating a Database

This chapter provides you with the information you need to create your first database and to create the tables and associated data used for the examples in this book. You will also learn about various data types and see how to create tables using them. Because the examples in this book are executed against a MySQL database, this chapter is somewhat skewed toward MySQL’s features and syntax, but most concepts are applicable to any server.

# Creating a MySQL Database

If you want the ability to experiment with the data used for the examples in this book, you have two options:

* Download and install the MySQL server version 8.0 (or later) and load the Sakila example database from <https://dev.mysql.com/doc/index-other.html>.
* Go to <https://learning.oreilly.com/scenarios/mysql-sandbox/9781492079705> to access the MySQL Sandbox, which has the Sakila Sample database loaded in a MySQL instance. If you don’t have one already, you’ll have to set up an O’Reilly account. Then, click on the Start button and begin.

If you choose the second option, once you start the scenario, a MySQL server is installed and started, and then the Sakila schema and data are loaded. When it’s ready, a standard mysql> prompt appears, and you can then start querying the sample database. This is certainly the easiest option, and I anticipate that most readers will choose this option; if this sounds good to you, feel free to skip ahead to the next section.

If you prefer to have your own copy of the data and want any changes you have made to be permanent, or if you are just interested in installing the MySQL server on your own machine, you may prefer the first option. You may also opt to use a MySQL server hosted in an environment such as Amazon Web Services or Google Cloud. In either case, you will need to perform the installation/configuration yourself, as it is beyond the scope of this book. Once your database is available, you will need to follow a few steps to load the Sakila sample database.

First, you will need to launch the mysql command-line client and provide a password, and then perform the following steps:

Go to <https://dev.mysql.com/doc/index-other.html> and download the files for “sakila database” under the Example Databases section.

Put the files in a local directory such as C:\temp\sakila-db (used for the next two steps, but overwrite with your directory path).

Type source c:\temp\sakila-db\sakila-schema.sql and press Enter.

Type source c:\temp\sakila-db\sakila-data.sql and press Enter.

You should now have a working database populated with all the data needed for the examples in this book.

##### Note

The Sakila sample database is made available by MySQL and is licensed via the New BSD license. Sakila contains data for a fictitious movie rental company, and includes tables such as store, inventory, film, customer, and payment. While actual movie rental stores are largely a thing of the past, with a little imagination we could rebrand it as a movie-streaming company by ignoring the staff and address tables and renaming store to streaming\_service. However, the examples in this book will stick to the original script (pun intended).

# Using the mysql Command-Line Tool

Unless you are using a temporary database session (the second option in the previous section), you will need to start the mysql command-line tool in order to interact with the database. To do so, you will need to open a Windows or Unix shell and execute the mysql utility. For example, if you are logging in using the root account, you would do the following:

mysql -u root -p;

You will then be asked for your password, after which you will see the mysql> prompt. To see all of the available databases, you can use the following command:

mysql> show databases;  
+--------------------+  
| Database           |  
+--------------------+  
| information\_schema |  
| mysql              |  
| performance\_schema |  
| sakila             |  
| sys                |  
+--------------------+  
5 rows in set (0.01 sec)

Since you will be using the Sakila database, you will need to specify the database you want to work with via the use command:

mysql> use sakila;  
Database changed

Whenever you invoke the mysql command-line tool, you can specify both the username and database to use, as in the following:

mysql -u root -p sakila;

This will save you from having to type use sakila; every time you start up the tool. Now that you have established a session and specified the database, you will be able to issue SQL statements and view the results. For example, if you want to know the current date and time, you could issue the following query:

mysql>   
SELECT now();  
  
+---------------------+  
| now() |  
+---------------------+  
| 2019-04-04 20:44:26 |  
+---------------------+  
1 row in set (0.01 sec)

The now() function is a built-in MySQL function that returns the current date and time. As you can see, the mysql command-line tool formats the results of your queries within a rectangle bounded by +, -, and | characters. After the results have been exhausted (in this case, there is only a single row of results), the mysql command-line tool shows how many rows were returned, along with how long the SQL statement took to execute.

#### About Missing from Clauses

With some database servers, you won’t be able to issue a query without a from clause that names at least one table. Oracle Database is a commonly used server for which this is true. For cases when you only need to call a function, Oracle provides a table called dual, which consists of a single column called dummy that contains a single row of data. In order to be compatible with Oracle Database, MySQL also provides a dual table. The previous query to determine the current date and time could therefore be written as:

mysql>   
SELECT now()  
  
   
FROM dual;  
  
+---------------------+  
| now() |  
+---------------------+  
| 2019-04-04 20:44:26 |  
+---------------------+  
1 row in set (0.01 sec)

If you are not using Oracle and have no need to be compatible with Oracle, you can ignore the dual table altogether and use just a select clause without a from clause.

When you are done with the mysql command-line tool, simply type quit; or exit; to return to the Unix or Windows command shell.

# MySQL Data Types

In general, all the popular database servers have the capacity to store the same types of data, such as strings, dates, and numbers. Where they typically differ is in the specialty data types, such as XML and JSON documents or spatial data. Since this is an introductory book on SQL and since 98% of the columns you encounter will be simple data types, this chapter covers only the character, date (a.k.a. temporal), and numeric data types. The use of SQL to query JSON documents will be explored in [Chapter 18](#Chapter_18__SQL_and_Big_Data__Wh_2).

## Character Data

Character data can be stored as either fixed-length or variable-length strings; the difference is that fixed-length strings are right-padded with spaces and always consume the same number of bytes, and variable-length strings are not right-padded with spaces and don’t always consume the same number of bytes. When defining a character column, you must specify the maximum size of any string to be stored in the column. For example, if you want to store strings up to 20 characters in length, you could use either of the following definitions:

char(20) /\* fixed-length \*/  
varchar(20) /\* variable-length \*/

The maximum length for char columns is currently 255 bytes, whereas varchar columns can be up to 65,535 bytes. If you need to store longer strings (such as emails, XML documents, etc.), then you will want to use one of the text types (mediumtext and longtext), which I cover later in this section. In general, you should use the char type when all strings to be stored in the column are of the same length, such as state abbreviations, and the varchar type when strings to be stored in the column are of varying lengths. Both char and varchar are used in a similar fashion in all the major database servers.

##### Note

An exception is made in the use of varchar for Oracle Database. Oracle users should use the varchar2 type when defining variable-length character columns.

## Character sets

For languages that use the Latin alphabet, such as English, there is a sufficiently small number of characters such that only a single byte is needed to store each character. Other languages, such as Japanese and Korean, contain large numbers of characters, thus requiring multiple bytes of storage for each character. Such character sets are therefore called multibyte character sets.

MySQL can store data using various character sets, both single- and multibyte. To view the supported character sets in your server, you can use the show command, as shown in the following example:

mysql>   
SHOW CHARACTER SET;  
  
+----------+---------------------------------+---------------------+--------+  
| Charset  | Description                     | Default collation   | Maxlen |  
+----------+---------------------------------+---------------------+--------+  
| armscii8 | ARMSCII-8 Armenian              | armscii8\_general\_ci |      1 |  
| ascii    | US ASCII                        | ascii\_general\_ci    |      1 |  
| big5     | Big5 Traditional Chinese        | big5\_chinese\_ci     |      2 |  
| binary   | Binary pseudo charset           | binary              |      1 |  
| cp1250   | Windows Central European        | cp1250\_general\_ci   |      1 |  
| cp1251   | Windows Cyrillic                | cp1251\_general\_ci   |      1 |  
| cp1256   | Windows Arabic                  | cp1256\_general\_ci   |      1 |  
| cp1257   | Windows Baltic                  | cp1257\_general\_ci   |      1 |  
| cp850    | DOS West European               | cp850\_general\_ci    |      1 |  
| cp852    | DOS Central European            | cp852\_general\_ci    |      1 |  
| cp866    | DOS Russian                     | cp866\_general\_ci    |      1 |  
| cp932    | SJIS for Windows Japanese       | cp932\_japanese\_ci   |      2 |  
| dec8     | DEC West European               | dec8\_swedish\_ci     |      1 |  
| eucjpms  | UJIS for Windows Japanese       | eucjpms\_japanese\_ci |      3 |  
| euckr    | EUC-KR Korean                   | euckr\_korean\_ci     |      2 |  
| gb18030  | China National Standard GB18030 | gb18030\_chinese\_ci  |      4 |  
| gb2312   | GB2312 Simplified Chinese       | gb2312\_chinese\_ci   |      2 |  
| gbk      | GBK Simplified Chinese          | gbk\_chinese\_ci      |      2 |  
| geostd8  | GEOSTD8 Georgian                | geostd8\_general\_ci  |      1 |  
| greek    | ISO 8859-7 Greek                | greek\_general\_ci    |      1 |  
| hebrew   | ISO 8859-8 Hebrew               | hebrew\_general\_ci   |      1 |  
| hp8      | HP West European                | hp8\_english\_ci      |      1 |  
| keybcs2  | DOS Kamenicky Czech-Slovak      | keybcs2\_general\_ci  |      1 |  
| koi8r    | KOI8-R Relcom Russian           | koi8r\_general\_ci    |      1 |  
| koi8u    | KOI8-U Ukrainian                | koi8u\_general\_ci    |      1 |  
| latin1   | cp1252 West European            | latin1\_swedish\_ci   |      1 |  
| latin2   | ISO 8859-2 Central European     | latin2\_general\_ci   |      1 |  
| latin5   | ISO 8859-9 Turkish              | latin5\_turkish\_ci   |      1 |  
| latin7   | ISO 8859-13 Baltic              | latin7\_general\_ci   |      1 |  
| macce    | Mac Central European            | macce\_general\_ci    |      1 |  
| macroman | Mac West European               | macroman\_general\_ci |      1 |  
| sjis     | Shift-JIS Japanese              | sjis\_japanese\_ci    |      2 |  
| swe7     | 7bit Swedish                    | swe7\_swedish\_ci     |      1 |  
| tis620   | TIS620 Thai                     | tis620\_thai\_ci      |      1 |  
| ucs2     | UCS-2 Unicode                   | ucs2\_general\_ci     |      2 |  
| ujis     | EUC-JP Japanese                 | ujis\_japanese\_ci    |      3 |  
| 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 |  
+----------+---------------------------------+---------------------+--------+  
41 rows in set (0.04 sec)

If the value in the fourth column, maxlen, is greater than 1, then the character set is a multibyte character set.

In prior versions of the MySQL server, the latin1 character set was automatically chosen as the default character set, but version 8 defaults to utf8mb4. However, you may choose to use a different character set for each character column in your database, and you can even store different character sets within the same table. To choose a character set other than the default when defining a column, simply name one of the supported character sets after the type definition, as in:

varchar(20) character set latin1

With MySQL, you may also set the default character set for your entire database:

create database european\_sales character set latin1;

While this is as much information regarding character sets as is appropriate for an introductory book, there is a great deal more to the topic of internationalization than what is shown here. If you plan to deal with multiple or unfamiliar character sets, you may want to pick up a book such as Jukka Korpela’s Unicode Explained: Internationalize Documents, Programs, and Web Sites (O’Reilly).

## Text data

If you need to store data that might exceed the 64 KB limit for varchar columns, you will need to use one of the text types.

[Table 2-1](#Table_2_1__MySQL_text_types) shows the available text types and their maximum sizes.

|  |  |
| --- | --- |
| Table 2-1. MySQL text types  Text type | Maximum number of bytes |

|  |  |
| --- | --- |
| tinytext | 255 |

|  |  |
| --- | --- |
| text | 65,535 |

|  |  |
| --- | --- |
| mediumtext | 16,777,215 |

|  |  |
| --- | --- |
| longtext | 4,294,967,295 |

When choosing to use one of the text types, you should be aware of the following:

* If the data being loaded into a text column exceeds the maximum size for that type, the data will be truncated.
* Trailing spaces will not be removed when data is loaded into the column.
* When using text columns for sorting or grouping, only the first 1,024 bytes are used, although this limit may be increased if necessary.
* The different text types are unique to MySQL. SQL Server has a single text type for large character data, whereas DB2 and Oracle use a data type called clob, for Character Large Object.
* Now that MySQL allows up to 65,535 bytes for varchar columns (it was limited to 255 bytes in version 4), there isn’t any particular need to use the tinytext or text type.

If you are creating a column for free-form data entry, such as a notes column to hold data about customer interactions with your company’s customer service department, then varchar will probably be adequate. If you are storing documents, however, you should choose either the mediumtext or longtext type.

##### Note

Oracle Database allows up to 2,000 bytes for char columns and 4,000 bytes for varchar2 columns. For larger documents you may use the clob type. SQL Server can handle up to 8,000 bytes for both char and varchar data, but you can store up to 2 GB of data in a column defined as varchar(max).

## Numeric Data

Although it might seem reasonable to have a single numeric data type called “numeric,” there are actually several different numeric data types that reflect the various ways in which numbers are used, as illustrated here:

A column indicating whether a customer order has been shipped

This type of column, referred to as a Boolean, would contain a 0 to indicate false and a 1 to indicate true.

A system-generated primary key for a transaction table

This data would generally start at 1 and increase in increments of one up to a potentially very large number.

An item number for a customer’s electronic shopping basket

The values for this type of column would be positive whole numbers between 1 and, perhaps, 200 (for shopaholics).

Positional data for a circuit board drill machine

High-precision scientific or manufacturing data often requires accuracy to eight decimal points.

To handle these types of data (and more), MySQL has several different numeric data types. The most commonly used numeric types are those used to store whole numbers, or integers. When specifying one of these types, you may also specify that the data is unsigned, which tells the server that all data stored in the column will be greater than or equal to zero. [Table 2-2](#Table_2_2__MySQL_integer_types) shows the five different data types used to store whole-number integers.

|  |  |  |
| --- | --- | --- |
| Table 2-2. MySQL integer types  Type | Signed range | Unsigned range |

|  |  |  |
| --- | --- | --- |
| tinyint | −128 to 127 | 0 to 255 |

|  |  |  |
| --- | --- | --- |
| smallint | −32,768 to 32,767 | 0 to 65,535 |

|  |  |  |
| --- | --- | --- |
| mediumint | −8,388,608 to 8,388,607 | 0 to 16,777,215 |

|  |  |  |
| --- | --- | --- |
| int | −2,147,483,648 to 2,147,483,647 | 0 to 4,294,967,295 |

|  |  |  |
| --- | --- | --- |
| bigint | −2^63 to 2^63 - 1 | 0 to 2^64 - 1 |

When you create a column using one of the integer types, MySQL will allocate an appropriate amount of space to store the data, which ranges from one byte for a tinyint to eight bytes for a bigint. Therefore, you should try to choose a type that will be large enough to hold the biggest number you can envision being stored in the column without needlessly wasting storage space.

For floating-point numbers (such as 3.1415927), you may choose from the numeric types shown in [Table 2-3](#Table_2_3__MySQL_floating_point).

|  |  |
| --- | --- |
| Table 2-3. MySQL floating-point types  Type | Numeric range |

|  |  |
| --- | --- |
| float( p , s ) | −3.402823466E+38 to −1.175494351E-38  and 1.175494351E-38 to 3.402823466E+38 |

|  |  |
| --- | --- |
| double( p , s ) | −1.7976931348623157E+308 to −2.2250738585072014E-308  and 2.2250738585072014E-308 to 1.7976931348623157E+308 |

When using a floating-point type, you can specify a precision (the total number of allowable digits both to the left and to the right of the decimal point) and a scale (the number of allowable digits to the right of the decimal point), but they are not required. These values are represented in [Table 2-3](#Table_2_3__MySQL_floating_point) as p and s. If you specify a precision and scale for your floating-point column, remember that the data stored in the column will be rounded if the number of digits exceeds the scale and/or precision of the column. For example, a column defined as float(4,2) will store a total of four digits, two to the left of the decimal and two to the right of the decimal. Therefore, such a column would handle the numbers 27.44 and 8.19 just fine, but the number 17.8675 would be rounded to 17.87, and attempting to store the number 178.375 in your float(4,2) column would generate an error.

Like the integer types, floating-point columns can be defined as unsigned, but this designation only prevents negative numbers from being stored in the column rather than altering the range of data that may be stored in the column.

## Temporal Data

Along with strings and numbers, you will almost certainly be working with information about dates and/or times. This type of data is referred to as temporal, and some examples of temporal data in a database include:

* The future date that a particular event is expected to happen, such as shipping a customer’s order
* The date that a customer’s order was shipped
* The date and time that a user modified a particular row in a table
* An employee’s birth date
* The year corresponding to a row in a yearly\_sales fact table in a data warehouse
* The elapsed time needed to complete a wiring harness on an automobile assembly line

MySQL includes data types to handle all of these situations. [Table 2-4](#Table_2_4__MySQL_temporal_types) shows the temporal data types supported by MySQL.

|  |  |  |
| --- | --- | --- |
| Table 2-4. MySQL temporal types  Type | Default format | Allowable values |

|  |  |  |
| --- | --- | --- |
| date | YYYY-MM-DD | 1000-01-01 to 9999-12-31 |

|  |  |  |
| --- | --- | --- |
| datetime | YYYY-MM-DD HH:MI:SS | 1000-01-01 00:00:00.000000  to 9999-12-31 23:59:59.999999 |

|  |  |  |
| --- | --- | --- |
| timestamp | YYYY-MM-DD HH:MI:SS | 1970-01-01 00:00:00.000000  to 2038-01-18 22:14:07.999999 |

|  |  |  |
| --- | --- | --- |
| year | YYYY | 1901 to 2155 |

|  |  |  |
| --- | --- | --- |
| time | HHH:MI:SS | −838:59:59.000000  to 838:59:59.000000 |

While database servers store temporal data in various ways, the purpose of a format string (second column of [Table 2-4](#Table_2_4__MySQL_temporal_types)) is to show how the data will be represented when retrieved, along with how a date string should be constructed when inserting or updating a temporal column. Thus, if you wanted to insert the date March 23, 2020, into a date column using the default format YYYY-MM-DD, you would use the string '2020-03-23'. [Chapter 7](#Chapter_7__Data_Generation__Mani_2) fully explores how temporal data is constructed and displayed.

The datetime, timestamp, and time types also allow fractional seconds of up to 6 decimal places (microseconds). When defining columns using one of these data types, you may supply a value from 0 to 6; for example, specifying datetime(2) would allow your time values to include hundredths of a second.

##### Note

Each database server allows a different range of dates for temporal columns. Oracle Database accepts dates ranging from 4712 BC to 9999 AD, while SQL Server only handles dates ranging from 1753 AD to 9999 AD (unless you are using SQL Server 2008’s datetime2 data type, which allows for dates ranging from 1 AD to 9999 AD). MySQL falls in between Oracle and SQL Server and can store dates from 1000 AD to 9999 AD. Although this might not make any difference for most systems that track current and future events, it is important to keep in mind if you are storing historical dates.

[Table 2-5](#Table_2_5__Date_format_component) describes the various components of the date formats shown in [Table 2-4](#Table_2_4__MySQL_temporal_types).

|  |  |  |
| --- | --- | --- |
| Table 2-5. Date format components  Component | Definition | Range |

|  |  |  |
| --- | --- | --- |
| YYYY | Year, including century | 1000 to 9999 |

|  |  |  |
| --- | --- | --- |
| MM | Month | 01 (January) to 12 (December) |

|  |  |  |
| --- | --- | --- |
| DD | Day | 01 to 31 |

|  |  |  |
| --- | --- | --- |
| HH | Hour | 00 to 23 |

|  |  |  |
| --- | --- | --- |
| HHH | Hours (elapsed) | −838 to 838 |

|  |  |  |
| --- | --- | --- |
| MI | Minute | 00 to 59 |

|  |  |  |
| --- | --- | --- |
| SS | Second | 00 to 59 |

Here’s how the various temporal types would be used to implement the examples shown earlier:

* Columns to hold the expected future shipping date of a customer order and an employee’s birth date would use the date type, since it is unrealistic to schedule a future shipment down to the second and unnecessary to know at what time a person was born.
* A column to hold information about when a customer order was actually shipped would use the datetime type, since it is important to track not only the date that the shipment occurred but the time as well.
* A column that tracks when a user last modified a particular row in a table would use the timestamp type. The timestamp type holds the same information as the datetime type (year, month, day, hour, minute, second), but a timestamp column will automatically be populated with the current date/time by the MySQL server when a row is added to a table or when a row is later modified.
* A column holding just year data would use the year type.
* Columns that hold data regarding the length of time needed to complete a task would use the time type. For this type of data, it would be unnecessary and confusing to store a date component, since you are interested only in the number of hours/minutes/seconds needed to complete the task. This information could be derived using two datetime columns (one for the task start date/time and the other for the task completion date/time) and subtracting one from the other, but it is simpler to use a single time column.

[Chapter 7](#Chapter_7__Data_Generation__Mani_2) explores how to work with each of these temporal data types.

# Table Creation

Now that you have a firm grasp on what data types may be stored in a MySQL database, it’s time to see how to use these types in table definitions. Let’s start by defining a table to hold information about a person.

## Step 1: Design

A good way to start designing a table is to do a bit of brainstorming to see what kind of information would be helpful to include. Here’s what I came up with after thinking for a short time about the types of information that describe a person:

* Name
* Eye color
* Birth date
* Address
* Favorite foods

This is certainly not an exhaustive list, but it’s good enough for now. The next step is to assign column names and data types. [Table 2-6](#Table_2_6__Person_table__first_p) shows my initial attempt.

|  |  |  |
| --- | --- | --- |
| Table 2-6. Person table, first pass  Column | Type | Allowable values |

|  |  |  |
| --- | --- | --- |
| name | varchar(40) |  |

|  |  |  |
| --- | --- | --- |
| eye\_color | char(2) | BL, BR, GR |

|  |  |  |
| --- | --- | --- |
| birth\_date | date |  |

|  |  |  |
| --- | --- | --- |
| address | varchar(100) |  |

|  |  |  |
| --- | --- | --- |
| favorite\_foods | varchar(200) |  |

The name, address, and favorite\_foods columns are of type varchar and allow for free-form data entry. The eye\_color column allows two characters that should equal only BR, BL, or GR. The birth\_date column is of type date, since a time component is not needed.

## Step 2: Refinement

In [Chapter 1](#Chapter_1__A_Little_Background_2), you were introduced to the concept of normalization, which is the process of ensuring that there are no duplicate (other than foreign keys) or compound columns in your database design. In looking at the columns in the person table a second time, the following issues arise:

* The name column is actually a compound object consisting of a first name and a last name.
* Since multiple people can have the same name, eye color, birth date, and so forth, there are no columns in the person table that guarantee uniqueness.
* The address column is also a compound object consisting of street, city, state/province, country, and postal code.
* The favorite\_foods column is a list containing zero, one, or more independent items. It would be best to create a separate table for this data that includes a foreign key to the person table so that you know to which person a particular food may be attributed.

After taking these issues into consideration, [Table 2-7](#Table_2_7__Person_table__second) gives a normalized version of the person table.

|  |  |  |
| --- | --- | --- |
| Table 2-7. Person table, second pass  Column | Type | Allowable values |

|  |  |  |
| --- | --- | --- |
| person\_id | smallint (unsigned) |  |

|  |  |  |
| --- | --- | --- |
| first\_name | varchar(20) |  |

|  |  |  |
| --- | --- | --- |
| last\_name | varchar(20) |  |

|  |  |  |
| --- | --- | --- |
| eye\_color | char(2) | BR, BL, GR |

|  |  |  |
| --- | --- | --- |
| birth\_date | date |  |

|  |  |  |
| --- | --- | --- |
| street | varchar(30) |  |

|  |  |  |
| --- | --- | --- |
| city | varchar(20) |  |

|  |  |  |
| --- | --- | --- |
| state | varchar(20) |  |

|  |  |  |
| --- | --- | --- |
| country | varchar(20) |  |

|  |  |  |
| --- | --- | --- |
| postal\_code | varchar(20) |  |

Now that the person table has a primary key (person\_id) to guarantee uniqueness, the next step is to build a favorite\_food table that includes a foreign key to the person table. [Table 2-8](#Table_2_8__favorite_food_table) shows the result.

|  |  |
| --- | --- |
| Table 2-8. favorite\_food table  Column | Type |

|  |  |
| --- | --- |
| person\_id | smallint (unsigned) |

|  |  |
| --- | --- |
| food | varchar(20) |

The person\_id and food columns comprise the primary key of the favorite\_food table, and the person\_id column is also a foreign key to the person table.

#### How Much Is Enough?

Moving the favorite\_foods column out of the person table was definitely a good idea, but are we done yet? What happens, for example, if one person lists “pasta” as a favorite food while another person lists “spaghetti”? Are they the same thing? In order to prevent this problem, you might decide that you want people to choose their favorite foods from a list of options, in which case you should create a food table with food\_id and food\_name columns and then change the favorite\_food table to contain a foreign key to the food table. While this design would be fully normalized, you might decide that you simply want to store the values that the user has entered, in which case you may leave the table as is.

## Step 3: Building SQL Schema Statements

Now that the design is complete for the two tables holding information about people and their favorite foods, the next step is to generate SQL statements to create the tables in the database. Here is the statement to create the person table:

CREATE TABLE person  
 (person\_id SMALLINT UNSIGNED,  
 fname VARCHAR(20),  
 lname VARCHAR(20),  
 eye\_color CHAR(2),  
 birth\_date DATE,  
 street VARCHAR(30),  
 city VARCHAR(20),  
 state VARCHAR(20),  
 country VARCHAR(20),  
 postal\_code VARCHAR(20),  
 CONSTRAINT pk\_person PRIMARY KEY (person\_id)  
 );

Everything in this statement should be fairly self-explanatory except for the last item; when you define your table, you need to tell the database server what column or columns will serve as the primary key for the table. You do this by creating a constraint on the table. You can add several types of constraints to a table definition. This constraint is a primary key constraint. It is created on the person\_id column and given the name pk\_person.

While on the topic of constraints, there is another type of constraint that would be useful for the person table. In [Table 2-6](#Table_2_6__Person_table__first_p), I added a third column to show the allowable values for certain columns (such as 'BR' and 'BL' for the eye\_color column). Another type of constraint called a check constraint constrains the allowable values for a particular column. MySQL allows a check constraint to be attached to a column definition, as in the following:

eye\_color CHAR(2)   
CHECK (eye\_color IN ('BR','BL','GR'))  
,

While check constraints operate as expected on most database servers, the MySQL server allows check constraints to be defined but does not enforce them. However, MySQL does provide another character data type called enum that merges the check constraint into the data type definition. Here’s what it would look like for the eye\_color column definition:

eye\_color   
ENUM('BR','BL','GR')  
,

Here’s how the person table definition looks with an enum data type for the eye\_color column:

CREATE TABLE person  
 (person\_id SMALLINT UNSIGNED,  
 fname VARCHAR(20),  
 lname VARCHAR(20),  
 eye\_color ENUM('BR','BL','GR'),  
 birth\_date DATE,  
 street VARCHAR(30),  
 city VARCHAR(20),  
 state VARCHAR(20),  
 country VARCHAR(20),  
 postal\_code VARCHAR(20),  
 CONSTRAINT pk\_person PRIMARY KEY (person\_id)  
 );

Later in this chapter, you will see what happens if you try to add data to a column that violates its check constraint (or, in the case of MySQL, its enumeration values).

You are now ready to run the create table statement using the mysql command-line tool. Here’s what it looks like:

mysql> CREATE TABLE person  
    ->  (person\_id SMALLINT UNSIGNED,  
    ->   fname VARCHAR(20),  
    ->   lname VARCHAR(20),  
    ->   eye\_color ENUM('BR','BL','GR'),  
    ->   birth\_date DATE,  
    ->   street VARCHAR(30),  
    ->   city VARCHAR(20),  
    ->   state VARCHAR(20),  
    ->   country VARCHAR(20),  
    ->   postal\_code VARCHAR(20),  
    ->   CONSTRAINT pk\_person PRIMARY KEY (person\_id)  
    ->  );  
Query OK, 0 rows affected (0.37 sec)

After processing the create table statement, the MySQL server returns the message “Query OK, 0 rows affected,” which tells me that the statement had no syntax errors.

If you want to make sure that the person table does, in fact, exist, you can use the describe command (or desc for short) to look at the table definition:

mysql> desc person;  
+-------------+----------------------+------+-----+---------+-------+  
| Field       | Type                 | Null | Key | Default | Extra |  
+-------------+----------------------+------+-----+---------+-------+  
| person\_id   | smallint(5) unsigned | NO   | PRI | NULL    |       |  
| fname       | varchar(20)          | YES  |     | NULL    |       |  
| lname       | varchar(20)          | YES  |     | NULL    |       |  
| eye\_color   | enum('BR','BL','GR') | YES  |     | NULL    |       |  
| birth\_date  | date                 | YES  |     | NULL    |       |  
| street      | varchar(30)          | YES  |     | NULL    |       |  
| city        | varchar(20)          | YES  |     | NULL    |       |  
| state       | varchar(20)          | YES  |     | NULL    |       |  
| country     | varchar(20)          | YES  |     | NULL    |       |  
| postal\_code | varchar(20)          | YES  |     | NULL    |       |  
+-------------+----------------------+------+-----+---------+-------+  
10 rows in set (0.00 sec)

Columns 1 and 2 of the describe output are self-explanatory. Column 3 shows whether a particular column can be omitted when data is inserted into the table. I purposefully left this topic out of the discussion for now (see the following sidebar for a short discourse), but we explore it fully in [Chapter 4](#Chapter_4__Filtering__Sometimes_2). The fourth column shows whether a column takes part in any keys (primary or foreign); in this case, the person\_id column is marked as the primary key. Column 5 shows whether a particular column will be populated with a default value if you omit the column when inserting data into the table. The sixth column (called “Extra”) shows any other pertinent information that might apply to a column.

#### What Is Null?

In some cases, it is not possible or applicable to provide a value for a particular column in your table. For example, when adding data about a new customer order, the ship\_date column cannot yet be determined. In this case, the column is said to be null (note that I do not say that it equals null), which indicates the absence of a value. Null is used for various cases where a value cannot be supplied, such as:

* Not applicable
* Unknown
* Empty set

When designing a table, you may specify which columns are allowed to be null (the default) and which columns are not allowed to be null (designated by adding the keywords not null after the type definition).

Now that you have created the person table, your next step will be to then create the favorite\_food table:

mysql>   
CREATE TABLE favorite\_food  
  
 ->   
(person\_id SMALLINT UNSIGNED,  
  
 ->   
food VARCHAR(20),  
  
 ->   
CONSTRAINT pk\_favorite\_food PRIMARY KEY (person\_id, food),  
  
 ->   
CONSTRAINT fk\_fav\_food\_person\_id FOREIGN KEY (person\_id)  
  
 ->   
REFERENCES person (person\_id)  
  
 ->   
);  
  
Query OK, 0 rows affected (0.10 sec)

This should look very similar to the create table statement for the person table, with the following exceptions:

* Since a person can have more than one favorite food (which is the reason this table was created in the first place), it takes more than just the person\_id column to guarantee uniqueness in the table. This table, therefore, has a two-column primary key: person\_id and food.
* The favorite\_food table contains another type of constraint which is called a foreign key constraint. This constrains the values of the person\_id column in the favorite\_food table to include only values found in the person table. With this constraint in place, I will not be able to add a row to the favorite\_food table indicating that person\_id 27 likes pizza if there isn’t already a row in the person table having a person\_id of 27.

##### Note

If you forget to create the foreign key constraint when you first create the table, you can add it later via the alter table statement.

describe shows the following after executing the create table statement:

mysql> desc favorite\_food;  
+-----------+----------------------+------+-----+---------+-------+  
| Field     | Type                 | Null | Key | Default | Extra |  
+-----------+----------------------+------+-----+---------+-------+  
| person\_id | smallint(5) unsigned | NO   | PRI | NULL    |       |  
| food      | varchar(20)          | NO   | PRI | NULL    |       |  
+-----------+----------------------+------+-----+---------+-------+  
2 rows in set (0.00 sec)

Now that the tables are in place, the next logical step is to add some data.

# Populating and Modifying Tables

With the person and favorite\_food tables in place, you can now begin to explore the four SQL data statements: insert, update, delete, and select.

## Inserting Data

Since there is not yet any data in the person and favorite\_food tables, the first of the four SQL data statements to be explored will be the insert statement. There are three main components to an insert statement:

* The name of the table into which to add the data
* The names of the columns in the table to be populated
* The values with which to populate the columns

You are not required to provide data for every column in the table (unless all the columns in the table have been defined as not null). In some cases, those columns that are not included in the initial insert statement will be given a value later via an update statement. In other cases, a column may never receive a value for a particular row of data (such as a customer order that is canceled before being shipped, thus rendering the ship\_date column inapplicable).

## Generating numeric key data

Before inserting data into the person table, it would be useful to discuss how values are generated for numeric primary keys. Other than picking a number out of thin air, you have a couple of options:

* Look at the largest value currently in the table and add one.
* Let the database server provide the value for you.

Although the first option may seem valid, it proves problematic in a multiuser environment, since two users might look at the table at the same time and generate the same value for the primary key. Instead, all database servers on the market today provide a safe, robust method for generating numeric keys. In some servers, such as the Oracle Database, a separate schema object is used (called a sequence); in the case of MySQL, however, you simply need to turn on the auto-increment feature for your primary key column. Normally, you would do this at table creation, but doing it now provides the opportunity to learn another SQL schema statement, alter table, which is used to modify the definition of an existing table:

ALTER TABLE person MODIFY person\_id SMALLINT UNSIGNED AUTO\_INCREMENT;

Warning

If you are running these statements in your database, you will first need to disable the foreign key constraint on the favorite\_food table, and then re-enable the constraints when finished. The progression of statements would be:

set foreign\_key\_checks=0;  
ALTER TABLE person   
 MODIFY person\_id SMALLINT UNSIGNED AUTO\_INCREMENT;  
set foreign\_key\_checks=1;

This statement essentially redefines the person\_id column in the person table. If you describe the table, you will now see the auto-increment feature listed under the “Extra” column for person\_id:

mysql>   
DESC person;  
  
+-------------+------------------------+------+-----+---------+-----------------+  
| Field | Type | Null | Key | Default | Extra |  
+-------------+------------------------+------+-----+---------+-----------------+  
| person\_id | smallint(5) unsigned | NO | PRI | NULL |   
auto\_increment  
 |  
| . | | | | | |  
| . | | | | | |  
| . | | | | | |

When you insert data into the person table, you simply provide a null value for the person\_id column, and MySQL will populate the column with the next available number (by default, MySQL starts at 1 for auto-increment columns).

## The insert statement

Now that all the pieces are in place, it’s time to add some data. The following statement creates a row in the person table for William Turner:

mysql> INSERT INTO person  
    ->   (person\_id, fname, lname, eye\_color, birth\_date)  
    -> VALUES (null, 'William','Turner', 'BR', '1972-05-27');  
Query OK, 1 row affected (0.22 sec)

The feedback (“Query OK, 1 row affected”) tells you that your statement syntax was proper and that one row was added to the database (since it was an insert statement). You can look at the data just added to the table by issuing a select statement:

mysql>   
SELECT person\_id, fname, lname, birth\_date  
  
 ->   
FROM person;  
  
+-----------+---------+--------+------------+  
| person\_id | fname | lname | birth\_date |  
+-----------+---------+--------+------------+  
| 1 | William | Turner | 1972-05-27 |  
+-----------+---------+--------+------------+  
1 row in set (0.06 sec)

As you can see, the MySQL server generated a value of 1 for the primary key. Since there is only a single row in the person table, I neglected to specify which row I am interested in and simply retrieved all the rows in the table. If there were more than one row in the table, however, I could add a where clause to specify that I want to retrieve data only for the row having a value of 1 for the person\_id column:

mysql>   
SELECT person\_id, fname, lname, birth\_date  
  
 ->   
FROM person  
  
 ->   
WHERE person\_id = 1;  
  
+-----------+---------+--------+------------+  
| person\_id | fname | lname | birth\_date |  
+-----------+---------+--------+------------+  
| 1 | William | Turner | 1972-05-27 |  
+-----------+---------+--------+------------+  
1 row in set (0.00 sec)

While this query specifies a particular primary key value, you can use any column in the table to search for rows, as shown by the following query, which finds all rows with a value of 'Turner' for the lname column:

mysql>   
SELECT person\_id, fname, lname, birth\_date  
  
 ->   
FROM person  
  
 ->   
WHERE lname = 'Turner';  
  
+-----------+---------+--------+------------+  
| person\_id | fname | lname | birth\_date |  
+-----------+---------+--------+------------+  
| 1 | William | Turner | 1972-05-27 |  
+-----------+---------+--------+------------+  
1 row in set (0.00 sec)

Before moving on, a couple of things about the earlier insert statement are worth mentioning:

* Values were not provided for any of the address columns. This is fine, since nulls are allowed for those columns.
* The value provided for the birth\_date column was a string. As long as you match the required format shown in [Table 2-4](#Table_2_4__MySQL_temporal_types), MySQL will convert the string to a date for you.
* The column names and the values provided must correspond in number and type. If you name seven columns and provide only six values or if you provide values that cannot be converted to the appropriate data type for the corresponding column, you will receive an error.

William Turner has also provided information about his favorite three foods, so here are three insert statements to store his food preferences:

mysql>   
INSERT INTO favorite\_food (person\_id, food)  
  
 ->   
VALUES (1, 'pizza');  
  
Query OK, 1 row affected (0.01 sec)  
mysql>   
INSERT INTO favorite\_food (person\_id, food)  
  
 ->   
VALUES (1, 'cookies');  
  
Query OK, 1 row affected (0.00 sec)  
mysql>   
INSERT INTO favorite\_food (person\_id, food)  
  
 ->   
VALUES (1, 'nachos');  
  
Query OK, 1 row affected (0.01 sec)

Here’s a query that retrieves William’s favorite foods in alphabetical order using an order by clause:

mysql>   
SELECT food  
  
 ->   
FROM favorite\_food  
  
 ->   
WHERE person\_id = 1  
  
 ->   
ORDER BY food;  
  
+---------+  
| food |  
+---------+  
| cookies |  
| nachos |  
| pizza |  
+---------+  
3 rows in set (0.02 sec)

The order by clause tells the server how to sort the data returned by the query. Without the order by clause, there is no guarantee that the data in the table will be retrieved in any particular order.

So that William doesn’t get lonely, you can execute another insert statement to add Susan Smith to the person table:

mysql>   
INSERT INTO person  
  
 ->   
(person\_id, fname, lname, eye\_color, birth\_date,  
  
 ->   
street, city, state, country, postal\_code)  
  
 ->   
VALUES (null, 'Susan','Smith', 'BL', '1975-11-02',  
  
 ->   
'23 Maple St.', 'Arlington', 'VA', 'USA', '20220');  
  
 Query OK, 1 row affected (0.01 sec)

Since Susan was kind enough to provide her address, we included five more columns than when William’s data was inserted. If you query the table again, you will see that Susan’s row has been assigned the value 2 for its primary key value:

mysql>   
SELECT person\_id, fname, lname, birth\_date  
  
 ->   
FROM person;  
  
+-----------+---------+--------+------------+  
| person\_id | fname | lname | birth\_date |  
+-----------+---------+--------+------------+  
| 1 | William | Turner | 1972-05-27 |  
| 2 | Susan | Smith | 1975-11-02 |  
+-----------+---------+--------+------------+  
2 rows in set (0.00 sec)

#### Can I Get That in XML?

If you will be working with XML data, you will be happy to know that most database servers provide a simple way to generate XML output from a query. With MySQL, for example, you can use the --xml option when invoking the mysql tool, and all your output will automatically be formatted using XML. Here’s what the favorite-food data looks like as an XML document:

C:\database> mysql -u lrngsql -p --xml bank  
Enter password: xxxxxx  
Welcome to the MySQL Monitor...  
  
Mysql> SELECT \* FROM favorite\_food;  
<?xml version="1.0"?>  
  
<resultset statement="select \* from favorite\_food"  
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">  
 <row>  
 <field name="person\_id">1</field>  
 <field name="food">cookies</field>  
 </row>  
 <row>  
 <field name="person\_id">1</field>  
 <field name="food">nachos</field>  
 </row>  
 <row>  
 <field name="person\_id">1</field>  
 <field name="food">pizza</field>  
 </row>  
</resultset>  
3 rows in set (0.00 sec)

With SQL Server, you don’t need to configure your command-line tool; you just need to add the for xml clause to the end of your query, as in:

SELECT \* FROM favorite\_food  
FOR XML AUTO, ELEMENTS

## Updating Data

When the data for William Turner was initially added to the table, data for the various address columns was not included in the insert statement. The next statement shows how these columns can be populated at a later time via an update statement:

mysql>   
UPDATE person  
  
 ->   
SET street = '1225 Tremont St.',  
  
 ->   
city = 'Boston',  
  
 ->   
state = 'MA',  
  
 ->   
country = 'USA',  
  
 ->   
postal\_code = '02138'  
  
 ->   
WHERE person\_id = 1;  
  
Query OK, 1 row affected (0.04 sec)  
Rows matched: 1 Changed: 1 Warnings: 0

The server responded with a two-line message: the “Rows matched: 1” item tells you that the condition in the where clause matched a single row in the table, and the “Changed: 1” item tells you that a single row in the table has been modified. Since the where clause specifies the primary key of William’s row, this is exactly what you would expect to have happen.

Depending on the conditions in your where clause, it is also possible to modify more than one row using a single statement. Consider, for example, what would happen if your where clause looked as follows:

WHERE person\_id < 10

Since both William and Susan have a person\_id value less than 10, both of their rows would be modified. If you leave off the where clause altogether, your update statement will modify every row in the table.

## Deleting Data

It seems that William and Susan aren’t getting along very well together, so one of them has got to go. Since William was there first, Susan will get the boot courtesy of the delete statement:

mysql>   
DELETE FROM person  
  
 ->   
WHERE person\_id = 2;  
  
Query OK, 1 row affected (0.01 sec)

Again, the primary key is being used to isolate the row of interest, so a single row is deleted from the table. Like the update statement, more than one row can be deleted depending on the conditions in your where clause, and all rows will be deleted if the where clause is omitted.

# When Good Statements Go Bad

So far, all of the SQL data statements shown in this chapter have been well formed and have played by the rules. Based on the table definitions for the person and favorite\_food tables, however, there are lots of ways that you can run afoul when inserting or modifying data. This section shows you some of the common mistakes that you might come across and how the MySQL server will respond.

## Nonunique Primary Key

Because the table definitions include the creation of primary key constraints, MySQL will make sure that duplicate key values are not inserted into the tables. The next statement attempts to bypass the auto-increment feature of the person\_id column and create another row in the person table with a person\_id of 1:

mysql>   
INSERT INTO person  
  
 ->   
(person\_id, fname, lname, eye\_color, birth\_date)  
  
 ->   
VALUES (1, 'Charles','Fulton', 'GR', '1968-01-15');  
  
ERROR 1062 (23000): Duplicate entry '1' for key 'PRIMARY'

There is nothing stopping you (with the current schema objects, at least) from creating two rows with identical names, addresses, birth dates, and so on, as long as they have different values for the person\_id column.

## Nonexistent Foreign Key

The table definition for the favorite\_food table includes the creation of a foreign key constraint on the person\_id column. This constraint ensures that all values of person\_id entered into the favorite\_food table exist in the person table. Here’s what would happen if you tried to create a row that violates this constraint:

mysql>   
INSERT INTO favorite\_food (person\_id, food)  
  
 ->   
VALUES (999, 'lasagna');  
  
ERROR 1452 (23000): Cannot add or update a child row: a foreign key constraint  
fails ('sakila'.'favorite\_food', CONSTRAINT 'fk\_fav\_food\_person\_id' FOREIGN KEY  
('person\_id') REFERENCES 'person' ('person\_id'))

In this case, the favorite\_food table is considered the child and the person table is considered the parent, since the favorite\_food table is dependent on the person table for some of its data. If you plan to enter data into both tables, you will need to create a row in parent before you can enter data into favorite\_food.

##### Note

Foreign key constraints are enforced only if your tables are created using the InnoDB storage engine. We discuss MySQL’s storage engines in [Chapter 12](#Chapter_12__Transactions__All_of_2).

## Column Value Violations

The eye\_color column in the person table is restricted to the values 'BR' for brown, 'BL' for blue, and 'GR' for green. If you mistakenly attempt to set the value of the column to any other value, you will receive the following response:

mysql>   
UPDATE person  
  
 ->   
SET eye\_color = 'ZZ'  
  
 ->   
WHERE person\_id = 1;  
  
ERROR 1265 (01000): Data truncated for column 'eye\_color' at row 1

The error message is a bit confusing, but it gives you the general idea that the server is unhappy about the value provided for the eye\_color column.

## Invalid Date Conversions

If you construct a string with which to populate a date column and that string does not match the expected format, you will receive another error. Here’s an example that uses a date format that does not match the default date format of YYYY-MM-DD:

mysql>   
UPDATE person  
  
 ->   
SET birth\_date = 'DEC-21-1980'  
  
 ->   
WHERE person\_id = 1;  
  
ERROR 1292 (22007): Incorrect date value: 'DEC-21-1980' for column 'birth\_date'  
at row 1

In general, it is always a good idea to explicitly specify the format string rather than relying on the default format. Here’s another version of the statement that uses the str\_to\_date function to specify which format string to use:

mysql>   
UPDATE person  
  
 ->   
SET birth\_date = str\_to\_date('DEC-21-1980' , '%b-%d-%Y')  
  
 ->   
WHERE person\_id = 1;  
  
Query OK, 1 row affected (0.12 sec)  
Rows matched: 1 Changed: 1 Warnings: 0

Not only is the database server happy, but William is happy as well (we just made him eight years younger, without the need for expensive cosmetic surgery!).

##### Note

Earlier in the chapter, when I discussed the various temporal data types, I showed date-formatting strings such as YYYY-MM-DD. While many database servers use this style of formatting, MySQL uses %Y to indicate a four-character year. Here are a few more formatters that you might need when converting strings to datetimes in MySQL:

%a The short weekday name, such as Sun, Mon, ...  
%b The short month name, such as Jan, Feb, ...  
%c The numeric month (0..12)  
%d The numeric day of the month (00..31)  
%f The number of microseconds (000000..999999)  
%H The hour of the day, in 24-hour format (00..23)  
%h The hour of the day, in 12-hour format (01..12)  
%i The minutes within the hour (00..59)  
%j The day of year (001..366)  
%M The full month name (January..December)  
%m The numeric month  
%p AM or PM  
%s The number of seconds (00..59)  
%W The full weekday name (Sunday..Saturday)  
%w The numeric day of the week (0=Sunday..6=Saturday)  
%Y The four-digit year

# The Sakila Database

For the remainder of the book, most examples will use a sample database called Sakila, which is made available by the nice people at MySQL. This database models a chain of DVD rental stores, which is a bit outdated, but with a bit of imagination it can be rebranded as a video-streaming company. Some of the tables include customer, film, actor, payment, rental, and category. The entire schema and example data should have been created when you followed the final steps at the beginning of the chapter for loading the MySQL server and generating the sample data. For a diagram of the tables and their columns and relationships, see [Appendix A](#Appendix_A__ER_Diagram_for_Examp_2).

[Table 2-9](#Table_2_9__Sakila_schema_definit) shows some of the tables used in the Sakila schema, along with short definitions of each.

|  |  |
| --- | --- |
| Table 2-9. Sakila schema definitions  Table name | Definition |

|  |  |
| --- | --- |
| film | A movie that has been released and can be rented |

|  |  |
| --- | --- |
| actor | A person who acts in films |

|  |  |
| --- | --- |
| customer | A person who watches films |

|  |  |
| --- | --- |
| category | A genre of films |

|  |  |
| --- | --- |
| payment | A rental of a film by a customer |

|  |  |
| --- | --- |
| language | A language spoken by the actors of a film |

|  |  |
| --- | --- |
| film\_actor | An actor in a film |

|  |  |
| --- | --- |
| inventory | A film available for rental |

Feel free to experiment with the tables as much as you want, including adding your own tables to expand the business functions. You can always drop the database and re-create it from the downloaded file if you want to make sure your sample data is intact. If you are using the temporary session, any changes you make will be lost when the session closes, so you may want to keep a script of your changes so you can re-create any changes you have made.

If you want to see the tables available in your database, you can use the show tables command, as in:

mysql> show tables;  
+----------------------------+  
| Tables\_in\_sakila           |  
+----------------------------+  
| actor                      |  
| actor\_info                 |  
| address                    |  
| category                   |  
| city                       |  
| country                    |  
| customer                   |  
| customer\_list              |  
| film                       |  
| film\_actor                 |  
| film\_category              |  
| film\_list                  |  
| film\_text                  |  
| inventory                  |  
| language                   |  
| nicer\_but\_slower\_film\_list |  
| payment                    |  
| rental                     |  
| sales\_by\_film\_category     |  
| sales\_by\_store             |  
| staff                      |  
| staff\_list                 |  
| store                      |  
+----------------------------+  
23 rows in set (0.02 sec)

Along with the 23 tables in the Sakila schema, your table listing may also include the two tables created in this chapter: person and favorite\_food. These tables will not be used in later chapters, so feel free to drop them by issuing the following set of commands:

mysql>   
DROP TABLE favorite\_food;  
  
Query OK, 0 rows affected (0.56 sec)  
mysql>   
DROP TABLE person;  
  
Query OK, 0 rows affected (0.05 sec)

If you want to look at the columns in a table, you can use the describe command. Here’s an example of the describe output for the customer table:

mysql> desc customer;  
+-------------+--------------+------+-----+-------------+----------------------+  
| Field       | Type         | Null | Key | Default     | Extra                |  
+-------------+--------------+------+-----+-------------+----------------------+  
| customer\_id | smallint(5) | NO   | PRI | NULL        | auto\_increment       |  
 unsigned   
| store\_id    | tinyint(3) | NO   | MUL | NULL        |                      |  
 unsigned   
| first\_name  | varchar(45) | NO   |     | NULL        |                      |  
| last\_name   | varchar(45) | NO   | MUL | NULL        |                      |  
| email       | varchar(50) | YES  |     | NULL        |                      |  
| address\_id  | smallint(5) | NO   | MUL | NULL        |                      |  
 unsigned   
| active      | tinyint(1) | NO   |     | 1           |                      |  
| create\_date | datetime | NO   |     | NULL        |                      |  
| last\_update | timestamp | YES  |     | CURRENT\_ | DEFAULT\_GENERATED on  
 TIMESTAMP update CURRENT\_  
 TIMESTAMP |   
+-------------+--------------+------+-----+-------------+----------------------+

The more comfortable you are with the example database, the better you will understand the examples and, consequently, the concepts in the following chapters.

# Chapter 3. Query Primer

So far, you have seen a few examples of database queries (a.k.a. select statements) sprinkled throughout the first two chapters. Now it’s time to take a closer look at the different parts of the select statement and how they interact. After finishing this chapter, you should have a basic understanding of how data is retrieved, joined, filtered, grouped, and sorted; these topics will be covered in detail in Chapters [4](#Chapter_4__Filtering__Sometimes_2) through [10](#Chapter_10__Joins_Revisited__By_2).

# Query Mechanics

Before dissecting the select statement, it might be interesting to look at how queries are executed by the MySQL server (or, for that matter, any database server). If you are using the mysql command-line tool (which I assume you are), then you have already logged in to the MySQL server by providing your username and password (and possibly a hostname if the MySQL server is running on a different computer). Once the server has verified that your username and password are correct, a database connection is generated for you to use. This connection is held by the application that requested it (which, in this case, is the mysql tool) until the application releases the connection (i.e., as a result of typing quit) or the server closes the connection (i.e., when the server is shut down). Each connection to the MySQL server is assigned an identifier, which is shown to you when you first log in:

Welcome to the MySQL monitor. Commands end with ; or \g.  
Your MySQL connection id is 11  
  
Server version: 8.0.15 MySQL Community Server - GPL  
  
Copyright (c) 2000, 2019, Oracle and/or its affiliates. All rights reserved.  
Oracle is a registered trademark of Oracle Corporation and/or its  
affiliates. Other names may be trademarks of their respective  
owners.  
Type 'help;' or '\h' for help. Type '\c' to clear the buffer.

In this case, my connection ID is 11. This information might be useful to your database administrator if something goes awry, such as a malformed query that runs for hours, so you might want to jot it down.

Once the server has verified your username and password and issued you a connection, you are ready to execute queries (along with other SQL statements). Each time a query is sent to the server, the server checks the following things prior to statement execution:

* Do you have permission to execute the statement?
* Do you have permission to access the desired data?
* Is your statement syntax correct?

If your statement passes these three tests, then your query is handed to the query optimizer, whose job it is to determine the most efficient way to execute your query. The optimizer looks at such things as the order in which to join the tables named in your from clause and what indexes are available, and then it picks an execution plan, which the server uses to execute your query.

##### Note

Understanding and influencing how your database server chooses execution plans is a fascinating topic that many of you will want to explore. For those readers using MySQL, you might consider reading Baron Schwartz et al.’s [High Performance MySQL](http://oreilly.com/catalog/9780596101718) (O’Reilly). Among other things, you will learn how to generate indexes, analyze execution plans, influence the optimizer via query hints, and tune your server’s startup parameters. If you are using Oracle Database or SQL Server, dozens of tuning books are available.

Once the server has finished executing your query, the result set is returned to the calling application (which is, once again, the mysql tool). As I mentioned in [Chapter 1](#Chapter_1__A_Little_Background_2), a result set is just another table containing rows and columns. If your query fails to yield any results, the mysql tool will show you the message found at the end of the following example:

mysql> SELECT first\_name, last\_name  
    -> FROM customer  
    -> WHERE last\_name = 'ZIEGLER';  
Empty set   
(0.02 sec)

If the query returns one or more rows, the mysql tool will format the results by adding column headers and constructing boxes around the columns using the -, |, and + symbols, as shown in the next example:

mysql> SELECT \*  
    -> FROM category;  
+-------------+-------------+---------------------+  
| category\_id | name        | last\_update         |  
+-------------+-------------+---------------------+  
|           1 | Action      | 2006-02-15 04:46:27 |  
|           2 | Animation   | 2006-02-15 04:46:27 |  
|           3 | Children    | 2006-02-15 04:46:27 |  
|           4 | Classics    | 2006-02-15 04:46:27 |  
|           5 | Comedy      | 2006-02-15 04:46:27 |  
|           6 | Documentary | 2006-02-15 04:46:27 |  
|           7 | Drama       | 2006-02-15 04:46:27 |  
|           8 | Family      | 2006-02-15 04:46:27 |  
|           9 | Foreign     | 2006-02-15 04:46:27 |  
|          10 | Games       | 2006-02-15 04:46:27 |  
|          11 | Horror      | 2006-02-15 04:46:27 |  
|          12 | Music       | 2006-02-15 04:46:27 |  
|          13 | New         | 2006-02-15 04:46:27 |  
|          14 | Sci-Fi      | 2006-02-15 04:46:27 |  
|          15 | Sports      | 2006-02-15 04:46:27 |  
|          16 | Travel      | 2006-02-15 04:46:27 |  
+-------------+-------------+---------------------+  
16 rows in set  
 (0.02 sec)

This query returns all three columns for of all the rows in the category table. After the last row of data is displayed, the mysql tool displays a message telling you how many rows were returned, which, in this case, is 16.

# Query Clauses

Several components or clauses make up the select statement. While only one of them is mandatory when using MySQL (the select clause), you will usually include at least two or three of the six available clauses. [Table 3-1](#Table_3_1__Query_clauses) shows the different clauses and their purposes.

|  |  |
| --- | --- |
| Table 3-1. Query clauses  Clause name | Purpose |

|  |  |
| --- | --- |
| select | Determines which columns to include in the query’s result set |

|  |  |
| --- | --- |
| from | Identifies the tables from which to retrieve data and how the tables should be joined |

|  |  |
| --- | --- |
| where | Filters out unwanted data |

|  |  |
| --- | --- |
| group by | Used to group rows together by common column values |

|  |  |
| --- | --- |
| having | Filters out unwanted groups |

|  |  |
| --- | --- |
| order by | Sorts the rows of the final result set by one or more columns |

All of the clauses shown in [Table 3-1](#Table_3_1__Query_clauses) are included in the ANSI specification. The following sections delve into the uses of the six major query clauses.

# The select Clause

Even though the select clause is the first clause of a select statement, it is one of the last clauses that the database server evaluates. The reason for this is that before you can determine what to include in the final result set, you need to know all of the possible columns that could be included in the final result set. In order to fully understand the role of the select clause, therefore, you will need to understand a bit about the from clause. Here’s a query to get started:

mysql> SELECT \*  
    -> FROM language;  
+-------------+----------+---------------------+  
| language\_id | name     | last\_update         |  
+-------------+----------+---------------------+  
|           1 | English  | 2006-02-15 05:02:19 |  
|           2 | Italian  | 2006-02-15 05:02:19 |  
|           3 | Japanese | 2006-02-15 05:02:19 |  
|           4 | Mandarin | 2006-02-15 05:02:19 |  
|           5 | French   | 2006-02-15 05:02:19 |  
|           6 | German   | 2006-02-15 05:02:19 |  
+-------------+----------+---------------------+  
6 rows in set (0.03 sec)

In this query, the from clause lists a single table (language), and the select clause indicates that all columns (designated by \*) in the language table should be included in the result set. This query could be described in English as follows:

Show me all the columns and all the rows in the language table.

In addition to specifying all the columns via the asterisk character, you can explicitly name the columns you are interested in, such as:

mysql> SELECT language\_id, name, last\_update  
    -> FROM language;  
+-------------+----------+---------------------+  
| language\_id | name     | last\_update         |  
+-------------+----------+---------------------+  
|           1 | English  | 2006-02-15 05:02:19 |  
|           2 | Italian  | 2006-02-15 05:02:19 |  
|           3 | Japanese | 2006-02-15 05:02:19 |  
|           4 | Mandarin | 2006-02-15 05:02:19 |  
|           5 | French   | 2006-02-15 05:02:19 |  
|           6 | German   | 2006-02-15 05:02:19 |  
+-------------+----------+---------------------+  
6 rows in set (0.00 sec)

The results are identical to the first query, since all the columns in the language table (language\_id, name, and last\_update) are named in the select clause. You can choose to include only a subset of the columns in the language table as well:

mysql> SELECT name  
    -> FROM language;  
+----------+  
| name     |  
+----------+  
| English  |  
| Italian  |  
| Japanese |  
| Mandarin |  
| French   |  
| German   |  
+----------+  
6 rows in set (0.00 sec)

The job of the select clause, therefore, is as follows:

The select clause determines which of all possible columns should be included in the query’s result set.

If you were limited to including only columns from the table or tables named in the from clause, things would be rather dull. However, you can spice things up in your select clause by including things such as:

* Literals, such as numbers or strings
* Expressions, such as transaction.amount \* −1
* Built-in function calls, such as ROUND(transaction.amount, 2)
* User-defined function calls

The next query demonstrates the use of a table column, a literal, an expression, and a built-in function call in a single query against the language table:

mysql> SELECT language\_id,  
    ->   'COMMON' language\_usage,  
    ->   language\_id \* 3.1415927 lang\_pi\_value,  
    ->   upper(name) language\_name  
    -> FROM language;  
+-------------+----------------+---------------+---------------+  
| language\_id | language\_usage | lang\_pi\_value | language\_name |  
+-------------+----------------+---------------+---------------+  
|           1 | COMMON         |     3.1415927 | ENGLISH       |  
|           2 | COMMON         |     6.2831854 | ITALIAN       |  
|           3 | COMMON         |     9.4247781 | JAPANESE      |  
|           4 | COMMON         |    12.5663708 | MANDARIN      |  
|           5 | COMMON         |    15.7079635 | FRENCH        |  
|           6 | COMMON         |    18.8495562 | GERMAN        |  
+-------------+----------------+---------------+---------------+  
6 rows in set (0.04 sec)

We cover expressions and built-in functions in detail later, but I wanted to give you a feel for what kinds of things can be included in the select clause. If you only need to execute a built-in function or evaluate a simple expression, you can skip the from clause entirely. Here’s an example:

mysql> SELECT version(),  
    ->   user(),  
    ->   database();  
+-----------+----------------+------------+  
| version() | user()         | database() |  
+-----------+----------------+------------+  
| 8.0.15    | root@localhost | sakila     |  
+-----------+----------------+------------+  
1 row in set (0.00 sec)

Since this query simply calls three built-in functions and doesn’t retrieve data from any tables, there is no need for a from clause.

## Column Aliases

Although the mysql tool will generate labels for the columns returned by your queries, you may want to assign your own labels. While you might want to assign a new label to a column from a table (if it is poorly or ambiguously named), you will almost certainly want to assign your own labels to those columns in your result set that are generated by expressions or built-in function calls. You can do so by adding a column alias after each element of your select clause. Here’s the previous query against the language table, which included column aliases for three of the columns:

mysql> SELECT language\_id,  
    ->   'COMMON'   
language\_usage  
,  
    ->   language\_id \* 3.1415927   
lang\_pi\_value  
,  
    ->   upper(name)   
language\_name  
  
    -> FROM language;  
+-------------+----------------+---------------+---------------+  
| language\_id | language\_usage | lang\_pi\_value | language\_name |  
+-------------+----------------+---------------+---------------+  
|           1 | COMMON         |     3.1415927 | ENGLISH       |  
|           2 | COMMON         |     6.2831854 | ITALIAN       |  
|           3 | COMMON         |     9.4247781 | JAPANESE      |  
|           4 | COMMON         |    12.5663708 | MANDARIN      |  
|           5 | COMMON         |    15.7079635 | FRENCH        |  
|           6 | COMMON         |    18.8495562 | GERMAN        |  
+-------------+----------------+---------------+---------------+  
6 rows in set (0.04 sec)

If you look at the select clause, you can see how the column aliases language\_usage, lang\_pi\_value, and language\_name are added after the second, third, and fourth columns. I think you will agree that the output is easier to understand with column aliases in place, and it would be easier to work with programmatically if you were issuing the query from within Java or Python rather than interactively via the mysql tool. In order to make your column aliases stand out even more, you also have the option of using the as keyword before the alias name, as in:

mysql> SELECT language\_id,  
    ->   'COMMON'   
AS   
language\_usage,  
    ->   language\_id \* 3.1415927   
AS   
lang\_pi\_value,  
    ->   upper(name)   
AS   
language\_name  
    -> FROM language;

Many people feel that including the optional as keyword improves readability, although I have chosen not to use it for the examples in this book.

## Removing Duplicates

In some cases, a query might return duplicate rows of data. For example, if you were to retrieve the IDs of all actors who appeared in a film, you would see the following:

mysql> SELECT actor\_id FROM film\_actor ORDER BY actor\_id;  
+----------+  
| actor\_id |  
+----------+  
|        1 |  
|        1 |  
|        1 |  
|        1 |  
|        1 |  
|        1 |  
|        1 |  
|        1 |  
|        1 |  
|        1 |  
...  
|      200 |  
|      200 |  
|      200 |  
|      200 |  
|      200 |  
|      200 |  
|      200 |  
|      200 |  
|      200 |  
+----------+  
5462 rows in set (0.01 sec)

Since some actors appeared in more than one film, you will see the same actor ID multiple times. What you probably want in this case is the distinct set of actors, instead of seeing the actor IDs repeated for each film in which they appeared. You can achieve this by adding the keyword distinct directly after the select keyword, as demonstrated by the following:

mysql> SELECT DISTINCT actor\_id FROM film\_actor ORDER BY actor\_id;  
+----------+  
| actor\_id |  
+----------+  
|        1 |  
|        2 |  
|        3 |  
|        4 |  
|        5 |  
|        6 |  
|        7 |  
|        8 |  
|        9 |  
|       10 |  
...  
|      192 |  
|      193 |  
|      194 |  
|      195 |  
|      196 |  
|      197 |  
|      198 |  
|      199 |  
|      200 |  
+----------+  
200 rows in set (0.01 sec)

The result set now contains 200 rows, one for each distinct actor, rather than 5,462 rows, one for each film appearance by an actor.

##### Note

If you simply want a list of all actors, you can query the actor table rather than reading through all the rows in film\_actor and removing duplicates.

If you do not want the server to remove duplicate data or you are sure there will be no duplicates in your result set, you can specify the all keyword instead of specifying distinct. However, the all keyword is the default and never needs to be explicitly named, so most programmers do not include all in their queries.

Warning

Keep in mind that generating a distinct set of results requires the data to be sorted, which can be time consuming for large result sets. Don’t fall into the trap of using distinct just to be sure there are no duplicates; instead, take the time to understand the data you are working with so that you will know whether duplicates are possible.

# The from Clause

Thus far, you have seen queries whose from clauses contain a single table. Although most SQL books define the from clause as simply a list of one or more tables, I would like to broaden the definition as follows:

The from clause defines the tables used by a query, along with the means of linking the tables together.

This definition is composed of two separate but related concepts, which we explore in the following sections.

## Tables

When confronted with the term table, most people think of a set of related rows stored in a database. While this does describe one type of table, I would like to use the word in a more general way by removing any notion of how the data might be stored and concentrating on just the set of related rows. Four different types of tables meet this relaxed definition:

* Permanent tables (i.e., created using the create table statement)
* Derived tables (i.e., rows returned by a subquery and held in memory)
* Temporary tables (i.e., volatile data held in memory)
* Virtual tables (i.e., created using the create view statement)

Each of these table types may be included in a query’s from clause. By now, you should be comfortable with including a permanent table in a from clause, so I will briefly describe the other types of tables that can be referenced in a from clause.

## Derived (subquery-generated) tables

A subquery is a query contained within another query. Subqueries are surrounded by parentheses and can be found in various parts of a select statement; within the from clause, however, a subquery serves the role of generating a derived table that is visible from all other query clauses and can interact with other tables named in the from clause. Here’s a simple example:

mysql> SELECT concat(cust.last\_name, ', ', cust.first\_name) full\_name  
    -> FROM  
    ->  (SELECT first\_name, last\_name, email  
    ->   FROM customer  
    ->   WHERE first\_name = 'JESSIE'  
    ->  )   
cust  
;  
+---------------+  
| full\_name     |  
+---------------+  
| BANKS, JESSIE |  
| MILAM, JESSIE |  
+---------------+  
2 rows in set (0.00 sec)

In this example, a subquery against the customer table returns three columns, and the containing query references two of the three available columns. The subquery is referenced by the containing query via its alias, which, in this case, is cust. The data in cust is held in memory for the duration of the query and is then discarded. This is a simplistic and not particularly useful example of a subquery in a from clause; you will find detailed coverage of subqueries in [Chapter 9](#Chapter_9__Subqueries__Subquerie_2).

## Temporary tables

Although the implementations differ, every relational database allows the ability to define volatile, or temporary, tables. These tables look just like permanent tables, but any data inserted into a temporary table will disappear at some point (generally at the end of a transaction or when your database session is closed). Here’s a simple example showing how actors whose last names start with J can be stored temporarily:

mysql> CREATE TEMPORARY TABLE actors\_j  
    ->  (actor\_id smallint(5),  
    ->   first\_name varchar(45),  
    ->   last\_name varchar(45)  
    ->  );  
Query OK, 0 rows affected (0.00 sec)  
  
mysql> INSERT INTO actors\_j  
    -> SELECT actor\_id, first\_name, last\_name  
    -> FROM actor  
    -> WHERE last\_name LIKE 'J%';  
Query OK, 7 rows affected (0.03 sec)  
Records: 7  Duplicates: 0  Warnings: 0  
  
mysql> SELECT \* FROM actors\_j;  
+----------+------------+-----------+  
| actor\_id | first\_name | last\_name |  
+----------+------------+-----------+  
|      119 | WARREN     | JACKMAN   |  
|      131 | JANE       | JACKMAN   |  
|        8 | MATTHEW    | JOHANSSON |  
|       64 | RAY        | JOHANSSON |  
|      146 | ALBERT     | JOHANSSON |  
|       82 | WOODY      | JOLIE     |  
|       43 | KIRK       | JOVOVICH  |  
+----------+------------+-----------+  
7 rows in set (0.00 sec)

These seven rows are held in memory temporarily and will disappear after your session is closed.

##### Note

Most database servers also drop the temporary table when the session ends. The exception is Oracle Database, which keeps the definition of the temporary table available for future sessions.

## Views

A view is a query that is stored in the data dictionary. It looks and acts like a table, but there is no data associated with a view (this is why I call it a virtual table). When you issue a query against a view, your query is merged with the view definition to create a final query to be executed.

To demonstrate, here’s a view definition that queries the employee table and includes four of the available columns:

mysql> CREATE VIEW cust\_vw AS  
    -> SELECT customer\_id, first\_name, last\_name, active  
    -> FROM customer;  
Query OK, 0 rows affected (0.12 sec)

When the view is created, no additional data is generated or stored: the server simply tucks away the select statement for future use. Now that the view exists, you can issue queries against it, as in:

mysql> SELECT first\_name, last\_name  
    -> FROM cust\_vw  
    -> WHERE active = 0;  
+------------+-----------+  
| first\_name | last\_name |  
+------------+-----------+  
| SANDRA     | MARTIN    |  
| JUDITH     | COX       |  
| SHEILA     | WELLS     |  
| ERICA      | MATTHEWS  |  
| HEIDI      | LARSON    |  
| PENNY      | NEAL      |  
| KENNETH    | GOODEN    |  
| HARRY      | ARCE      |  
| NATHAN     | RUNYON    |  
| THEODORE   | CULP      |  
| MAURICE    | CRAWLEY   |  
| BEN        | EASTER    |  
| CHRISTIAN  | JUNG      |  
| JIMMIE     | EGGLESTON |  
| TERRANCE   | ROUSH     |  
+------------+-----------+  
15 rows in set (0.00 sec)

Views are created for various reasons, including to hide columns from users and to simplify complex database designs.

## Table Links

The second deviation from the simple from clause definition is the mandate that if more than one table appears in the from clause, the conditions used to link the tables must be included as well. This is not a requirement of MySQL or any other database server, but it is the ANSI-approved method of joining multiple tables, and it is the most portable across the various database servers. We explore joining multiple tables in depth in Chapters [5](#Chapter_5__Querying_Multiple_Tab_2) and [10](#Chapter_10__Joins_Revisited__By_2), but here’s a simple example in case I have piqued your curiosity:

mysql> SELECT customer.first\_name, customer.last\_name,  
    ->   time(rental.rental\_date) rental\_time  
    -> FROM customer  
    ->   INNER JOIN rental  
    ->     
ON customer.customer\_id = rental.customer\_id  
  
    -> WHERE date(rental.rental\_date) = '2005-06-14';  
+------------+-----------+-------------+  
| first\_name | last\_name | rental\_time |  
+------------+-----------+-------------+  
| JEFFERY    | PINSON    | 22:53:33    |  
| ELMER      | NOE       | 22:55:13    |  
| MINNIE     | ROMERO    | 23:00:34    |  
| MIRIAM     | MCKINNEY  | 23:07:08    |  
| DANIEL     | CABRAL    | 23:09:38    |  
| TERRANCE   | ROUSH     | 23:12:46    |  
| JOYCE      | EDWARDS   | 23:16:26    |  
| GWENDOLYN  | MAY       | 23:16:27    |  
| CATHERINE  | CAMPBELL  | 23:17:03    |  
| MATTHEW    | MAHAN     | 23:25:58    |  
| HERMAN     | DEVORE    | 23:35:09    |  
| AMBER      | DIXON     | 23:42:56    |  
| TERRENCE   | GUNDERSON | 23:47:35    |  
| SONIA      | GREGORY   | 23:50:11    |  
| CHARLES    | KOWALSKI  | 23:54:34    |  
| JEANETTE   | GREENE    | 23:54:46    |  
+------------+-----------+-------------+  
16 rows in set (0.01 sec)

The previous query displays data from both the customer table (first\_name, last\_name) and the rental table (rental\_date), so both tables are included in the from clause. The mechanism for linking the two tables (referred to as a join) is the customer ID stored in both the customer and rental tables. Thus, the database server is instructed to use the value of the customer\_id column in the customer table to find all of the customer’s rentals in the rental table. Join conditions for the two tables are found in the on subclause of the from clause; in this case, the join condition is ON customer.customer\_id = rental.customer\_id. The where clause is not part of the join and is only included to keep the result set fairly small, since there are more than 16,000 rows in the rental table. Again, please refer to [Chapter 5](#Chapter_5__Querying_Multiple_Tab_2) for a thorough discussion of joining multiple tables.

## Defining Table Aliases

When multiple tables are joined in a single query, you need a way to identify which table you are referring to when you reference columns in the select, where, group by, having, and order by clauses. You have two choices when referencing a table outside the from clause:

* Use the entire table name, such as employee.emp\_id.
* Assign each table an alias and use the alias throughout the query.

In the previous query, I chose to use the entire table name in the select and on clauses. Here’s what the same query looks like using table aliases:

SELECT c.first\_name, c.last\_name,  
  time(r.rental\_date) rental\_time  
FROM customer   
c  
  
  INNER JOIN rental   
r  
  
  ON c.customer\_id = r.customer\_id  
WHERE date(r.rental\_date) = '2005-06-14';

If you look closely at the from clause, you will see that the customer table is assigned the alias c, and the rental table is assigned the alias r. These aliases are then used in the on clause when defining the join condition as well as in the select clause when specifying the columns to include in the result set. I hope you will agree that using aliases makes for a more compact statement without causing confusion (as long as your choices for alias names are reasonable). Additionally, you may use the as keyword with your table aliases, similar to what was demonstrated earlier for column aliases:

SELECT c.first\_name, c.last\_name,  
  time(r.rental\_date) rental\_time  
FROM customer   
AS   
c  
  INNER JOIN rental   
AS   
r  
  ON c.customer\_id = r.customer\_id  
WHERE date(r.rental\_date) = '2005-06-14';

I have found that roughly half of the database developers I have worked with use the as keyword with their column and table aliases, and half do not.

# The where Clause

In some cases, you may want to retrieve all rows from a table, especially for small tables such as language. Most of the time, however, you will not want to retrieve every row from a table but will want a way to filter out those rows that are not of interest. This is a job for the where clause.

The where clause is the mechanism for filtering out unwanted rows from your result set.

For example, perhaps you are interested in renting a film but you are only interested in movies rated G that can be kept for at least a week. The following query employs a where clause to retrieve only the films meeting these criteria:

mysql> SELECT title  
    -> FROM film  
    ->   
WHERE rating = 'G' AND rental\_duration >= 7;  
  
+-------------------------+  
| title                   |  
+-------------------------+  
| BLANKET BEVERLY         |  
| BORROWERS BEDAZZLED     |  
| BRIDE INTRIGUE          |  
| CATCH AMISTAD           |  
| CITIZEN SHREK           |  
| COLDBLOODED DARLING     |  
| CONTROL ANTHEM          |  
| CRUELTY UNFORGIVEN      |  
| DARN FORRESTER          |  
| DESPERATE TRAINSPOTTING |  
| DIARY PANIC             |  
| DRACULA CRYSTAL         |  
| EMPIRE MALKOVICH        |  
| FIREHOUSE VIETNAM       |  
| GILBERT PELICAN         |  
| GRADUATE LORD           |  
| GREASE YOUTH            |  
| GUN BONNIE              |  
| HOOK CHARIOTS           |  
| MARRIED GO              |  
| MENAGERIE RUSHMORE      |  
| MUSCLE BRIGHT           |  
| OPERATION OPERATION     |  
| PRIMARY GLASS           |  
| REBEL AIRPORT           |  
| SPIKING ELEMENT         |  
| TRUMAN CRAZY            |  
| WAKE JAWS               |  
| WAR NOTTING             |  
+-------------------------+  
29 rows in set (0.00 sec)

In this case, the where clause filtered out 971 of the 1000 rows in the film table. This where clause contains two filter conditions, but you can include as many conditions as are required; individual conditions are separated using operators such as and, or, and not (see [Chapter 4](#Chapter_4__Filtering__Sometimes_2) for a complete discussion of the where clause and filter conditions).

Let’s see what would happen if you change the operator separating the two conditions from and to or:

mysql> SELECT title  
    -> FROM film  
    -> WHERE rating = 'G'   
OR   
rental\_duration >= 7;  
+---------------------------+  
| title                     |  
+---------------------------+  
| ACE GOLDFINGER            |  
| ADAPTATION HOLES          |  
| AFFAIR PREJUDICE          |  
| AFRICAN EGG               |  
| ALAMO VIDEOTAPE           |  
| AMISTAD MIDSUMMER         |  
| ANGELS LIFE               |  
| ANNIE IDENTITY            |  
|... |  
| WATERSHIP FRONTIER        |  
| WEREWOLF LOLA             |  
| WEST LION                 |  
| WESTWARD SEABISCUIT       |  
| WOLVES DESIRE             |  
| WON DARES                 |  
| WORKER TARZAN             |  
| YOUNG LANGUAGE            |  
+---------------------------+  
340 rows in set (0.00 sec)

When you separate conditions using the and operator, all conditions must evaluate to true to be included in the result set; when you use or, however, only one of the conditions needs to evaluate to true for a row to be included, which explains why the size of the result set has jumped from 29 to 340 rows.

So, what should you do if you need to use both and and or operators in your where clause? Glad you asked. You should use parentheses to group conditions together. The next query specifies that only those films that are rated G and are available for 7 or more days, or are rated PG-13 and are available 3 or fewer days, be included in the result set:

mysql> SELECT title, rating, rental\_duration  
    -> FROM film  
    -> WHERE (rating = 'G' AND rental\_duration >= 7)  
    ->   OR (rating = 'PG-13' AND rental\_duration < 4);  
+-------------------------+--------+-----------------+  
| title                   | rating | rental\_duration |  
+-------------------------+--------+-----------------+  
| ALABAMA DEVIL           | PG-13  |               3 |  
| BACKLASH UNDEFEATED     | PG-13  |               3 |  
| BILKO ANONYMOUS         | PG-13  |               3 |  
| BLANKET BEVERLY         | G      |               7 |  
| BORROWERS BEDAZZLED     | G      |               7 |  
| BRIDE INTRIGUE          | G      |               7 |  
| CASPER DRAGONFLY        | PG-13  |               3 |  
| CATCH AMISTAD           | G      |               7 |  
| CITIZEN SHREK           | G      |               7 |  
| COLDBLOODED DARLING     | G      |               7 |  
|... |  
| TREASURE COMMAND        | PG-13  |               3 |  
| TRUMAN CRAZY            | G      |               7 |  
| WAIT CIDER              | PG-13  |               3 |  
| WAKE JAWS               | G      |               7 |  
| WAR NOTTING             | G      |               7 |  
| WORLD LEATHERNECKS      | PG-13  |               3 |  
+-------------------------+--------+-----------------+  
68 rows in set (0.00 sec)

You should always use parentheses to separate groups of conditions when mixing different operators so that you, the database server, and anyone who comes along later to modify your code will be on the same page.

# The group by and having Clauses

All the queries thus far have retrieved raw data without any manipulation. Sometimes, however, you will want to find trends in your data that will require the database server to cook the data a bit before you retrieve your result set. One such mechanism is the group by clause, which is used to group data by column values. For example, let’s say you wanted to find all of the customers who have rented 40 or more films. Rather than looking through all 16,044 rows in the rental table, you can write a query that instructs the server to group all rentals by customer, count the number of rentals for each customer, and then return only those customers whose rental count is at least 40. When using the group by clause to generate groups of rows, you may also use the having clause, which allows you to filter grouped data in the same way the where clause lets you filter raw data.

Here’s what the query looks like:

mysql> SELECT c.first\_name, c.last\_name, count(\*)  
    -> FROM customer c  
    ->   INNER JOIN rental r  
    ->   ON c.customer\_id = r.customer\_id  
    -> GROUP BY c.first\_name, c.last\_name  
    -> HAVING count(\*) >= 40;  
+------------+-----------+----------+  
| first\_name | last\_name | count(\*) |  
+------------+-----------+----------+  
| TAMMY      | SANDERS   |       41 |  
| CLARA      | SHAW      |       42 |  
| ELEANOR    | HUNT      |       46 |  
| SUE        | PETERS    |       40 |  
| MARCIA     | DEAN      |       42 |  
| WESLEY     | BULL      |       40 |  
| KARL       | SEAL      |       45 |  
+------------+-----------+----------+  
7 rows in set (0.03 sec)

I wanted to briefly mention these two clauses so that they don’t catch you by surprise later in the book, but they are a bit more advanced than the other four select clauses. Therefore, I ask that you wait until [Chapter 8](#Chapter_8__Grouping_and_Aggregat_2) for a full description of how and when to use group by and having.

# The order by Clause

In general, the rows in a result set returned from a query are not in any particular order. If you want your result set to be sorted, you will need to instruct the server to sort the results using the order by clause:

The order by clause is the mechanism for sorting your result set using either raw column data or expressions based on column data.

For example, here’s another look at an earlier query that returns all customers who rented a film on June 14, 2005:

mysql> SELECT c.first\_name, c.last\_name,  
    ->   time(r.rental\_date) rental\_time  
    -> FROM customer c  
    ->   INNER JOIN rental r  
    ->   ON c.customer\_id = r.customer\_id  
    -> WHERE date(r.rental\_date) = '2005-06-14';  
+------------+-----------+-------------+  
| first\_name | last\_name | rental\_time |  
+------------+-----------+-------------+  
| JEFFERY    | PINSON    | 22:53:33    |  
| ELMER      | NOE       | 22:55:13    |  
| MINNIE     | ROMERO    | 23:00:34    |  
| MIRIAM     | MCKINNEY  | 23:07:08    |  
| DANIEL     | CABRAL    | 23:09:38    |  
| TERRANCE   | ROUSH     | 23:12:46    |  
| JOYCE      | EDWARDS   | 23:16:26    |  
| GWENDOLYN  | MAY       | 23:16:27    |  
| CATHERINE  | CAMPBELL  | 23:17:03    |  
| MATTHEW    | MAHAN     | 23:25:58    |  
| HERMAN     | DEVORE    | 23:35:09    |  
| AMBER      | DIXON     | 23:42:56    |  
| TERRENCE   | GUNDERSON | 23:47:35    |  
| SONIA      | GREGORY   | 23:50:11    |  
| CHARLES    | KOWALSKI  | 23:54:34    |  
| JEANETTE   | GREENE    | 23:54:46    |  
+------------+-----------+-------------+  
16 rows in set (0.01 sec)

If you would like the results to be in alphabetical order by last name, you can add the last\_name column to the order by clause:

mysql> SELECT c.first\_name, c.last\_name,  
    ->   time(r.rental\_date) rental\_time  
    -> FROM customer c  
    ->   INNER JOIN rental r  
    ->   ON c.customer\_id = r.customer\_id  
    -> WHERE date(r.rental\_date) = '2005-06-14'  
    ->   
ORDER BY c.last\_name  
;  
+------------+-----------+-------------+  
| first\_name | last\_name | rental\_time |  
+------------+-----------+-------------+  
| DANIEL     | CABRAL    | 23:09:38    |  
| CATHERINE  | CAMPBELL  | 23:17:03    |  
| HERMAN     | DEVORE    | 23:35:09    |  
| AMBER      | DIXON     | 23:42:56    |  
| JOYCE      | EDWARDS   | 23:16:26    |  
| JEANETTE   | GREENE    | 23:54:46    |  
| SONIA      | GREGORY   | 23:50:11    |  
| TERRENCE   | GUNDERSON | 23:47:35    |  
| CHARLES    | KOWALSKI  | 23:54:34    |  
| MATTHEW    | MAHAN     | 23:25:58    |  
| GWENDOLYN  | MAY       | 23:16:27    |  
| MIRIAM     | MCKINNEY  | 23:07:08    |  
| ELMER      | NOE       | 22:55:13    |  
| JEFFERY    | PINSON    | 22:53:33    |  
| MINNIE     | ROMERO    | 23:00:34    |  
| TERRANCE   | ROUSH     | 23:12:46    |  
+------------+-----------+-------------+  
16 rows in set (0.01 sec)

While it is not the case in this example, large customer lists will often contain multiple people having the same last name, so you may want to extend the sort criteria to include the person’s first name as well.

You can accomplish this by adding the first\_name column after the last\_name column in the order by clause:

mysql> SELECT c.first\_name, c.last\_name,  
    ->   time(r.rental\_date) rental\_time  
    -> FROM customer c  
    ->   INNER JOIN rental r  
    ->   ON c.customer\_id = r.customer\_id  
    -> WHERE date(r.rental\_date) = '2005-06-14'  
    -> ORDER BY c.last\_name  
, c.first\_name  
;  
+------------+-----------+-------------+  
| first\_name | last\_name | rental\_time |  
+------------+-----------+-------------+  
| DANIEL     | CABRAL    | 23:09:38    |  
| CATHERINE  | CAMPBELL  | 23:17:03    |  
| HERMAN     | DEVORE    | 23:35:09    |  
| AMBER      | DIXON     | 23:42:56    |  
| JOYCE      | EDWARDS   | 23:16:26    |  
| JEANETTE   | GREENE    | 23:54:46    |  
| SONIA      | GREGORY   | 23:50:11    |  
| TERRENCE   | GUNDERSON | 23:47:35    |  
| CHARLES    | KOWALSKI  | 23:54:34    |  
| MATTHEW    | MAHAN     | 23:25:58    |  
| GWENDOLYN  | MAY       | 23:16:27    |  
| MIRIAM     | MCKINNEY  | 23:07:08    |  
| ELMER      | NOE       | 22:55:13    |  
| JEFFERY    | PINSON    | 22:53:33    |  
| MINNIE     | ROMERO    | 23:00:34    |  
| TERRANCE   | ROUSH     | 23:12:46    |  
+------------+-----------+-------------+  
16 rows in set (0.01 sec)

The order in which columns appear in your order by clause does make a difference when you include more than one column. If you were to switch the order of the two columns in the order by clause, Amber Dixon would appear first in the result set.

## Ascending Versus Descending Sort Order

When sorting, you have the option of specifying ascending or descending order via the asc and desc keywords. The default is ascending, so you will need to add the desc keyword if you want to use a descending sort. For example, the following query shows all customers who rented films on June 14, 2005, in descending order of rental time:

mysql> SELECT c.first\_name, c.last\_name,  
    ->   time(r.rental\_date) rental\_time  
    -> FROM customer c  
    ->   INNER JOIN rental r  
    ->   ON c.customer\_id = r.customer\_id  
    -> WHERE date(r.rental\_date) = '2005-06-14'  
    -> ORDER BY time(r.rental\_date)   
desc  
;  
+------------+-----------+-------------+  
| first\_name | last\_name | rental\_time |  
+------------+-----------+-------------+  
| JEANETTE   | GREENE    | 23:54:46    |  
| CHARLES    | KOWALSKI  | 23:54:34    |  
| SONIA      | GREGORY   | 23:50:11    |  
| TERRENCE   | GUNDERSON | 23:47:35    |  
| AMBER      | DIXON     | 23:42:56    |  
| HERMAN     | DEVORE    | 23:35:09    |  
| MATTHEW    | MAHAN     | 23:25:58    |  
| CATHERINE  | CAMPBELL  | 23:17:03    |  
| GWENDOLYN  | MAY       | 23:16:27    |  
| JOYCE      | EDWARDS   | 23:16:26    |  
| TERRANCE   | ROUSH     | 23:12:46    |  
| DANIEL     | CABRAL    | 23:09:38    |  
| MIRIAM     | MCKINNEY  | 23:07:08    |  
| MINNIE     | ROMERO    | 23:00:34    |  
| ELMER      | NOE       | 22:55:13    |  
| JEFFERY    | PINSON    | 22:53:33    |  
+------------+-----------+-------------+  
16 rows in set (0.01 sec)

Descending sorts are commonly used for ranking queries, such as “show me the top five account balances.” MySQL includes a limit clause that allows you to sort your data and then discard all but the first X rows.

## Sorting via Numeric Placeholders

If you are sorting using the columns in your select clause, you can opt to reference the columns by their position in the select clause rather than by name. This can be especially helpful if you are sorting on an expression, such as in the previous example. Here’s the previous example one last time, with an order by clause specifying a descending sort using the third element in the select clause:

mysql> SELECT c.first\_name, c.last\_name,  
    ->   time(r.rental\_date) rental\_time  
    -> FROM customer c  
    ->   INNER JOIN rental r  
    ->   ON c.customer\_id = r.customer\_id  
    -> WHERE date(r.rental\_date) = '2005-06-14'  
    ->   
ORDER BY 3  
 desc;  
+------------+-----------+-------------+  
| first\_name | last\_name | rental\_time |  
+------------+-----------+-------------+  
| JEANETTE   | GREENE    | 23:54:46    |  
| CHARLES    | KOWALSKI  | 23:54:34    |  
| SONIA      | GREGORY   | 23:50:11    |  
| TERRENCE   | GUNDERSON | 23:47:35    |  
| AMBER      | DIXON     | 23:42:56    |  
| HERMAN     | DEVORE    | 23:35:09    |  
| MATTHEW    | MAHAN     | 23:25:58    |  
| CATHERINE  | CAMPBELL  | 23:17:03    |  
| GWENDOLYN  | MAY       | 23:16:27    |  
| JOYCE      | EDWARDS   | 23:16:26    |  
| TERRANCE   | ROUSH     | 23:12:46    |  
| DANIEL     | CABRAL    | 23:09:38    |  
| MIRIAM     | MCKINNEY  | 23:07:08    |  
| MINNIE     | ROMERO    | 23:00:34    |  
| ELMER      | NOE       | 22:55:13    |  
| JEFFERY    | PINSON    | 22:53:33    |  
+------------+-----------+-------------+  
16 rows in set (0.01 sec)

You might want to use this feature sparingly, since adding a column to the select clause without changing the numbers in the order by clause can lead to unexpected results. Personally, I may reference columns positionally when writing ad hoc queries, but I always reference columns by name when writing code.

# Test Your Knowledge

The following exercises are designed to strengthen your understanding of the select statement and its various clauses. Please see [Appendix B](#Appendix_B__Solutions_to_Exercis_2) for solutions.

## Exercise 3-1

Retrieve the actor ID, first name, and last name for all actors. Sort by last name and then by first name.

## Exercise 3-2

Retrieve the actor ID, first name, and last name for all actors whose last name equals 'WILLIAMS' or 'DAVIS'.

## Exercise 3-3

Write a query against the rental table that returns the IDs of the customers who rented a film on July 5, 2005 (use the rental.rental\_date column, and you can use the date() function to ignore the time component). Include a single row for each distinct customer ID.

## Exercise 3-4

Fill in the blanks (denoted by <#>) for this multitable query to achieve the following results:

mysql> SELECT c.email, r.return\_date  
    -> FROM customer c  
    ->   INNER JOIN rental <1>  
    ->   ON c.customer\_id = <2>  
    -> WHERE date(r.rental\_date) = '2005-06-14'  
    -> ORDER BY <3> <4>;  
+---------------------------------------+---------------------+  
| email                                 | return\_date         |  
+---------------------------------------+---------------------+  
| DANIEL.CABRAL@sakilacustomer.org      | 2005-06-23 22:00:38 |  
| TERRANCE.ROUSH@sakilacustomer.org     | 2005-06-23 21:53:46 |  
| MIRIAM.MCKINNEY@sakilacustomer.org    | 2005-06-21 17:12:08 |  
| GWENDOLYN.MAY@sakilacustomer.org      | 2005-06-20 02:40:27 |  
| JEANETTE.GREENE@sakilacustomer.org    | 2005-06-19 23:26:46 |  
| HERMAN.DEVORE@sakilacustomer.org      | 2005-06-19 03:20:09 |  
| JEFFERY.PINSON@sakilacustomer.org     | 2005-06-18 21:37:33 |  
| MATTHEW.MAHAN@sakilacustomer.org      | 2005-06-18 05:18:58 |  
| MINNIE.ROMERO@sakilacustomer.org      | 2005-06-18 01:58:34 |  
| SONIA.GREGORY@sakilacustomer.org      | 2005-06-17 21:44:11 |  
| TERRENCE.GUNDERSON@sakilacustomer.org | 2005-06-17 05:28:35 |  
| ELMER.NOE@sakilacustomer.org          | 2005-06-17 02:11:13 |  
| JOYCE.EDWARDS@sakilacustomer.org      | 2005-06-16 21:00:26 |  
| AMBER.DIXON@sakilacustomer.org        | 2005-06-16 04:02:56 |  
| CHARLES.KOWALSKI@sakilacustomer.org   | 2005-06-16 02:26:34 |  
| CATHERINE.CAMPBELL@sakilacustomer.org | 2005-06-15 20:43:03 |  
+---------------------------------------+---------------------+  
16 rows in set (0.03 sec)

# Chapter 4. Filtering

Sometimes you will want to work with every row in a table, such as:

* Purging all data from a table used to stage new data warehouse feeds
* Modifying all rows in a table after a new column has been added
* Retrieving all rows from a message queue table

In cases like these, your SQL statements won’t need to have a where clause, since you don’t need to exclude any rows from consideration. Most of the time, however, you will want to narrow your focus to a subset of a table’s rows. Therefore, all the SQL data statements (except the insert statement) include an optional where clause containing one or more filter conditions used to restrict the number of rows acted on by the SQL statement. Additionally, the select statement includes a having clause in which filter conditions pertaining to grouped data may be included. This chapter explores the various types of filter conditions that you can employ in the where clauses of select, update, and delete statements; I demonstrate the use of filter conditions in the having clause of a select statement in [Chapter 8](#Chapter_8__Grouping_and_Aggregat_2).

# Condition Evaluation

A where clause may contain one or more conditions, separated by the operators and and or. If multiple conditions are separated only by the and operator, then all the conditions must evaluate to true for the row to be included in the result set. Consider the following where clause:

WHERE first\_name = 'STEVEN' AND create\_date > '2006-01-01'

Given these two conditions, only rows where the first name is Steven and the creation date was after January 1, 2006, will be included in the result set. Though this example uses only two conditions, no matter how many conditions are in your where clause, if they are separated by the and operator, they must all evaluate to true for the row to be included in the result set.

If all conditions in the where clause are separated by the or operator, however, only one of the conditions must evaluate to true for the row to be included in the result set. Consider the following two conditions:

WHERE first\_name = 'STEVEN' OR create\_date > '2006-01-01'

There are now various ways for a given row to be included in the result set:

* The first name is Steven, and the creation date was after January 1, 2006.
* The first name is Steven, and the creation date was on or before January 1, 2006.
* The first name is anything other than Steven, but the creation date was after January 1, 2006.

[Table 4-1](#Table_4_1__Two_condition_evaluat) shows the possible outcomes for a where clause containing two conditions separated by the or operator.

|  |  |
| --- | --- |
| Table 4-1. Two-condition evaluation using or  Intermediate result | Final result |

|  |  |
| --- | --- |
| WHERE true OR true | true |

|  |  |
| --- | --- |
| WHERE true OR false | true |

|  |  |
| --- | --- |
| WHERE false OR true | true |

|  |  |
| --- | --- |
| WHERE false OR false | false |

In the case of the preceding example, the only way for a row to be excluded from the result set is if the person’s first name was not Steven and the creation date was on or before January 1, 2006.

## Using Parentheses

If your where clause includes three or more conditions using both the and and or operators, you should use parentheses to make your intent clear, both to the database server and to anyone else reading your code. Here’s a where clause that extends the previous example by checking to make sure that the first name is Steven or the last name is Young, and the creation date is after January 1, 2006:

WHERE (first\_name = 'STEVEN' OR last\_name = 'YOUNG')  
  AND create\_date > '2006-01-01'

There are now three conditions; for a row to make it to the final result set, either the first or second condition (or both) must evaluate to true, and the third condition must evaluate to true. [Table 4-2](#Table_4_2__Three_condition_evalu) shows the possible outcomes for this where clause.

|  |  |
| --- | --- |
| Table 4-2. Three-condition evaluation using and, or  Intermediate result | Final result |

|  |  |
| --- | --- |
| WHERE (true OR true) AND true | true |

|  |  |
| --- | --- |
| WHERE (true OR false) AND true | true |

|  |  |
| --- | --- |
| WHERE (false OR true) AND true | true |

|  |  |
| --- | --- |
| WHERE (false OR false) AND true | false |

|  |  |
| --- | --- |
| WHERE (true OR true) AND false | false |

|  |  |
| --- | --- |
| WHERE (true OR false) AND false | false |

|  |  |
| --- | --- |
| WHERE (false OR true) AND false | false |

|  |  |
| --- | --- |
| WHERE (false OR false) AND false | false |

As you can see, the more conditions you have in your where clause, the more combinations there are for the server to evaluate. In this case, only three of the eight combinations yield a final result of true.

## Using the not Operator

Hopefully, the previous three-condition example is fairly easy to understand. Consider the following modification, however:

WHERE   
NOT  
 (first\_name = 'STEVEN' OR last\_name = 'YOUNG')  
  AND create\_date > '2006-01-01'

Did you spot the change from the previous example? I added the not operator before the first set of conditions. Now, instead of looking for people with the first name of Steven or the last name of Young whose record was created after January 1, 2006, I am retrieving only rows where the first name is not Steven or the last name is not Young whose record was created after January 1, 2006. [Table 4-3](#Table_4_3__Three_condition_evalu) shows the possible outcomes for this example.

|  |  |
| --- | --- |
| Table 4-3. Three-condition evaluation using and, or, and not  Intermediate result | Final result |

|  |  |
| --- | --- |
| WHERE NOT (true OR true) AND true | false |

|  |  |
| --- | --- |
| WHERE NOT (true OR false) AND true | false |

|  |  |
| --- | --- |
| WHERE NOT (false OR true) AND true | false |

|  |  |
| --- | --- |
| WHERE NOT (false OR false) AND true | true |

|  |  |
| --- | --- |
| WHERE NOT (true OR true) AND false | false |

|  |  |
| --- | --- |
| WHERE NOT (true OR false) AND false | false |

|  |  |
| --- | --- |
| WHERE NOT (false OR true) AND false | false |

|  |  |
| --- | --- |
| WHERE NOT (false OR false) AND false | false |

While it is easy for the database server to handle, it is typically difficult for a person to evaluate a where clause that includes the not operator, which is why you won’t encounter it very often. In this case, you can rewrite the where clause to avoid using the not operator:

WHERE first\_name <> 'STEVEN' AND last\_name <> 'YOUNG'  
  AND create\_date > '2006-01-01'

While I’m sure that the server doesn’t have a preference, you probably have an easier time understanding this version of the where clause.

# Building a Condition

Now that you have seen how the server evaluates multiple conditions, let’s take a step back and look at what comprises a single condition. A condition is made up of one or more expressions combined with one or more operators. An expression can be any of the following:

* A number
* A column in a table or view
* A string literal, such as 'Maple Street'
* A built-in function, such as concat('Learning', ' ', 'SQL')
* A subquery
* A list of expressions, such as ('Boston', 'New York', 'Chicago')

The operators used within conditions include:

* Comparison operators, such as =, !=, <, >, <>, like, in, and between
* Arithmetic operators, such as +, −, \*, and /

The following section demonstrates how you can combine these expressions and operators to manufacture the various types of conditions.

# Condition Types

There are many different ways to filter out unwanted data. You can look for specific values, sets of values, or ranges of values to include or exclude, or you can use various pattern-searching techniques to look for partial matches when dealing with string data. The next four subsections explore each of these condition types in detail.

## Equality Conditions

A large percentage of the filter conditions that you write or come across will be of the form 'column = expression' as in:

title = 'RIVER OUTLAW'  
fed\_id = '111-11-1111'  
amount = 375.25  
film\_id = (SELECT film\_id FROM film WHERE title = 'RIVER OUTLAW')

Conditions such as these are called equality conditions because they equate one expression to another. The first three examples equate a column to a literal (two strings and a number), and the fourth example equates a column to the value returned from a subquery. The following query uses two equality conditions, one in the on clause (a join condition) and the other in the where clause (a filter condition):

mysql> SELECT c.email  
    -> FROM customer c  
    ->   INNER JOIN rental r  
    ->   ON c.customer\_id = r.customer\_id  
    -> WHERE date(r.rental\_date) = '2005-06-14';  
+---------------------------------------+  
| email                                 |  
+---------------------------------------+  
| CATHERINE.CAMPBELL@sakilacustomer.org |  
| JOYCE.EDWARDS@sakilacustomer.org      |  
| AMBER.DIXON@sakilacustomer.org        |  
| JEANETTE.GREENE@sakilacustomer.org    |  
| MINNIE.ROMERO@sakilacustomer.org      |  
| GWENDOLYN.MAY@sakilacustomer.org      |  
| SONIA.GREGORY@sakilacustomer.org      |  
| MIRIAM.MCKINNEY@sakilacustomer.org    |  
| CHARLES.KOWALSKI@sakilacustomer.org   |  
| DANIEL.CABRAL@sakilacustomer.org      |  
| MATTHEW.MAHAN@sakilacustomer.org      |  
| JEFFERY.PINSON@sakilacustomer.org     |  
| HERMAN.DEVORE@sakilacustomer.org      |  
| ELMER.NOE@sakilacustomer.org          |  
| TERRANCE.ROUSH@sakilacustomer.org     |  
| TERRENCE.GUNDERSON@sakilacustomer.org |  
+---------------------------------------+  
16 rows in set (0.03 sec)

This query shows all email addresses of every customer who rented a film on June 14, 2005.

## Inequality conditions

Another fairly common type of condition is the inequality condition, which asserts that two expressions are not equal. Here’s the previous query with the filter condition in the where clause changed to an inequality condition:

mysql> SELECT c.email  
    -> FROM customer c  
    ->   INNER JOIN rental r  
    ->   ON c.customer\_id = r.customer\_id  
    -> WHERE date(r.rental\_date) <> '2005-06-14';  
  
+-----------------------------------+  
| email                         |  
+-----------------------------------+  
| MARY.SMITH@sakilacustomer.org |  
| MARY.SMITH@sakilacustomer.org |  
| MARY.SMITH@sakilacustomer.org |  
| MARY.SMITH@sakilacustomer.org |  
| MARY.SMITH@sakilacustomer.org |  
| MARY.SMITH@sakilacustomer.org |  
| MARY.SMITH@sakilacustomer.org |  
| MARY.SMITH@sakilacustomer.org |  
| MARY.SMITH@sakilacustomer.org |  
| MARY.SMITH@sakilacustomer.org |  
...  
| AUSTIN.CINTRON@sakilacustomer.org |  
| AUSTIN.CINTRON@sakilacustomer.org |  
| AUSTIN.CINTRON@sakilacustomer.org |  
| AUSTIN.CINTRON@sakilacustomer.org |  
| AUSTIN.CINTRON@sakilacustomer.org |  
| AUSTIN.CINTRON@sakilacustomer.org |  
| AUSTIN.CINTRON@sakilacustomer.org |  
| AUSTIN.CINTRON@sakilacustomer.org |  
+-----------------------------------+  
16028 rows in set (0.03 sec)

This query returns all email addresses for films rented on any other date than June 14, 2005. When building inequality conditions, you may choose to use either the != or <> operator.

## Data modification using equality conditions

Equality/inequality conditions are commonly used when modifying data. For example, let’s say that the movie rental company has a policy of removing old account rows once per year. Your task is to remove rows from the rental table where the rental date was in 2004. Here’s one way to tackle it:

DELETE FROM rental  
WHERE year(rental\_date) = 2004;

This statement includes a single equality condition; here’s an example that uses two inequality conditions to remove any rows where the rental date was not in 2005 or 2006:

DELETE FROM rental  
WHERE year(rental\_date) <> 2005 AND year(rental\_date) <> 2006;

##### Note

When crafting examples of delete and update statements, I try to write each statement such that no rows are modified. That way, when you execute the statements, your data will remain unchanged, and your output from select statements will always match that shown in this book.

Since MySQL sessions are in auto-commit mode by default (see [Chapter 12](#Chapter_12__Transactions__All_of_2)), you would not be able to roll back (undo) any changes made to the example data if one of my statements modified the data. You may, of course, do whatever you want with the example data, including wiping it clean and rerunning the scripts to populate the tables, but I try to leave it intact.

## Range Conditions

Along with checking that an expression is equal to (or not equal to) another expression, you can build conditions that check whether an expression falls within a certain range. This type of condition is common when working with numeric or temporal data. Consider the following query:

mysql> SELECT customer\_id, rental\_date  
    -> FROM rental  
    -> WHERE rental\_date < '2005-05-25';  
+-------------+---------------------+  
| customer\_id | rental\_date         |  
+-------------+---------------------+  
|         130 | 2005-05-24 22:53:30 |  
|         459 | 2005-05-24 22:54:33 |  
|         408 | 2005-05-24 23:03:39 |  
|         333 | 2005-05-24 23:04:41 |  
|         222 | 2005-05-24 23:05:21 |  
|         549 | 2005-05-24 23:08:07 |  
|         269 | 2005-05-24 23:11:53 |  
|         239 | 2005-05-24 23:31:46 |  
+-------------+---------------------+  
8 rows in set (0.00 sec)

This query finds all film rentals prior to May 25, 2005. As well as specifying an upper limit for the rental date, you may also want to specify a lower range:

mysql> SELECT customer\_id, rental\_date  
    -> FROM rental  
    -> WHERE rental\_date <= '2005-06-16'  
    ->   AND rental\_date >= '2005-06-14';  
+-------------+---------------------+  
| customer\_id | rental\_date         |  
+-------------+---------------------+  
|         416 | 2005-06-14 22:53:33 |  
|         516 | 2005-06-14 22:55:13 |  
|         239 | 2005-06-14 23:00:34 |  
|         285 | 2005-06-14 23:07:08 |  
|         310 | 2005-06-14 23:09:38 |  
|         592 | 2005-06-14 23:12:46 |  
...  
|         148 | 2005-06-15 23:20:26 |  
|         237 | 2005-06-15 23:36:37 |  
|         155 | 2005-06-15 23:55:27 |  
|         341 | 2005-06-15 23:57:20 |  
|         149 | 2005-06-15 23:58:53 |  
+-------------+---------------------+  
364 rows in set (0.00 sec)

This version of the query retrieves all films rented on June 14 or 15 of 2005.

## The between operator

When you have both an upper and lower limit for your range, you may choose to use a single condition that utilizes the between operator rather than using two separate conditions, as in:

mysql> SELECT customer\_id, rental\_date  
    -> FROM rental  
    -> WHERE rental\_date BETWEEN '2005-06-14' AND '2005-06-16';  
+-------------+---------------------+  
| customer\_id | rental\_date         |  
+-------------+---------------------+  
|         416 | 2005-06-14 22:53:33 |  
|         516 | 2005-06-14 22:55:13 |  
|         239 | 2005-06-14 23:00:34 |  
|         285 | 2005-06-14 23:07:08 |  
|         310 | 2005-06-14 23:09:38 |  
|         592 | 2005-06-14 23:12:46 |  
...  
|         148 | 2005-06-15 23:20:26 |  
|         237 | 2005-06-15 23:36:37 |  
|         155 | 2005-06-15 23:55:27 |  
|         341 | 2005-06-15 23:57:20 |  
|         149 | 2005-06-15 23:58:53 |  
+-------------+---------------------+  
364 rows in set (0.00 sec)

When using the between operator, there are a couple of things to keep in mind. You should always specify the lower limit of the range first (after between) and the upper limit of the range second (after and). Here’s what happens if you mistakenly specify the upper limit first:

mysql> SELECT customer\_id, rental\_date  
    -> FROM rental  
    -> WHERE rental\_date BETWEEN '2005-06-16' AND '2005-06-14';  
Empty set (0.00 sec)

As you can see, no data is returned. This is because the server is, in effect, generating two conditions from your single condition using the <= and >= operators, as in:

SELECT customer\_id, rental\_date  
    -> FROM rental  
    -> WHERE rental\_date >= '2005-06-16'   
  -> AND rental\_date <= '2005-06-14';  
Empty set (0.00 sec)

Since it is impossible to have a date that is both greater than June 16, 2005, and less than June 14, 2005, the query returns an empty set. This brings me to the second pitfall when using between, which is to remember that your upper and lower limits are inclusive, meaning that the values you provide are included in the range limits. In this case, I want to return any films rented on June 14 or 15, so I specify 2005-06-14 as the lower end of the range and 2005-06-16 as the upper end. Since I am not specifying the time component of the date, the time defaults to midnight, so the effective range is 2005-06-14 00:00:00 to 2005-06-16 00:00:00, which will include any rentals made on June 14 or 15.

Along with dates, you can also build conditions to specify ranges of numbers. Numeric ranges are fairly easy to grasp, as demonstrated by the following:

mysql> SELECT customer\_id, payment\_date, amount  
    -> FROM payment  
    -> WHERE amount BETWEEN 10.0 AND 11.99;  
+-------------+---------------------+--------+  
| customer\_id | payment\_date        | amount |  
+-------------+---------------------+--------+  
|           2 | 2005-07-30 13:47:43 |  10.99 |  
|           3 | 2005-07-27 20:23:12 |  10.99 |  
|          12 | 2005-08-01 06:50:26 |  10.99 |  
|          13 | 2005-07-29 22:37:41 |  11.99 |  
|          21 | 2005-06-21 01:04:35 |  10.99 |  
|          29 | 2005-07-09 21:55:19 |  10.99 |  
...  
|         571 | 2005-06-20 08:15:27 |  10.99 |  
|         572 | 2005-06-17 04:05:12 |  10.99 |  
|         573 | 2005-07-31 12:14:19 |  10.99 |  
|         591 | 2005-07-07 20:45:51 |  11.99 |  
|         592 | 2005-07-06 22:58:31 |  11.99 |  
|         595 | 2005-07-31 11:51:46 |  10.99 |  
+-------------+---------------------+--------+  
114 rows in set (0.01 sec)

All payments between $10 and $11.99 are returned. Again, make sure that you specify the lower amount first.

## String ranges

While ranges of dates and numbers are easy to understand, you can also build conditions that search for ranges of strings, which are a bit harder to visualize. Say, for example, you are searching for customers whose last name falls within a range. Here’s a query that returns customers whose last name falls between FA and FR:

mysql> SELECT last\_name, first\_name  
    -> FROM customer  
    -> WHERE last\_name BETWEEN 'FA' AND 'FR';  
+------------+------------+  
| last\_name  | first\_name |  
+------------+------------+  
| FARNSWORTH | JOHN       |  
| FENNELL    | ALEXANDER  |  
| FERGUSON   | BERTHA     |  
| FERNANDEZ  | MELINDA    |  
| FIELDS     | VICKI      |  
| FISHER     | CINDY      |  
| FLEMING    | MYRTLE     |  
| FLETCHER   | MAE        |  
| FLORES     | JULIA      |  
| FORD       | CRYSTAL    |  
| FORMAN     | MICHEAL    |  
| FORSYTHE   | ENRIQUE    |  
| FORTIER    | RAUL       |  
| FORTNER    | HOWARD     |  
| FOSTER     | PHYLLIS    |  
| FOUST      | JACK       |  
| FOWLER     | JO         |  
| FOX        | HOLLY      |  
+------------+------------+  
18 rows in set (0.00 sec)

While there are five customers whose last name starts with FR, they are not included in the results, since a name like FRANKLIN is outside of the range. However, we can pick up four of the five customers by extending the righthand range to FRB:

mysql> SELECT last\_name, first\_name  
    -> FROM customer  
    -> WHERE last\_name BETWEEN 'FA' AND 'FRB';  
+------------+------------+  
| last\_name  | first\_name |  
+------------+------------+  
| FARNSWORTH | JOHN       |  
| FENNELL    | ALEXANDER  |  
| FERGUSON   | BERTHA     |  
| FERNANDEZ  | MELINDA    |  
| FIELDS     | VICKI      |  
| FISHER     | CINDY      |  
| FLEMING    | MYRTLE     |  
| FLETCHER   | MAE        |  
| FLORES     | JULIA      |  
| FORD       | CRYSTAL    |  
| FORMAN     | MICHEAL    |  
| FORSYTHE   | ENRIQUE    |  
| FORTIER    | RAUL       |  
| FORTNER    | HOWARD     |  
| FOSTER     | PHYLLIS    |  
| FOUST      | JACK       |  
| FOWLER     | JO         |  
| FOX        | HOLLY      |  
| FRALEY     | JUAN       |  
| FRANCISCO  | JOEL       |  
| FRANKLIN   | BETH       |  
| FRAZIER    | GLENDA     |  
+------------+------------+  
22 rows in set (0.00 sec)

To work with string ranges, you need to know the order of the characters within your character set (the order in which the characters within a character set are sorted is called a collation).

## Membership Conditions

In some cases, you will not be restricting an expression to a single value or range of values but rather to a finite set of values. For example, you might want to locate all films that have a rating of either 'G' or 'PG':

mysql> SELECT title, rating  
    -> FROM film  
    -> WHERE rating = 'G' OR rating = 'PG';  
+---------------------------+--------+  
| title                     | rating |  
+---------------------------+--------+  
| ACADEMY DINOSAUR          | PG     |  
| ACE GOLDFINGER            | G      |  
| AFFAIR PREJUDICE          | G      |  
| AFRICAN EGG               | G      |  
| AGENT TRUMAN              | PG     |  
| ALAMO VIDEOTAPE           | G      |  
| ALASKA PHANTOM            | PG     |  
| ALI FOREVER               | PG     |  
| AMADEUS HOLY              | PG     |  
...  
| WEDDING APOLLO            | PG     |  
| WEREWOLF LOLA             | G      |  
| WEST LION                 | G      |  
| WIZARD COLDBLOODED        | PG     |  
| WON DARES                 | PG     |  
| WONDERLAND CHRISTMAS      | PG     |  
| WORDS HUNTER              | PG     |  
| WORST BANGER              | PG     |  
| YOUNG LANGUAGE            | G      |  
+---------------------------+--------+  
372 rows in set (0.00 sec)

While this where clause (two conditions or’d together) wasn’t too tedious to generate, imagine if the set of expressions contained 10 or 20 members. For these situations, you can use the in operator instead:

SELECT title, rating  
FROM film  
WHERE rating IN ('G','PG');

With the in operator, you can write a single condition no matter how many expressions are in the set.

## Using subqueries

Along with writing your own set of expressions, such as ('G','PG'), you can use a subquery to generate a set for you on the fly. For example, if you can assume that any film whose title includes the string 'PET' would be safe for family viewing, you could execute a subquery against the film table to retrieve all ratings associated with these films and then retrieve all films having any of these ratings:

mysql> SELECT title, rating  
    -> FROM film  
    -> WHERE rating IN (SELECT rating FROM film WHERE title LIKE '%PET%');  
+---------------------------+--------+  
| title                     | rating |  
+---------------------------+--------+  
| ACADEMY DINOSAUR          | PG     |  
| ACE GOLDFINGER            | G      |  
| AFFAIR PREJUDICE          | G      |  
| AFRICAN EGG               | G      |  
| AGENT TRUMAN              | PG     |  
| ALAMO VIDEOTAPE           | G      |  
| ALASKA PHANTOM            | PG     |  
| ALI FOREVER               | PG     |  
| AMADEUS HOLY              | PG     |  
...  
| WEDDING APOLLO            | PG     |  
| WEREWOLF LOLA             | G      |  
| WEST LION                 | G      |  
| WIZARD COLDBLOODED        | PG     |  
| WON DARES                 | PG     |  
| WONDERLAND CHRISTMAS      | PG     |  
| WORDS HUNTER              | PG     |  
| WORST BANGER              | PG     |  
| YOUNG LANGUAGE            | G      |  
+---------------------------+--------+  
372 rows in set (0.00 sec)

The subquery returns the set 'G' and 'PG', and the main query checks to see whether the value of the rating column can be found in the set returned by the subquery.

## Using not in

Sometimes you want to see whether a particular expression exists within a set of expressions, and sometimes you want to see whether the expression does not exist within the set. For these situations, you can use the not in operator:

SELECT title, rating  
FROM film  
WHERE rating NOT IN ('PG-13','R', 'NC-17');

This query finds all accounts that are not rated 'PG-13' ,'R', or 'NC-17', which will return the same set of 372 rows as the previous queries.

## Matching Conditions

So far, you have been introduced to conditions that identify an exact string, a range of strings, or a set of strings; the final condition type deals with partial string matches. You may, for example, want to find all customers whose last name begins with Q. You could use a built-in function to strip off the first letter of the last\_name column, as in the following:

mysql> SELECT last\_name, first\_name  
    -> FROM customer  
    -> WHERE left(last\_name, 1) = 'Q';  
+-------------+------------+  
| last\_name   | first\_name |  
+-------------+------------+  
| QUALLS      | STEPHEN    |  
| QUINTANILLA | ROGER      |  
| QUIGLEY     | TROY       |  
+-------------+------------+  
3 rows in set (0.00 sec)

While the built-in function left() does the job, it doesn’t give you much flexibility. Instead, you can use wildcard characters to build search expressions, as demonstrated in the next section.

## Using wildcards

When searching for partial string matches, you might be interested in:

* Strings beginning/ending with a certain character
* Strings beginning/ending with a substring
* Strings containing a certain character anywhere within the string
* Strings containing a substring anywhere within the string
* Strings with a specific format, regardless of individual characters

You can build search expressions to identify these and many other partial string matches by using the wildcard characters shown in [Table 4-4](#Table_4_4__Wildcard_characters).

|  |  |
| --- | --- |
| Table 4-4. Wildcard characters  Wildcard character | Matches |

|  |  |
| --- | --- |
| \_ | Exactly one character |

|  |  |
| --- | --- |
| % | Any number of characters (including 0) |

The underscore character takes the place of a single character, while the percent sign can take the place of a variable number of characters. When building conditions that utilize search expressions, you use the like operator, as in:

mysql> SELECT last\_name, first\_name  
    -> FROM customer  
    -> WHERE last\_name LIKE '\_A\_T%S';  
+-----------+------------+  
| last\_name | first\_name |  
+-----------+------------+  
| MATTHEWS  | ERICA      |  
| WALTERS   | CASSANDRA  |  
| WATTS     | SHELLY     |  
+-----------+------------+  
3 rows in set (0.00 sec)

The search expression in the previous example specifies strings containing an A in the second position and a T in the fourth position, followed by any number of characters and ending in S. [Table 4-5](#Table_4_5__Sample_search_express) shows some more search expressions and their interpretations.

|  |  |
| --- | --- |
| Table 4-5. Sample search expressions  Search expression | Interpretation |

|  |  |
| --- | --- |
| F% | Strings beginning with F |

|  |  |
| --- | --- |
| %t | Strings ending with t |

|  |  |
| --- | --- |
| %bas% | Strings containing the substring 'bas' |

|  |  |
| --- | --- |
| \_ \_t\_ | Four-character strings with a t in the third position |

|  |  |
| --- | --- |
| \_ \_ \_-\_ \_-\_ \_ \_ \_ | 11-character strings with dashes in the fourth and seventh positions |

The wildcard characters work fine for building simple search expressions; if your needs are a bit more sophisticated, however, you can use multiple search expressions, as demonstrated by the following:

mysql> SELECT last\_name, first\_name  
    -> FROM customer  
    -> WHERE last\_name LIKE 'Q%' OR last\_name LIKE 'Y%';  
+-------------+------------+  
| last\_name   | first\_name |  
+-------------+------------+  
| QUALLS      | STEPHEN    |  
| QUIGLEY     | TROY       |  
| QUINTANILLA | ROGER      |  
| YANEZ       | LUIS       |  
| YEE         | MARVIN     |  
| YOUNG       | CYNTHIA    |  
+-------------+------------+  
6 rows in set (0.00 sec)

This query finds all customers whose last name begins with Q or Y.

## Using regular expressions

If you find that the wildcard characters don’t provide enough flexibility, you can use regular expressions to build search expressions. A regular expression is, in essence, a search expression on steroids. If you are new to SQL but have coded using programming languages such as Perl, then you might already be intimately familiar with regular expressions. If you have never used regular expressions, then you may want to consult Jeffrey E. F. Friedl’s [Mastering Regular Expressions](http://oreilly.com/catalog/9780596528126/) (O’Reilly), since it is far too large a topic to try to cover in this book.

Here’s what the previous query (find all customers whose last name starts with Q or Y) would look like using the MySQL implementation of regular expressions:

mysql> SELECT last\_name, first\_name  
    -> FROM customer  
    -> WHERE last\_name REGEXP '^[QY]';  
+-------------+------------+  
| last\_name   | first\_name |  
+-------------+------------+  
| YOUNG       | CYNTHIA    |  
| QUALLS      | STEPHEN    |  
| QUINTANILLA | ROGER      |  
| YANEZ       | LUIS       |  
| YEE         | MARVIN     |  
| QUIGLEY     | TROY       |  
+-------------+------------+  
6 rows in set (0.16 sec)

The regexp operator takes a regular expression ('^[QY]' in this example) and applies it to the expression on the lefthand side of the condition (the column last\_name). The query now contains a single condition using a regular expression rather than two conditions using wildcard characters.

Both Oracle Database and Microsoft SQL Server also support regular expressions. With Oracle Database, you would use the regexp\_like function instead of the regexp operator shown in the previous example, whereas SQL Server allows regular expressions to be used with the like operator.

# Null: That Four-Letter Word

I put it off as long as I could, but it’s time to broach a topic that tends to be met with fear, uncertainty, and dread: the null value. null is the absence of a value; before an employee is terminated, for example, her end\_date column in the employee table should be null. There is no value that can be assigned to the end\_date column that would make sense in this situation. null is a bit slippery, however, as there are various flavors of null:

Not applicable

Such as the employee ID column for a transaction that took place at an ATM machine

Value not yet known

Such as when the federal ID is not known at the time a customer row is created

Value undefined

Such as when an account is created for a product that has not yet been added to the database

##### Note

Some theorists argue that there should be a different expression to cover each of these (and more) situations, but most practitioners would agree that having multiple null values would be far too confusing.

When working with null, you should remember:

* An expression can be null, but it can never equal null.
* Two nulls are never equal to each other.

To test whether an expression is null, you need to use the is null operator, as demonstrated by the following:

mysql> SELECT rental\_id, customer\_id  
    -> FROM rental  
    -> WHERE return\_date IS NULL;  
+-----------+-------------+  
| rental\_id | customer\_id |  
+-----------+-------------+  
|     11496 |         155 |  
|     11541 |         335 |  
|     11563 |          83 |  
|     11577 |         219 |  
|     11593 |          99 |  
...  
|     15867 |         505 |  
|     15875 |          41 |  
|     15894 |         168 |  
|     15966 |         374 |  
+-----------+-------------+  
183 rows in set (0.01 sec)

This query finds all film rentals that were never returned. Here’s the same query using = null instead of is null:

mysql> SELECT rental\_id, customer\_id  
    -> FROM rental  
    -> WHERE return\_date = NULL;  
Empty set (0.01 sec)

As you can see, the query parses and executes but does not return any rows. This is a common mistake made by inexperienced SQL programmers, and the database server will not alert you to your error, so be careful when constructing conditions that test for null.

If you want to see whether a value has been assigned to a column, you can use the is not null operator, as in:

mysql> SELECT rental\_id, customer\_id, return\_date  
    -> FROM rental  
    -> WHERE return\_date IS NOT NULL;  
+-----------+-------------+---------------------+  
| rental\_id | customer\_id | return\_date         |  
+-----------+-------------+---------------------+  
|         1 |         130 | 2005-05-26 22:04:30 |  
|         2 |         459 | 2005-05-28 19:40:33 |  
|         3 |         408 | 2005-06-01 22:12:39 |  
|         4 |         333 | 2005-06-03 01:43:41 |  
|         5 |         222 | 2005-06-02 04:33:21 |  
|         6 |         549 | 2005-05-27 01:32:07 |  
|         7 |         269 | 2005-05-29 20:34:53 |  
...  
|     16043 |         526 | 2005-08-31 03:09:03 |  
|     16044 |         468 | 2005-08-25 04:08:39 |  
|     16045 |          14 | 2005-08-25 23:54:26 |  
|     16046 |          74 | 2005-08-27 18:02:47 |  
|     16047 |         114 | 2005-08-25 02:48:48 |  
|     16048 |         103 | 2005-08-31 21:33:07 |  
|     16049 |         393 | 2005-08-30 01:01:12 |  
+-----------+-------------+---------------------+  
15861 rows in set (0.02 sec)

This version of the query returns all rentals that were returned, which is the majority of the rows in the table (15,861 out of 16,044).

Before putting null aside for a while, it would be helpful to investigate one more potential pitfall. Suppose that you have been asked to find all rentals that were not returned during May through August of 2005. Your first instinct might be to do the following:

mysql> SELECT rental\_id, customer\_id, return\_date  
    -> FROM rental  
    -> WHERE return\_date NOT BETWEEN '2005-05-01' AND '2005-09-01';  
+-----------+-------------+---------------------+  
| rental\_id | customer\_id | return\_date         |  
+-----------+-------------+---------------------+  
|     15365 |         327 | 2005-09-01 03:14:17 |  
|     15388 |          50 | 2005-09-01 03:50:23 |  
|     15392 |         410 | 2005-09-01 01:14:15 |  
|     15401 |         103 | 2005-09-01 03:44:10 |  
|     15415 |         204 | 2005-09-01 02:05:56 |  
...  
|     15977 |         550 | 2005-09-01 22:12:10 |  
|     15982 |         370 | 2005-09-01 21:51:31 |  
|     16005 |         466 | 2005-09-02 02:35:22 |  
|     16020 |         311 | 2005-09-01 18:17:33 |  
|     16033 |         226 | 2005-09-01 02:36:15 |  
|     16037 |          45 | 2005-09-01 02:48:04 |  
|     16040 |         195 | 2005-09-02 02:19:33 |  
+-----------+-------------+---------------------+  
62 rows in set (0.01 sec)

While it is true that these 62 rentals were returned outside of the May to August window, if you look carefully at the data, you will see that all of the rows returned have a non-null return date. But what about the 183 rentals that were never returned? One might argue that these 183 rows were also not returned between May and August, so they should also be included in the result set. To answer the question correctly, therefore, you need to account for the possibility that some rows might contain a null in the return\_date column:

mysql> SELECT rental\_id, customer\_id, return\_date  
    -> FROM rental  
    -> WHERE return\_date IS NULL  
    ->   OR return\_date NOT BETWEEN '2005-05-01' AND '2005-09-01';  
+-----------+-------------+---------------------+  
| rental\_id | customer\_id | return\_date         |  
+-----------+-------------+---------------------+  
|     11496 |         155 | NULL                |  
|     11541 |         335 | NULL                |  
|     11563 |          83 | NULL                |  
|     11577 |         219 | NULL                |  
|     11593 |          99 | NULL                |  
...  
|     15939 |         382 | 2005-09-01 17:25:21 |  
|     15942 |         210 | 2005-09-01 18:39:40 |  
|     15966 |         374 | NULL                |  
|     15971 |         187 | 2005-09-02 01:28:33 |  
|     15973 |         343 | 2005-09-01 20:08:41 |  
|     15977 |         550 | 2005-09-01 22:12:10 |  
|     15982 |         370 | 2005-09-01 21:51:31 |  
|     16005 |         466 | 2005-09-02 02:35:22 |  
|     16020 |         311 | 2005-09-01 18:17:33 |  
|     16033 |         226 | 2005-09-01 02:36:15 |  
|     16037 |          45 | 2005-09-01 02:48:04 |  
|     16040 |         195 | 2005-09-02 02:19:33 |  
+-----------+-------------+---------------------+  
245 rows in set (0.01 sec)

The result set now includes the 62 rentals that were returned outside of the May to August window, along with the 183 rentals that were never returned, for a total of 245 rows. When working with a database that you are not familiar with, it is a good idea to find out which columns in a table allow nulls so that you can take appropriate measures with your filter conditions to keep data from slipping through the cracks.

# Test Your Knowledge

The following exercises test your understanding of filter conditions. Please see [Appendix B](#Appendix_B__Solutions_to_Exercis_2) for solutions.

You’ll need to refer to the following subset of rows from the payment table for the first two exercises:

+------------+-------------+--------+--------------------+  
| payment\_id | customer\_id | amount | date(payment\_date) |  
+------------+-------------+--------+--------------------+  
|        101 |           4 |   8.99 | 2005-08-18         |  
|        102 |           4 |   1.99 | 2005-08-19         |  
|        103 |           4 |   2.99 | 2005-08-20         |  
|        104 |           4 |   6.99 | 2005-08-20         |  
|        105 |           4 |   4.99 | 2005-08-21         |  
|        106 |           4 |   2.99 | 2005-08-22         |  
|        107 |           4 |   1.99 | 2005-08-23         |  
|        108 |           5 |   0.99 | 2005-05-29         |  
|        109 |           5 |   6.99 | 2005-05-31         |  
|        110 |           5 |   1.99 | 2005-05-31         |  
|        111 |           5 |   3.99 | 2005-06-15         |  
|        112 |           5 |   2.99 | 2005-06-16         |  
|        113 |           5 |   4.99 | 2005-06-17         |  
|        114 |           5 |   2.99 | 2005-06-19         |  
|        115 |           5 |   4.99 | 2005-06-20         |  
|        116 |           5 |   4.99 | 2005-07-06         |  
|        117 |           5 |   2.99 | 2005-07-08         |  
|        118 |           5 |   4.99 | 2005-07-09         |  
|        119 |           5 |   5.99 | 2005-07-09         |  
|        120 |           5 |   1.99 | 2005-07-09         |  
+------------+-------------+--------+--------------------+

## Exercise 4-1

Which of the payment IDs would be returned by the following filter conditions?

customer\_id <> 5 AND (amount > 8 OR date(payment\_date) = '2005-08-23')

## Exercise 4-2

Which of the payment IDs would be returned by the following filter conditions?

customer\_id = 5 AND NOT (amount > 6 OR date(payment\_date) = '2005-06-19')

## Exercise 4-3

Construct a query that retrieves all rows from the payments table where the amount is either 1.98, 7.98, or 9.98.

## Exercise 4-4

Construct a query that finds all customers whose last name contains an A in the second position and a W anywhere after the A.

# Chapter 5. Querying Multiple Tables

Back in [Chapter 2](#Chapter_2__Creating_and_Populati_2), I demonstrated how related concepts are broken into separate pieces through a process known as normalization. The end result of this exercise was two tables: person and favorite\_food. If, however, you want to generate a single report showing a person’s name, address, and favorite foods, you will need a mechanism to bring the data from these two tables back together again; this mechanism is known as a join, and this chapter concentrates on the simplest and most common join, the inner join. [Chapter 10](#Chapter_10__Joins_Revisited__By_2) demonstrates all of the different join types.

# What Is a Join?

Queries against a single table are certainly not rare, but you will find that most of your queries will require two, three, or even more tables. To illustrate, let’s look at the definitions for the customer and address tables and then define a query that retrieves data from both tables:

mysql> desc customer;  
+-------------+----------------------+------+-----+-------------------+  
| Field       | Type                 | Null | Key | Default           |  
+-------------+----------------------+------+-----+-------------------+  
| customer\_id | smallint(5) unsigned | NO   | PRI | NULL              |  
| store\_id    | tinyint(3) unsigned  | NO   | MUL | NULL              |  
| first\_name  | varchar(45)          | NO   |     | NULL              |  
| last\_name   | varchar(45)          | NO   | MUL | NULL              |  
| email       | varchar(50)          | YES  |     | NULL              |  
|   
address\_id  
  | smallint(5) unsigned | NO   | MUL | NULL              |  
| active      | tinyint(1)           | NO   |     | 1                 |  
| create\_date | datetime             | NO   |     | NULL              |  
| last\_update | timestamp            | YES  |     | CURRENT\_TIMESTAMP |  
+-------------+----------------------+------+-----+-------------------+  
  
mysql> desc address;  
+-------------+----------------------+------+-----+-------------------+  
| Field       | Type                 | Null | Key | Default           |  
+-------------+----------------------+------+-----+-------------------+  
|   
address\_id  
  | smallint(5) unsigned | NO   | PRI | NULL              |  
| address     | varchar(50)          | NO   |     | NULL              |  
| address2    | varchar(50)          | YES  |     | NULL              |  
| district    | varchar(20)          | NO   |     | NULL              |  
| city\_id     | smallint(5) unsigned | NO   | MUL | NULL              |  
| postal\_code | varchar(10)          | YES  |     | NULL              |  
| phone       | varchar(20)          | NO   |     | NULL              |  
| location    | geometry             | NO   | MUL | NULL              |  
| last\_update | timestamp            | NO   |     | CURRENT\_TIMESTAMP |  
+-------------+----------------------+------+-----+-------------------+

Let’s say you want to retrieve the first and last names of each customer, along with their street address. Your query will therefore need to retrieve the customer.first\_name, customer.last\_name, and address.address columns. But how can you retrieve data from both tables in the same query? The answer lies in the customer.address\_id column, which holds the ID of the customer’s record in the address table (in more formal terms, the customer.address\_id column is the foreign key to the address table). The query, which you will see shortly, instructs the server to use the customer.address\_id column as the transportation between the customer and address tables, thereby allowing columns from both tables to be included in the query’s result set. This type of operation is known as a join.

##### Note

A foreign key constraint can optionally be created to verify that the values in one table exist in another table. For the previous example, a foreign key constraint could be created on the customer table to ensure that any values inserted into the customer.address\_id column can be found in the address.address\_id column. Please note that it is not necessary to have a foreign key constraint in place in order to join two tables.

## Cartesian Product

The easiest way to start is to put the customer and address tables into the from clause of a query and see what happens. Here’s a query that retrieves the customer’s first and last names along with the street address, with a from clause naming both tables separated by the join keyword:

mysql> SELECT c.first\_name, c.last\_name, a.address  
    -> FROM customer c JOIN address a;  
+------------+-----------+----------------------+  
| first\_name | last\_name | address           |  
+------------+-----------+----------------------+  
| MARY       | SMITH     | 47 MySakila Drive |  
| PATRICIA   | JOHNSON   | 47 MySakila Drive |  
| LINDA      | WILLIAMS  | 47 MySakila Drive |  
| BARBARA    | JONES     | 47 MySakila Drive |  
| ELIZABETH  | BROWN     | 47 MySakila Drive |  
| JENNIFER   | DAVIS     | 47 MySakila Drive |  
| MARIA      | MILLER    | 47 MySakila Drive |  
| SUSAN      | WILSON    | 47 MySakila Drive |  
...  
| SETH       | HANNON    | 1325 Fukuyama Street |  
| KENT       | ARSENAULT | 1325 Fukuyama Street |  
| TERRANCE   | ROUSH     | 1325 Fukuyama Street |  
| RENE       | MCALISTER | 1325 Fukuyama Street |  
| EDUARDO    | HIATT     | 1325 Fukuyama Street |  
| TERRENCE   | GUNDERSON | 1325 Fukuyama Street |  
| ENRIQUE    | FORSYTHE  | 1325 Fukuyama Street |  
| FREDDIE    | DUGGAN    | 1325 Fukuyama Street |  
| WADE       | DELVALLE  | 1325 Fukuyama Street |  
| AUSTIN     | CINTRON   | 1325 Fukuyama Street |  
+------------+-----------+----------------------+  
361197 rows in set (0.03 sec)

Hmmm...there are only 599 customers and 603 rows in the address table, so how did the result set end up with 361,197 rows? Looking more closely, you can see that many of the customers seem to have the same street address. Because the query didn’t specify how the two tables should be joined, the database server generated the Cartesian product, which is every permutation of the two tables (599 customers x 603 addresses = 361,197 permutations). This type of join is known as a cross join, and it is rarely used (on purpose, at least). Cross joins are one of the join types that we study in [Chapter 10](#Chapter_10__Joins_Revisited__By_2).

## Inner Joins

To modify the previous query so that only a single row is returned for each customer, you need to describe how the two tables are related. Earlier, I showed that the customer.address\_id column serves as the link between the two tables, so this information needs to be added to the on subclause of the from clause:

mysql> SELECT c.first\_name, c.last\_name, a.address  
    -> FROM customer c JOIN address a  
    ->   ON c.address\_id = a.address\_id;  
+-------------+--------------+----------------------------------------+  
| first\_name  | last\_name    | address                                |  
+-------------+--------------+----------------------------------------+  
| MARY        | SMITH        | 1913 Hanoi Way                         |  
| PATRICIA    | JOHNSON      | 1121 Loja Avenue                       |  
| LINDA       | WILLIAMS     | 692 Joliet Street                      |  
| BARBARA     | JONES        | 1566 Inegl Manor                       |  
| ELIZABETH   | BROWN        | 53 Idfu Parkway                        |  
| JENNIFER    | DAVIS        | 1795 Santiago de Compostela Way        |  
| MARIA       | MILLER       | 900 Santiago de Compostela Parkway     |  
| SUSAN       | WILSON       | 478 Joliet Way                         |  
| MARGARET    | MOORE        | 613 Korolev Drive                      |  
...  
| TERRANCE    | ROUSH        | 42 Fontana Avenue                      |  
| RENE        | MCALISTER    | 1895 Zhezqazghan Drive                 |  
| EDUARDO     | HIATT        | 1837 Kaduna Parkway                    |  
| TERRENCE    | GUNDERSON    | 844 Bucuresti Place                    |  
| ENRIQUE     | FORSYTHE     | 1101 Bucuresti Boulevard               |  
| FREDDIE     | DUGGAN       | 1103 Quilmes Boulevard                 |  
| WADE        | DELVALLE     | 1331 Usak Boulevard                    |  
| AUSTIN      | CINTRON      | 1325 Fukuyama Street                   |  
+-------------+--------------+----------------------------------------+  
599 rows in set (0.00 sec)

Instead of 361,197 rows, you now have the expected 599 rows due to the addition of the on subclause, which instructs the server to join the customer and address tables by using the address\_id column to traverse from one table to the other. For example, Mary Smith’s row in the customer table contains a value of 5 in the address\_id column (not shown in the example). The server uses this value to look up the row in the address table having a value of 5 in its address\_id column and then retrieves the value '1913 Hanoi Way' from the address column in that row.

If a value exists for the address\_id column in one table but not the other, then the join fails for the rows containing that value, and those rows are excluded from the result set. This type of join is known as an inner join, and it is the most commonly used type of join. To clarify, if a row in the customer table has the value 999 in the address\_id column and there’s no row in the address table with a value of 999 in the address\_id column, then that customer row would not be included in the result set. If you want to include all rows from one table or the other regardless of whether a match exists, you need to specify an outer join, but this will be explored [Chapter 10](#Chapter_10__Joins_Revisited__By_2).

In the previous example, I did not specify in the from clause which type of join to use. However, when you wish to join two tables using an inner join, you should explicitly specify this in your from clause; here’s the same example, with the addition of the join type (note the keyword inner):

SELECT c.first\_name, c.last\_name, a.address  
FROM customer c   
INNER JOIN  
 address a  
  ON c.address\_id = a.address\_id;

If you do not specify the type of join, then the server will do an inner join by default. As you will see later in the book, however, there are several types of joins, so you should get in the habit of specifying the exact type of join that you require, especially for the benefit of any other people who might use/maintain your queries in the future.

If the names of the columns used to join the two tables are identical, which is true in the previous query, you can use the using subclause instead of the on subclause, as in:

SELECT c.first\_name, c.last\_name, a.address  
FROM customer c INNER JOIN address a  
    
USING   
(address\_id);

Since using is a shorthand notation that you can use in only a specific situation, I prefer always to use the on subclause to avoid confusion.

## The ANSI Join Syntax

The notation used throughout this book for joining tables was introduced in the SQL92 version of the ANSI SQL standard. All the major databases (Oracle Database, Microsoft SQL Server, MySQL, IBM DB2 Universal Database, and Sybase Adaptive Server) have adopted the SQL92 join syntax. Because most of these servers have been around since before the release of the SQL92 specification, they all include an older join syntax as well. For example, all these servers would understand the following variation of the previous query:

mysql> SELECT c.first\_name, c.last\_name, a.address  
    -> FROM customer c, address a  
    -> WHERE c.address\_id = a.address\_id;  
+------------+------------+------------------------------------+  
| first\_name | last\_name | address                            |  
+------------+------------+------------------------------------+  
| MARY       | SMITH     | 1913 Hanoi Way                     |  
| PATRICIA   | JOHNSON   | 1121 Loja Avenue                   |  
| LINDA      | WILLIAMS  | 692 Joliet Street                  |  
| BARBARA    | JONES     | 1566 Inegl Manor                   |  
| ELIZABETH  | BROWN     | 53 Idfu Parkway                    |  
| JENNIFER   | DAVIS     | 1795 Santiago de Compostela Way    |  
| MARIA      | MILLER    | 900 Santiago de Compostela Parkway |  
| SUSAN      | WILSON    | 478 Joliet Way                     |  
| MARGARET   | MOORE     | 613 Korolev Drive                  |  
...  
| TERRANCE   | ROUSH      | 42 Fontana Avenue               |  
| RENE       | MCALISTER  | 1895 Zhezqazghan Drive          |  
| EDUARDO    | HIATT      | 1837 Kaduna Parkway             |  
| TERRENCE   | GUNDERSON  | 844 Bucuresti Place             |  
| ENRIQUE    | FORSYTHE   | 1101 Bucuresti Boulevard        |  
| FREDDIE    | DUGGAN     | 1103 Quilmes Boulevard          |  
| WADE       | DELVALLE   | 1331 Usak Boulevard             |  
| AUSTIN     | CINTRON    | 1325 Fukuyama Street            |  
+------------+------------+------------------------------------+  
599 rows in set (0.00 sec)

This older method of specifying joins does not include the on subclause; instead, tables are named in the from clause separated by commas, and join conditions are included in the where clause. While you may decide to ignore the SQL92 syntax in favor of the older join syntax, the ANSI join syntax has the following advantages:

* Join conditions and filter conditions are separated into two different clauses (the on subclause and the where clause, respectively), making a query easier to understand.
* The join conditions for each pair of tables are contained in their own on clause, making it less likely that part of a join will be mistakenly omitted.
* Queries that use the SQL92 join syntax are portable across database servers, whereas the older syntax is slightly different across the different servers.

The benefits of the SQL92 join syntax are easier to identify for complex queries that include both join and filter conditions. Consider the following query, which returns only those customers whose postal code is 52137:

mysql> SELECT c.first\_name, c.last\_name, a.address  
    -> FROM customer c, address a  
    -> WHERE c.address\_id = a.address\_id  
    ->   AND a.postal\_code = 52137;  
+------------+-----------+------------------------+  
| first\_name | last\_name | address                |  
+------------+-----------+------------------------+  
| JAMES      | GANNON    | 1635 Kuwana Boulevard  |  
| FREDDIE    | DUGGAN    | 1103 Quilmes Boulevard |  
+------------+-----------+------------------------+  
2 rows in set (0.01 sec)

At first glance, it is not so easy to determine which conditions in the where clause are join conditions and which are filter conditions. It is also not readily apparent which type of join is being employed (to identify the type of join, you would need to look closely at the join conditions in the where clause to see whether any special characters are employed), nor is it easy to determine whether any join conditions have been mistakenly left out. Here’s the same query using the SQL92 join syntax:

mysql> SELECT c.first\_name, c.last\_name, a.address  
    -> FROM customer c INNER JOIN address a  
    ->   ON c.address\_id = a.address\_id  
    -> WHERE a.postal\_code = 52137;  
+------------+-----------+------------------------+  
| first\_name | last\_name | address                |  
+------------+-----------+------------------------+  
| JAMES      | GANNON    | 1635 Kuwana Boulevard  |  
| FREDDIE    | DUGGAN    | 1103 Quilmes Boulevard |  
+------------+-----------+------------------------+  
2 rows in set (0.00 sec)

With this version, it is clear which condition is used for the join and which condition is used for filtering. Hopefully, you will agree that the version using SQL92 join syntax is easier to understand.

# Joining Three or More Tables

Joining three tables is similar to joining two tables, but with one slight wrinkle. With a two-table join, there are two tables and one join type in the from clause, and a single on subclause to define how the tables are joined. With a three-table join, there are three tables and two join types in the from clause, and two on subclauses.

To illustrate, let’s change the previous query to return the customer’s city rather than their street address. The city name, however, is not stored in the address table but is accessed via a foreign key to the city table. Here are the table definitions:

mysql> desc address;  
+-------------+----------------------+------+-----+-------------------+  
| Field       | Type                 | Null | Key | Default           |  
+-------------+----------------------+------+-----+-------------------+  
| address\_id  | smallint(5) unsigned | NO   | PRI | NULL              |  
| address     | varchar(50)          | NO   |     | NULL              |  
| address2    | varchar(50)          | YES  |     | NULL              |  
| district    | varchar(20)          | NO   |     | NULL              |  
|   
city\_id  
     | smallint(5) unsigned | NO   | MUL | NULL              |  
| postal\_code | varchar(10)          | YES  |     | NULL              |  
| phone       | varchar(20)          | NO   |     | NULL              |  
| location    | geometry             | NO   | MUL | NULL              |  
| last\_update | timestamp            | NO   |     | CURRENT\_TIMESTAMP |  
+-------------+----------------------+------+-----+-------------------+  
  
mysql> desc city;  
+-------------+----------------------+------+-----+-------------------+  
| Field       | Type                 | Null | Key | Default           |  
+-------------+----------------------+------+-----+-------------------+  
|   
city\_id  
     | smallint(5) unsigned | NO   | PRI | NULL              |  
| city        | varchar(50)          | NO   |     | NULL              |  
| country\_id  | smallint(5) unsigned | NO   | MUL | NULL              |  
| last\_update | timestamp            | NO   |     | CURRENT\_TIMESTAMP |  
+-------------+----------------------+------+-----+-------------------+

To show each customer’s city, you will need to traverse from the customer table to the address table using the address\_id column and then from the address table to the city table using the city\_id column. The query would look like the following:

mysql> SELECT c.first\_name, c.last\_name, ct.city  
    -> FROM customer c  
    ->   INNER JOIN address a  
    ->   ON c.address\_id = a.address\_id  
    ->   INNER JOIN city ct  
    ->   ON a.city\_id = ct.city\_id;  
+-------------+--------------+----------------------------+  
| first\_name  | last\_name    | city                       |  
+-------------+--------------+----------------------------+  
| JULIE       | SANCHEZ      | A Corua (La Corua)         |  
| PEGGY       | MYERS        | Abha                       |  
| TOM         | MILNER       | Abu Dhabi                  |  
| GLEN        | TALBERT      | Acua                       |  
| LARRY       | THRASHER     | Adana                      |  
| SEAN        | DOUGLASS     | Addis Abeba                |  
...  
| MICHELE     | GRANT        | Yuncheng                   |  
| GARY        | COY          | Yuzhou                     |  
| PHYLLIS     | FOSTER       | Zalantun                   |  
| CHARLENE    | ALVAREZ      | Zanzibar                   |  
| FRANKLIN    | TROUTMAN     | Zaoyang                    |  
| FLOYD       | GANDY        | Zapopan                    |  
| CONSTANCE   | REID         | Zaria                      |  
| JACK        | FOUST        | Zeleznogorsk               |  
| BYRON       | BOX          | Zhezqazghan                |  
| GUY         | BROWNLEE     | Zhoushan                   |  
| RONNIE      | RICKETTS     | Ziguinchor                 |  
+-------------+--------------+----------------------------+  
599 rows in set (0.03 sec)

For this query, there are three tables, two join types, and two on subclauses in the from clause, so things have gotten quite a bit busier. At first glance, it might seem like the order in which the tables appear in the from clause is important, but if you switch the table order, you will get the exact same results. All three of these variations return the same results:

SELECT c.first\_name, c.last\_name, ct.city  
FROM customer c  
  INNER JOIN address a  
  ON c.address\_id = a.address\_id  
  INNER JOIN city ct  
  ON a.city\_id = ct.city\_id;  
  
SELECT c.first\_name, c.last\_name, ct.city  
FROM city ct  
  INNER JOIN address a  
  ON a.city\_id = ct.city\_id  
  INNER JOIN customer c  
  ON c.address\_id = a.address\_id;  
  
SELECT c.first\_name, c.last\_name, ct.city  
FROM address a  
  INNER JOIN city ct  
  ON a.city\_id = ct.city\_id  
  INNER JOIN customer c  
  ON c.address\_id = a.address\_id;

The only difference you may see would be the order in which the rows are returned, since there is no order by clause to specify how the results should be ordered.

#### Does Join Order Matter?

If you are confused about why all three versions of the customer/address/city query yield the same results, keep in mind that SQL is a nonprocedural language, meaning that you describe what you want to retrieve and which database objects need to be involved, but it is up to the database server to determine how best to execute your query. Using statistics gathered from your database objects, the server must pick one of three tables as a starting point (the chosen table is thereafter known as the driving table) and then decide in which order to join the remaining tables. Therefore, the order in which tables appear in your from clause is not significant.

If, however, you believe that the tables in your query should always be joined in a particular order, you can place the tables in the desired order and then specify the keyword straight\_join in MySQL, request the force order option in SQL Server, or use either the ordered or the leading optimizer hint in Oracle Database. For example, to tell the MySQL server to use the city table as the driving table and to then join the address and customer tables, you could do the following:

SELECT STRAIGHT\_JOIN c.first\_name, c.last\_name, ct.city  
FROM city ct  
  INNER JOIN address a  
  ON a.city\_id = ct.city\_id  
  INNER JOIN customer c  
  ON c.address\_id = a.address\_id

## Using Subqueries as Tables

You have already seen several examples of queries that include multiple tables, but there is one variation worth mentioning: what to do if some of the data sets are generated by subqueries. Subqueries are the focus of [Chapter 9](#Chapter_9__Subqueries__Subquerie_2), but I already introduced the concept of a subquery in the from clause in the previous chapter. The following query joins the customer table to a subquery against the address and city tables:

mysql> SELECT c.first\_name, c.last\_name, addr.address, addr.city  
    -> FROM customer c  
    ->   INNER JOIN  
    ->      
(  
SELECT a.address\_id, a.address, ct.city  
    ->     FROM address a  
    ->       INNER JOIN city ct  
    ->       ON a.city\_id = ct.city\_id  
    ->     WHERE a.district = 'California'  
    ->      
) addr  
  
    ->   ON c.address\_id = addr.address\_id;  
+------------+-----------+------------------------+----------------+  
| first\_name | last\_name | address                | city           |  
+------------+-----------+------------------------+----------------+  
| PATRICIA   | JOHNSON   | 1121 Loja Avenue       | San Bernardino |  
| BETTY      | WHITE     | 770 Bydgoszcz Avenue   | Citrus Heights |  
| ALICE      | STEWART   | 1135 Izumisano Parkway | Fontana        |  
| ROSA       | REYNOLDS  | 793 Cam Ranh Avenue    | Lancaster      |  
| RENEE      | LANE      | 533 al-Ayn Boulevard   | Compton        |  
| KRISTIN    | JOHNSTON  | 226 Brest Manor        | Sunnyvale      |  
| CASSANDRA  | WALTERS   | 920 Kumbakonam Loop    | Salinas        |  
| JACOB      | LANCE     | 1866 al-Qatif Avenue   | El Monte       |  
| RENE       | MCALISTER | 1895 Zhezqazghan Drive | Garden Grove   |  
+------------+-----------+------------------------+----------------+  
9 rows in set (0.00 sec)

The subquery, which starts on line 4 and is given the alias addr, finds all addresses that are in California. The outer query joins the subquery results to the customer table to return the first name, last name, street address, and city of all customers who live in California. While this query could have been written without the use of a subquery by simply joining the three tables, it can sometimes be advantageous from a performance and/or readability aspect to use one or more subqueries.

One way to visualize what is going on is to run the subquery by itself and look at the results. Here are the results of the subquery from the prior example:

mysql> SELECT a.address\_id, a.address, ct.city  
    -> FROM address a  
    ->   INNER JOIN city ct  
    ->   ON a.city\_id = ct.city\_id  
    -> WHERE a.district = 'California';  
+------------+------------------------+----------------+  
| address\_id | address                | city           |  
+------------+------------------------+----------------+  
|          6 | 1121 Loja Avenue       | San Bernardino |  
|         18 | 770 Bydgoszcz Avenue   | Citrus Heights |  
|         55 | 1135 Izumisano Parkway | Fontana        |  
|        116 | 793 Cam Ranh Avenue    | Lancaster      |  
|        186 | 533 al-Ayn Boulevard   | Compton        |  
|        218 | 226 Brest Manor        | Sunnyvale      |  
|        274 | 920 Kumbakonam Loop    | Salinas        |  
|        425 | 1866 al-Qatif Avenue   | El Monte       |  
|        599 | 1895 Zhezqazghan Drive | Garden Grove   |  
+------------+------------------------+----------------+  
9 rows in set (0.00 sec)

This result set consists of all nine California addresses. When joined to the customer table via the address\_id column, your result set will contain information about the customers assigned to these addresses.

## Using the Same Table Twice

If you are joining multiple tables, you might find that you need to join the same table more than once. In the sample database, for example, actors are related to the films in which they appeared via the film\_actor table. If you want to find all of the films in which two specific actors appear, you could write a query such as this one, which joins the film table to the film\_actor table to the actor table:

mysql> SELECT f.title  
    -> FROM film f  
    ->   INNER JOIN film\_actor fa  
    ->   ON f.film\_id = fa.film\_id  
    ->   INNER JOIN actor a  
    ->   ON fa.actor\_id = a.actor\_id  
    -> WHERE ((a.first\_name = 'CATE' AND a.last\_name = 'MCQUEEN')  
    ->    OR (a.first\_name = 'CUBA' AND a.last\_name = 'BIRCH'));  
+----------------------+  
| title                |  
+----------------------+  
| ATLANTIS CAUSE       |  
| BLOOD ARGONAUTS      |  
| COMMANDMENTS EXPRESS |  
| DYNAMITE TARZAN      |  
| EDGE KISSING         |  
...  
| TOWERS HURRICANE     |  
| TROJAN TOMORROW      |  
| VIRGIN DAISY         |  
| VOLCANO TEXAS        |  
| WATERSHIP FRONTIER   |  
+----------------------+  
54 rows in set (0.00 sec)

This query returns all movies in which either Cate McQueen or Cuba Birch appeared. However, let’s say that you want to retrieve only those films in which both of these actors appeared. To accomplish this, you will need to find all rows in the film table that have two rows in the film\_actor table, one of which is associated with Cate McQueen, and the other associated with Cuba Birch. Therefore, you will need to include the film\_actor and actor tables twice, each with a different alias so that the server knows which one you are referring to in the various clauses:

mysql> SELECT f.title  
    ->  FROM film f  
    ->    INNER JOIN film\_actor fa1  
    ->    ON f.film\_id = fa1.film\_id  
    ->    INNER JOIN actor a1  
    ->    ON fa1.actor\_id = a1.actor\_id  
    ->    INNER JOIN film\_actor fa2  
    ->    ON f.film\_id = fa2.film\_id  
    ->    INNER JOIN actor a2  
    ->    ON fa2.actor\_id = a2.actor\_id  
    -> WHERE (a1.first\_name = 'CATE' AND a1.last\_name = 'MCQUEEN')  
    ->   AND (a2.first\_name = 'CUBA' AND a2.last\_name = 'BIRCH');  
+------------------+  
| title            |  
+------------------+  
| BLOOD ARGONAUTS  |  
| TOWERS HURRICANE |  
+------------------+  
2 rows in set (0.00 sec)

Between them, the two actors appeared in 52 different films, but there are only two films in which both actors appeared. This is one example of a query that requires the use of table aliases, since the same tables are used multiple times.

# Self-Joins

Not only can you include the same table more than once in the same query, but you can actually join a table to itself. This might seem like a strange thing to do at first, but there are valid reasons for doing so. Some tables include a self-referencing foreign key, which means that it includes a column that points to the primary key within the same table. While the sample database doesn’t include such a relationship, let’s imagine that the film table includes the column prequel\_film\_id, which points to the film’s parent (e.g., the film Fiddler Lost II would use this column to point to the parent film Fiddler Lost). Here’s what the table would look like if we were to add this additional column:

mysql> desc film;  
+----------------------+-----------------------+------+-----+-------------------+  
| Field                | Type                  | Null | Key | Default           |  
+----------------------+-----------------------+------+-----+-------------------+  
| film\_id              | smallint(5) unsigned | NO   | PRI | NULL              |  
| title                | varchar(255)          | NO   | MUL | NULL              |  
| description          | text                  | YES  |     | NULL              |  
| release\_year         | year(4)               | YES  |     | NULL              |  
| language\_id          | tinyint(3) unsigned   | NO   | MUL | NULL              |  
| original\_language\_id | tinyint(3) unsigned   | YES  | MUL | NULL              |  
| rental\_duration      | tinyint(3) unsigned   | NO   |     | 3                 |  
| rental\_rate          | decimal(4,2)          | NO   |     | 4.99              |  
| length               | smallint(5) unsigned  | YES  |     | NULL              |  
| replacement\_cost     | decimal(5,2)          | NO   |     | 19.99             |  
| rating               | enum('G','PG','PG-13',  
 'R','NC-17')       | YES  |     | G            |  
| special\_features     | set('Trailers',...,  
 'Behind the Scenes')| YES  |     | NULL              |  
| last\_update          | timestamp             | NO   |     | CURRENT\_  
 TIMESTAMP |  
|   
prequel\_film\_id  
     | smallint(5) unsigned | YES  | MUL | NULL              |  
+----------------------+-----------------------+------+-----+-------------------+

Using a self-join, you can write a query that lists every film that has a prequel, along with the prequel’s title:

mysql> SELECT f.title, f\_prnt.title prequel  
    -> FROM film   
f  
  
    ->   INNER JOIN film   
f\_prnt  
  
    ->   ON f\_prnt.film\_id = f.prequel\_film\_id  
    -> WHERE f.prequel\_film\_id IS NOT NULL;  
+-----------------+--------------+  
| title           | prequel      |  
+-----------------+--------------+  
| FIDDLER LOST II | FIDDLER LOST |  
+-----------------+--------------+  
1 row in set (0.00 sec)

This query joins the film table to itself using the prequel\_film\_id foreign key, and the table aliases f and f\_prnt are assigned in order to make it clear which table is used for which purpose.

# Test Your Knowledge

The following exercises are designed to test your understanding of inner joins. Please see [Appendix B](#Appendix_B__Solutions_to_Exercis_2) for the solutions to these exercises.

## Exercise 5-1

Fill in the blanks (denoted by <#>) for the following query to obtain the results that follow:

mysql> SELECT c.first\_name, c.last\_name, a.address, ct.city  
    -> FROM customer c  
    ->   INNER JOIN address <1>  
    ->   ON c.address\_id = a.address\_id  
    ->   INNER JOIN city ct  
    ->   ON a.city\_id = <2>  
    -> WHERE a.district = 'California';  
+------------+-----------+------------------------+----------------+  
| first\_name | last\_name | address                | city           |  
+------------+-----------+------------------------+----------------+  
| PATRICIA   | JOHNSON   | 1121 Loja Avenue       | San Bernardino |  
| BETTY      | WHITE     | 770 Bydgoszcz Avenue   | Citrus Heights |  
| ALICE      | STEWART   | 1135 Izumisano Parkway | Fontana        |  
| ROSA       | REYNOLDS  | 793 Cam Ranh Avenue    | Lancaster      |  
| RENEE      | LANE      | 533 al-Ayn Boulevard   | Compton        |  
| KRISTIN    | JOHNSTON  | 226 Brest Manor        | Sunnyvale      |  
| CASSANDRA  | WALTERS   | 920 Kumbakonam Loop    | Salinas        |  
| JACOB      | LANCE     | 1866 al-Qatif Avenue   | El Monte       |  
| RENE       | MCALISTER | 1895 Zhezqazghan Drive | Garden Grove   |  
+------------+-----------+------------------------+----------------+  
9 rows in set (0.00 sec)

## Exercise 5-2

Write a query that returns the title of every film in which an actor with the first name JOHN appeared.

## Exercise 5-3

Construct a query that returns all addresses that are in the same city. You will need to join the address table to itself, and each row should include two different addresses.

# Chapter 6. Working with Sets

Although you can interact with the data in a database one row at a time, relational databases are really all about sets. This chapter explores how you can combine multiple result sets using various set operators. After a quick overview of set theory, I’ll demonstrate how to use the set operators union, intersect, and except to blend multiple data sets together.

# Set Theory Primer

In many parts of the world, basic set theory is included in elementary-level math curriculums. Perhaps you recall looking at something like what is shown in [Figure 6-1](#Figure_6_1__The_union_operation).

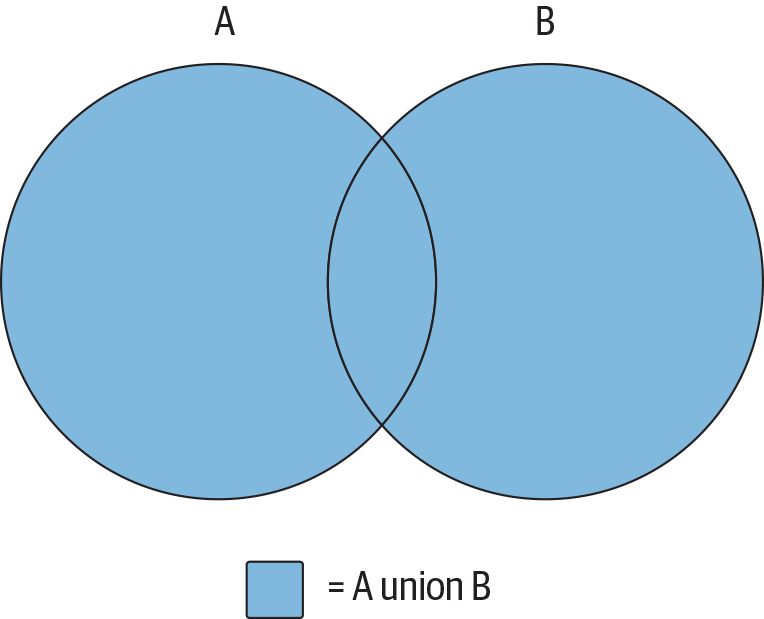


Figure 6-1. The union operation

The shaded area in [Figure 6-1](#Figure_6_1__The_union_operation) represents the union of sets A and B, which is the combination of the two sets (with any overlapping regions included only once). Is this starting to look familiar? If so, then you’ll finally get a chance to put that knowledge to use; if not, don’t worry, because it’s easy to visualize using a couple of diagrams.

Using circles to represent two data sets (A and B), imagine a subset of data that is common to both sets; this common data is represented by the overlapping area shown in [Figure 6-1](#Figure_6_1__The_union_operation). Since set theory is rather uninteresting without an overlap between data sets, I use the same diagram to illustrate each set operation. There is another set operation that is concerned only with the overlap between two data sets; this operation is known as the intersection and is demonstrated in [Figure 6-2](#Figure_6_2__The_intersection_ope).

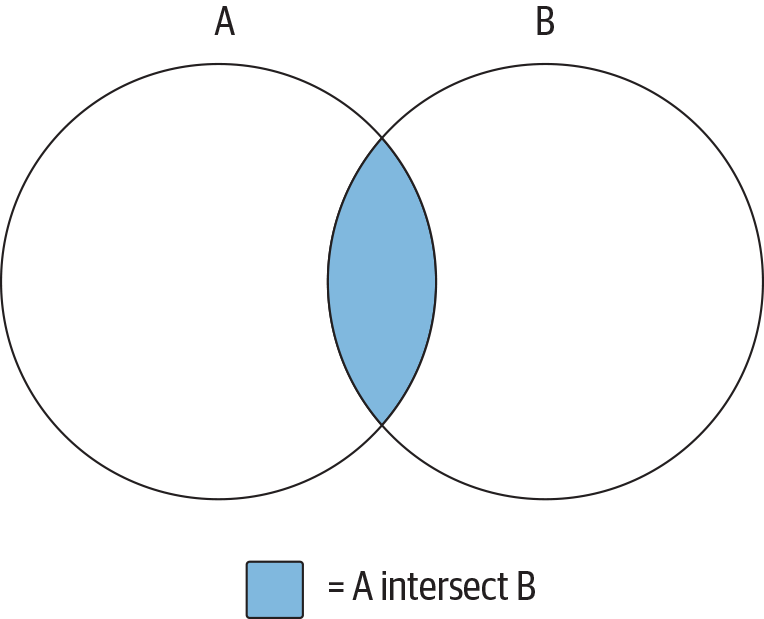


Figure 6-2. The intersection operation

The data set generated by the intersection of sets A and B is just the area of overlap between the two sets. If the two sets have no overlap, then the intersection operation yields the empty set.

The third and final set operation, which is demonstrated in [Figure 6-3](#Figure_6_3__The_except_operation), is known as the except operation.

[Figure 6-3](#Figure_6_3__The_except_operation) shows the results of A except B, which is the whole of set A minus any overlap with set B. If the two sets have no overlap, then the operation A except B yields the whole of set A.

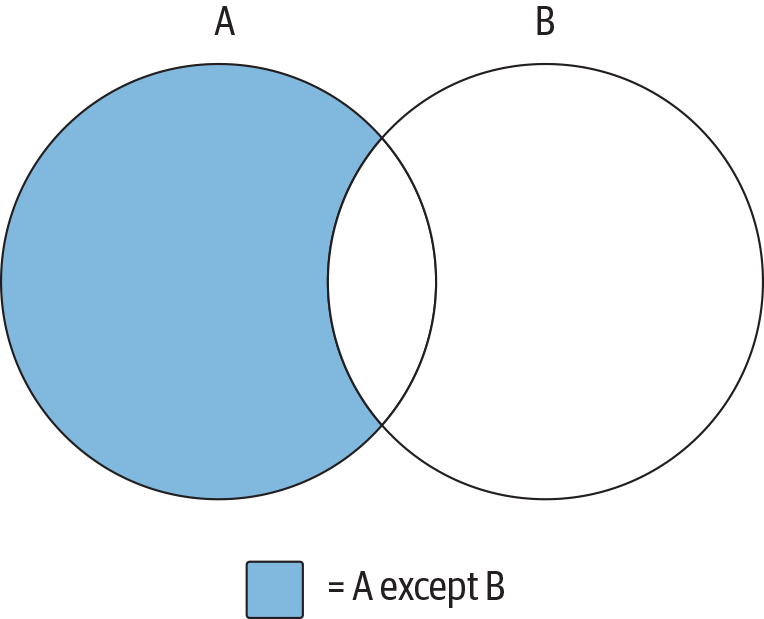


Figure 6-3. The except operation

Using these three operations, or by combining different operations together, you can generate whatever results you need. For example, imagine that you want to build a set demonstrated by [Figure 6-4](#Figure_6_4__Mystery_data_set).

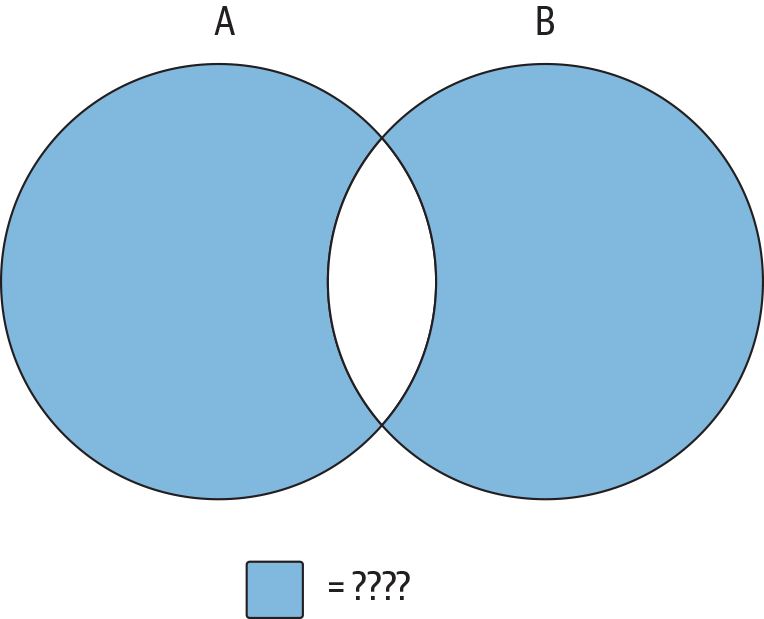


Figure 6-4. Mystery data set

The data set you are looking for includes all of sets A and B without the overlapping region. You can’t achieve this outcome with just one of the three operations shown earlier; instead, you will need to first build a data set that encompasses all of sets A and B, and then utilize a second operation to remove the overlapping region. If the combined set is described as A union B, and the overlapping region is described as A intersect B, then the operation needed to generate the data set represented by [Figure 6-4](#Figure_6_4__Mystery_data_set) would look as follows:

(A union B) except (A intersect B)

Of course, there are often multiple ways to achieve the same results; you could reach a similar outcome using the following operation:

(A except B) union (B except A)

While these concepts are fairly easy to understand using diagrams, the next sections show you how these concepts are applied to a relational database using the SQL set operators.

# Set Theory in Practice

The circles used in the previous section’s diagrams to represent data sets don’t convey anything about what the data sets comprise. When dealing with actual data, however, there is a need to describe the composition of the data sets involved if they are to be combined. Imagine, for example, what would happen if you tried to generate the union of the customer table and the city table, whose definitions are as follows:

mysql> desc customer;  
+-------------+----------------------+------+-----+-------------------+  
| Field       | Type                 | Null | Key | Default           |  
+-------------+----------------------+------+-----+-------------------+  
| customer\_id | smallint(5) unsigned | NO   | PRI | NULL              |  
| store\_id    | tinyint(3) unsigned  | NO   | MUL | NULL              |  
| first\_name  | varchar(45)          | NO   |     | NULL              |  
| last\_name   | varchar(45)          | NO   | MUL | NULL              |  
| email       | varchar(50)          | YES  |     | NULL              |  
| address\_id  | smallint(5) unsigned | NO   | MUL | NULL              |  
| active      | tinyint(1)           | NO   |     | 1                 |  
| create\_date | datetime             | NO   |     | NULL              |  
| last\_update | timestamp            | YES  |     | CURRENT\_TIMESTAMP |  
+-------------+----------------------+------+-----+-------------------+  
  
mysql> desc city;  
+-------------+----------------------+------+-----+-------------------+  
| Field       | Type                 | Null | Key | Default           |  
+-------------+----------------------+------+-----+-------------------+  
| city\_id     | smallint(5) unsigned | NO   | PRI | NULL              |  
| city        | varchar(50)          | NO   |     | NULL              |  
| country\_id  | smallint(5) unsigned | NO   | MUL | NULL              |  
| last\_update | timestamp            | NO   |     | CURRENT\_TIMESTAMP |  
+-------------+----------------------+------+-----+-------------------+

When combined, the first column in the result set would include both the customer.customer\_id and city.city\_id columns, the second column would be the combination of the customer.store\_id and city.city columns, and so forth. While some column pairs are easy to combine (e.g., two numeric columns), it is unclear how other column pairs should be combined, such as a numeric column with a string column or a string column with a date column. Additionally, the fifth through ninth columns of the combined tables would include data from only the customer table’s fifth through ninth columns, since the city table has only four columns. Clearly, there needs to be some commonality between two data sets that you wish to combine.

Therefore, when performing set operations on two data sets, the following guidelines must apply:

* Both data sets must have the same number of columns.
* The data types of each column across the two data sets must be the same (or the server must be able to convert one to the other).

With these rules in place, it is easier to envision what “overlapping data” means in practice; each column pair from the two sets being combined must contain the same string, number, or date for rows in the two tables to be considered the same.

You perform a set operation by placing a set operator between two select statements, as demonstrated by the following:

mysql>   
SELECT 1 num, 'abc' str  
  
 ->   
UNION  
  
 ->   
SELECT 9 num, 'xyz' str;  
  
+-----+-----+  
| num | str |  
+-----+-----+  
| 1 | abc |  
| 9 | xyz |  
+-----+-----+  
2 rows in set (0.02 sec)

Each of the individual queries yields a data set consisting of a single row having a numeric column and a string column. The set operator, which in this case is union, tells the database server to combine all rows from the two sets. Thus, the final set includes two rows of two columns. This query is known as a compound query because it comprises multiple, otherwise-independent queries. As you will see later, compound queries may include more than two queries if multiple set operations are needed to attain the final results.

# Set Operators

The SQL language includes three set operators that allow you to perform each of the various set operations described earlier in the chapter. Additionally, each set operator has two flavors, one that includes duplicates and another that removes duplicates (but not necessarily all of the duplicates). The following subsections define each operator and demonstrate how they are used.

## The union Operator

The union and union all operators allow you to combine multiple data sets. The difference between the two is that union sorts the combined set and removes duplicates, whereas union all does not. With union all, the number of rows in the final data set will always equal the sum of the number of rows in the sets being combined. This operation is the simplest set operation to perform (from the server’s point of view), since there is no need for the server to check for overlapping data. The following example demonstrates how you can use the union all operator to generate a set of first and last names from multiple tables:

mysql> SELECT 'CUST' typ, c.first\_name, c.last\_name  
    -> FROM customer c  
    -> UNION ALL  
    -> SELECT 'ACTR' typ, a.first\_name, a.last\_name  
    -> FROM actor a;  
+------+------------+-------------+  
| typ  | first\_name | last\_name |  
+------+------------+-------------+  
| CUST | MARY       | SMITH     |  
| CUST | PATRICIA   | JOHNSON   |  
| CUST | LINDA      | WILLIAMS  |  
| CUST | BARBARA    | JONES     |  
| CUST | ELIZABETH  | BROWN     |  
| CUST | JENNIFER   | DAVIS     |  
| CUST | MARIA      | MILLER    |  
| CUST | SUSAN      | WILSON    |  
| CUST | MARGARET   | MOORE     |  
| CUST | DOROTHY    | TAYLOR    |  
| CUST | LISA       | ANDERSON  |  
| CUST | NANCY      | THOMAS    |  
| CUST | KAREN      | JACKSON   |  
...  
| ACTR | BURT       | TEMPLE      |  
| ACTR | MERYL      | ALLEN       |  
| ACTR | JAYNE      | SILVERSTONE |  
| ACTR | BELA       | WALKEN      |  
| ACTR | REESE      | WEST        |  
| ACTR | MARY       | KEITEL      |  
| ACTR | JULIA      | FAWCETT     |  
| ACTR | THORA      | TEMPLE      |  
+------+------------+-------------+  
799 rows in set (0.00 sec)

The query returns 799 names, with 599 rows coming from the customer table and the other 200 coming from the actor table. The first column, which has the alias typ, is not necessary, but was added to show the source of each name returned by the query.

Just to drive home the point that the union all operator doesn’t remove duplicates, here’s another version of the previous example, but with two identical queries against the actor table:

mysql> SELECT 'ACTR' typ, a.first\_name, a.last\_name  
    -> FROM actor a  
    -> UNION ALL  
    -> SELECT 'ACTR' typ, a.first\_name, a.last\_name  
    -> FROM actor a;  
+------+-------------+--------------+  
| typ  | first\_name  | last\_name    |  
+------+-------------+--------------+  
| ACTR | PENELOPE    | GUINESS      |  
| ACTR | NICK        | WAHLBERG     |  
| ACTR | ED          | CHASE        |  
| ACTR | JENNIFER    | DAVIS        |  
| ACTR | JOHNNY      | LOLLOBRIGIDA |  
| ACTR | BETTE       | NICHOLSON    |  
| ACTR | GRACE       | MOSTEL       |  
...  
| ACTR | BURT        | TEMPLE       |  
| ACTR | MERYL       | ALLEN        |  
| ACTR | JAYNE       | SILVERSTONE  |  
| ACTR | BELA        | WALKEN       |  
| ACTR | REESE       | WEST         |  
| ACTR | MARY        | KEITEL       |  
| ACTR | JULIA       | FAWCETT      |  
| ACTR | THORA       | TEMPLE       |  
+------+-------------+--------------+  
400 rows in set (0.00 sec)

As you can see by the results, the 200 rows from the actor table are included twice, for a total of 400 rows.

While you are unlikely to repeat the same query twice in a compound query, here is another compound query that returns duplicate data:

mysql> SELECT c.first\_name, c.last\_name  
    -> FROM customer c  
    -> WHERE c.first\_name LIKE 'J%' AND c.last\_name LIKE 'D%'  
    -> UNION ALL  
    -> SELECT a.first\_name, a.last\_name  
    -> FROM actor a  
    -> WHERE a.first\_name LIKE 'J%' AND a.last\_name LIKE 'D%';  
+------------+-----------+  
| first\_name | last\_name |  
+------------+-----------+  
| JENNIFER   | DAVIS     |  
| JENNIFER   | DAVIS     |  
| JUDY       | DEAN      |  
| JODIE      | DEGENERES |  
| JULIANNE   | DENCH     |  
+------------+-----------+  
5 rows in set (0.00 sec)

Both queries return the names of people having the initials JD. Of the five rows in the result set, one of them is a duplicate (Jennifer Davis). If you would like your combined table to exclude duplicate rows, you need to use the union operator instead of union all:

mysql> SELECT c.first\_name, c.last\_name  
    -> FROM customer c  
    -> WHERE c.first\_name LIKE 'J%' AND c.last\_name LIKE 'D%'  
    ->   
UNION  
  
    -> SELECT a.first\_name, a.last\_name  
    -> FROM actor a  
    -> WHERE a.first\_name LIKE 'J%' AND a.last\_name LIKE 'D%';  
+------------+-----------+  
| first\_name | last\_name |  
+------------+-----------+  
| JENNIFER   | DAVIS     |  
| JUDY       | DEAN      |  
| JODIE      | DEGENERES |  
| JULIANNE   | DENCH     |  
+------------+-----------+  
4 rows in set (0.00 sec)

For this version of the query, only the four distinct names are included in the result set, rather than the five rows returned when using union all.

## The intersect Operator

The ANSI SQL specification includes the intersect operator for performing intersections. Unfortunately, version 8.0 of MySQL does not implement the intersect operator. If you are using Oracle or SQL Server 2008, you will be able to use intersect; since I am using MySQL for all examples in this book, however, the result sets for the example queries in this section are fabricated and cannot be executed with any versions up to and including version 8.0. I also refrain from showing the MySQL prompt (mysql>), since the statements are not being executed by the MySQL server.

If the two queries in a compound query return nonoverlapping data sets, then the intersection will be an empty set. Consider the following query:

SELECT c.first\_name, c.last\_name  
FROM customer c  
WHERE c.first\_name LIKE 'D%' AND c.last\_name LIKE 'T%'  
INTERSECT  
  
SELECT a.first\_name, a.last\_name  
FROM actor a  
WHERE a.first\_name LIKE 'D%' AND a.last\_name LIKE 'T%';  
Empty set (0.04 sec)

While there are both actors and customers having the initials DT, these sets are completely nonoverlapping, so the intersection of the two sets yields the empty set. If we switch back to the initials JD, however, the intersection will yield a single row:

SELECT c.first\_name, c.last\_name  
FROM customer c  
WHERE c.first\_name LIKE 'J%' AND c.last\_name LIKE 'D%'  
INTERSECT  
SELECT a.first\_name, a.last\_name  
FROM actor a  
WHERE a.first\_name LIKE 'J%' AND a.last\_name LIKE 'D%';  
+------------+-----------+  
| first\_name | last\_name |  
+------------+-----------+  
| JENNIFER   | DAVIS     |  
+------------+-----------+  
1 row in set (0.00 sec)

The intersection of these two queries yields Jennifer Davis, which is the only name found in both queries’ result sets.

Along with the intersect operator, which removes any duplicate rows found in the overlapping region, the ANSI SQL specification calls for an intersect all operator, which does not remove duplicates. The only database server that currently implements the intersect all operator is IBM’s DB2 Universal Server.

## The except Operator

The ANSI SQL specification includes the except operator for performing the except operation. Once again, unfortunately, version 8.0 of MySQL does not implement the except operator, so the same rules apply for this section as for the previous section.

##### Note

If you are using Oracle Database, you will need to use the non-ANSI-compliant minus operator instead.

The except operator returns the first result set minus any overlap with the second result set. Here’s the example from the previous section, but using except instead of intersect, and with the order of the queries reversed:

SELECT a.first\_name, a.last\_name  
FROM actor a  
WHERE a.first\_name LIKE 'J%' AND a.last\_name LIKE 'D%'  
EXCEPT  
  
SELECT c.first\_name, c.last\_name  
FROM customer c  
WHERE c.first\_name LIKE 'J%' AND c.last\_name LIKE 'D%';  
+------------+-----------+  
| first\_name | last\_name |  
+------------+-----------+  
| JUDY       | DEAN      |  
| JODIE      | DEGENERES |  
| JULIANNE   | DENCH     |  
+------------+-----------+  
3 rows in set (0.00 sec)

In this version of the query, the result set consists of the three rows from the first query minus Jennifer Davis, who is found in the result sets from both queries. There is also an except all operator specified in the ANSI SQL specification, but once again, only IBM’s DB2 Universal Server has implemented the except all operator.

The except all operator is a bit tricky, so here is an example that demonstrates how duplicate data is handled. Let’s say you have two data sets that look like the following:

Set A

+----------+  
| actor\_id |  
+----------+  
| 10 |  
| 11 |  
| 12 |  
| 10 |  
| 10 |  
+----------+

Set B

+----------+  
| actor\_id |  
+----------+  
| 10 |  
| 10 |  
+----------+

The operation A except B yields the following:

+----------+  
| actor\_id |  
+----------+  
| 11 |  
| 12 |  
+----------+

If you change the operation to A except all B, you will see the following:

+----------+  
| actor\_id |  
+----------+  
| 10 |  
| 11 |  
| 12 |  
+----------+

Therefore, the difference between the two operations is that except removes all occurrences of duplicate data from set A, whereas except all removes only one occurrence of duplicate data from set A for every occurrence in set B.

# Set Operation Rules

The following sections outline some rules that you must follow when working with compound queries.

## Sorting Compound Query Results

If you want the results of your compound query to be sorted, you can add an order by clause after the last query. When specifying column names in the order by clause, you will need to choose from the column names in the first query of the compound query. Frequently, the column names are the same for both queries in a compound query, but this does not need to be the case, as demonstrated by the following:

mysql> SELECT a.first\_name   
fname  
, a.last\_name   
lname  
  
    -> FROM actor a  
    -> WHERE a.first\_name LIKE 'J%' AND a.last\_name LIKE 'D%'  
    -> UNION ALL  
    -> SELECT c.first\_name, c.last\_name  
    -> FROM customer c  
    -> WHERE c.first\_name LIKE 'J%' AND c.last\_name LIKE 'D%'  
    -> ORDER BY   
lname, fname  
;  
+----------+-----------+  
| fname    | lname     |  
+----------+-----------+  
| JENNIFER | DAVIS     |  
| JENNIFER | DAVIS     |  
| JUDY     | DEAN      |  
| JODIE    | DEGENERES |  
| JULIANNE | DENCH     |  
+----------+-----------+  
5 rows in set (0.00 sec)

The column names specified in the two queries are different in this example. If you specify a column name from the second query in your order by clause, you will see the following error:

mysql> SELECT a.first\_name fname, a.last\_name lname  
    -> FROM actor a  
    -> WHERE a.first\_name LIKE 'J%' AND a.last\_name LIKE 'D%'  
    -> UNION ALL  
    -> SELECT c.first\_name, c.last\_name  
    -> FROM customer c  
    -> WHERE c.first\_name LIKE 'J%' AND c.last\_name LIKE 'D%'  
    -> ORDER BY   
last\_name, first\_name  
;  
ERROR 1054 (42S22): Unknown column 'last\_name' in 'order clause'

I recommend giving the columns in both queries identical column aliases in order to avoid this issue.

## Set Operation Precedence

If your compound query contains more than two queries using different set operators, you need to think about the order in which to place the queries in your compound statement to achieve the desired results. Consider the following three-query compound statement:

mysql> SELECT a.first\_name, a.last\_name  
    -> FROM actor a  
    -> WHERE a.first\_name LIKE 'J%' AND a.last\_name LIKE 'D%'  
    ->   
UNION ALL  
  
    -> SELECT a.first\_name, a.last\_name  
    -> FROM actor a  
    -> WHERE a.first\_name LIKE 'M%' AND a.last\_name LIKE 'T%'  
    ->   
UNION  
  
    -> SELECT c.first\_name, c.last\_name  
    -> FROM customer c  
    -> WHERE c.first\_name LIKE 'J%' AND c.last\_name LIKE 'D%';  
+------------+-----------+  
| first\_name | last\_name |  
+------------+-----------+  
| JENNIFER   | DAVIS     |  
| JUDY       | DEAN      |  
| JODIE      | DEGENERES |  
| JULIANNE   | DENCH     |  
| MARY       | TANDY     |  
| MENA       | TEMPLE    |  
+------------+-----------+  
6 rows  
 in set (0.00 sec)

This compound query includes three queries that return sets of nonunique names; the first and second queries are separated with the union all operator, while the second and third queries are separated with the union operator. While it might not seem to make much difference where the union and union all operators are placed, it does, in fact, make a difference. Here’s the same compound query with the set operators reversed:

mysql> SELECT a.first\_name, a.last\_name  
    -> FROM actor a  
    -> WHERE a.first\_name LIKE 'J%' AND a.last\_name LIKE 'D%'  
    ->   
UNION  
  
    -> SELECT a.first\_name, a.last\_name  
    -> FROM actor a  
    -> WHERE a.first\_name LIKE 'M%' AND a.last\_name LIKE 'T%'  
    ->   
UNION ALL  
  
    -> SELECT c.first\_name, c.last\_name  
    -> FROM customer c  
    -> WHERE c.first\_name LIKE 'J%' AND c.last\_name LIKE 'D%';  
+------------+-----------+  
| first\_name | last\_name |  
+------------+-----------+  
| JENNIFER   | DAVIS     |  
| JUDY       | DEAN      |  
| JODIE      | DEGENERES |  
| JULIANNE   | DENCH     |  
| MARY       | TANDY     |  
| MENA       | TEMPLE    |  
| JENNIFER   | DAVIS     |  
+------------+-----------+  
7 rows  
 in set (0.00 sec)

Looking at the results, it’s obvious that it does make a difference how the compound query is arranged when using different set operators. In general, compound queries containing three or more queries are evaluated in order from top to bottom, but with the following caveats:

* The ANSI SQL specification calls for the intersect operator to have precedence over the other set operators.
* You may dictate the order in which queries are combined by enclosing multiple queries in parentheses.

MySQL does not yet allow parentheses in compound queries, but if you are using a different database server, you can wrap adjoining queries in parentheses to override the default top-to-bottom processing of compound queries, as in:

SELECT a.first\_name, a.last\_name  
FROM actor a  
WHERE a.first\_name LIKE 'J%' AND a.last\_name LIKE 'D%'  
UNION  
(  
SELECT a.first\_name, a.last\_name  
 FROM actor a  
 WHERE a.first\_name LIKE 'M%' AND a.last\_name LIKE 'T%'  
 UNION ALL  
 SELECT c.first\_name, c.last\_name  
 FROM customer c  
 WHERE c.first\_name LIKE 'J%' AND c.last\_name LIKE 'D%'  
)

For this compound query, the second and third queries would be combined using the union all operator, then the results would be combined with the first query using the union operator.

# Test Your Knowledge

The following exercises are designed to test your understanding of set operations. See [Appendix B](#Appendix_B__Solutions_to_Exercis_2) for the answers to these exercises.

## Exercise 6-1

If set A = {L M N O P} and set B = {P Q R S T}, what sets are generated by the following operations?

* A union B
* A union all B
* A intersect B
* A except B

## Exercise 6-2

Write a compound query that finds the first and last names of all actors and customers whose last name starts with L.

## Exercise 6-3

Sort the results from Exercise 6-2 by the last\_name column.

# Chapter 7. Data Generation, Manipulation, and Conversion

As I mentioned in the preface, this book strives to teach generic SQL techniques that can be applied across multiple database servers. This chapter, however, deals with the generation, conversion, and manipulation of string, numeric, and temporal data, and the SQL language does not include commands covering this functionality. Rather, built-in functions are used to facilitate data generation, conversion, and manipulation, and while the SQL standard does specify some functions, the database vendors often do not comply with the function specifications.

Therefore, my approach for this chapter is to show you some of the common ways in which data is generated and manipulated within SQL statements and then demonstrate some of the built-in functions implemented by Microsoft SQL Server, Oracle Database, and MySQL. Along with reading this chapter, I strongly recommend you download a reference guide covering all the functions implemented by your server. If you work with more than one database server, there are several reference guides that cover multiple servers, such as Kevin Kline et al.’s [SQL in a Nutshell](http://shop.oreilly.com/product/9780596518851.do) and Jonathan Gennick’s [SQL Pocket Guide](http://shop.oreilly.com/product/9780596526887.do), both from O’Reilly.

# Working with String Data

When working with string data, you will be using one of the following character data types:

CHAR

Holds fixed-length, blank-padded strings. MySQL allows CHAR values up to 255 characters in length, Oracle Database permits up to 2,000 characters, and SQL Server allows up to 8,000 characters.

varchar

Holds variable-length strings. MySQL permits up to 65,535 characters in a varchar column, Oracle Database (via the varchar2 type) allows up to 4,000 characters, and SQL Server allows up to 8,000 characters.

text (MySQL and SQL Server) or clob (Oracle Database)

Holds very large variable-length strings (generally referred to as documents in this context). MySQL has multiple text types (tinytext, text, mediumtext, and longtext) for documents up to 4 GB in size. SQL Server has a single text type for documents up to 2 GB in size, and Oracle Database includes the clob data type, which can hold documents up to a whopping 128 TB. SQL Server 2005 also includes the varchar(max) data type and recommends its use instead of the text type, which will be removed from the server in some future release.

To demonstrate how you can use these various types, I use the following table for some of the examples in this section:

CREATE TABLE string\_tbl  
 (char\_fld CHAR(30),  
 vchar\_fld VARCHAR(30),  
 text\_fld TEXT  
 );

The next two subsections show how you can generate and manipulate string data.

## String Generation

The simplest way to populate a character column is to enclose a string in quotes, as in the following examples:

mysql>   
INSERT INTO string\_tbl (char\_fld, vchar\_fld, text\_fld)  
  
 ->   
VALUES ('This is char data',  
  
 ->   
'This is varchar data',  
  
 ->   
'This is text data');  
  
Query OK, 1 row affected (0.00 sec)

When inserting string data into a table, remember that if the length of the string exceeds the maximum size for the character column (either the designated maximum or the maximum allowed for the data type), the server will throw an exception. Although this is the default behavior for all three servers, you can configure MySQL and SQL Server to silently truncate the string instead of throwing an exception. To demonstrate how MySQL handles this situation, the following update statement attempts to modify the vchar\_fld column, whose maximum length is defined as 30, with a string that is 46 characters in length:

mysql>   
UPDATE string\_tbl  
  
 ->   
SET vchar\_fld = 'This is a piece of extremely long varchar data';  
  
ERROR 1406 (22001): Data too long for column 'vchar\_fld' at row 1

Since MySQL 6.0, the default behavior is now “strict” mode, which means that exceptions are thrown when problems arise, whereas in older versions of the server the string would have been truncated and a warning issued. If you would rather have the engine truncate the string and issue a warning instead of raising an exception, you can opt to be in ANSI mode. The following example shows how to check which mode you are in and then how to change the mode using the set command:

mysql>   
SELECT @@session.sql\_mode;  
  
+----------------------------------------------------------------+  
| @@session.sql\_mode |  
+----------------------------------------------------------------+  
| STRICT\_TRANS\_TABLES,NO\_ENGINE\_SUBSTITUTION |  
+----------------------------------------------------------------+  
1 row in set (0.00 sec)  
  
mysql>   
SET sql\_mode='ansi';  
  
Query OK, 0 rows affected (0.08 sec)  
  
mysql>   
SELECT @@session.sql\_mode;  
  
+--------------------------------------------------------------------------------+  
| @@session.sql\_mode |  
+--------------------------------------------------------------------------------+  
| REAL\_AS\_FLOAT,PIPES\_AS\_CONCAT,ANSI\_QUOTES,IGNORE\_SPACE,ONLY\_FULL\_GROUP\_BY,ANSI |  
+--------------------------------------------------------------------------------+  
1 row in set (0.00 sec)

If you rerun the previous update statement, you will find that the column has been modified, but the following warning is generated:

mysql>   
SHOW WARNINGS;  
  
+---------+------+------------------------------------------------+  
| Level | Code | Message |  
+---------+------+------------------------------------------------+  
| Warning | 1265 | Data truncated for column 'vchar\_fld' at row 1 |  
+---------+------+------------------------------------------------+  
1 row in set (0.00 sec)

If you retrieve the vchar\_fld column, you will see that the string has indeed been truncated:

mysql>   
SELECT vchar\_fld  
  
 ->   
FROM string\_tbl;  
  
+--------------------------------+  
| vchar\_fld |  
+--------------------------------+  
| This is a piece of extremely l |  
+--------------------------------+  
1 row in set (0.05 sec)

As you can see, only the first 30 characters of the 46-character string made it into the vchar\_fld column. The best way to avoid string truncation (or exceptions, in the case of Oracle Database or MySQL in strict mode) when working with varchar columns is to set the upper limit of a column to a high enough value to handle the longest strings that might be stored in the column (keeping in mind that the server allocates only enough space to store the string, so it is not wasteful to set a high upper limit for varchar columns).

## Including single quotes

Since strings are demarcated by single quotes, you will need to be alert for strings that include single quotes or apostrophes. For example, you won’t be able to insert the following string because the server will think that the apostrophe in the word doesn’t marks the end of the string:

UPDATE string\_tbl  
SET text\_fld = 'This string doesn't work';

To make the server ignore the apostrophe in the word doesn’t, you will need to add an escape to the string so that the server treats the apostrophe like any other character in the string. All three servers allow you to escape a single quote by adding another single quote directly before, as in:

mysql>   
UPDATE string\_tbl  
  
 ->   
SET text\_fld = 'This string didn''t work, but it does now';  
  
Query OK, 1 row affected (0.01 sec)  
Rows matched: 1 Changed: 1 Warnings: 0

##### Note

Oracle Database and MySQL users may also choose to escape a single quote by adding a backslash character immediately before, as in:

UPDATE string\_tbl SET text\_fld =  
 'This string didn\'t work, but it does now'

If you retrieve a string for use in a screen or report field, you don’t need to do anything special to handle embedded quotes:

mysql>   
SELECT text\_fld  
  
 ->   
FROM string\_tbl;  
  
+------------------------------------------+  
| text\_fld |  
+------------------------------------------+  
| This string didn't work, but it does now |  
+------------------------------------------+  
1 row in set (0.00 sec)

However, if you are retrieving the string to add to a file that another program will read, you may want to include the escape as part of the retrieved string. If you are using MySQL, you can use the built-in function quote(), which places quotes around the entire string and adds escapes to any single quotes/apostrophes within the string. Here’s what our string looks like when retrieved via the quote() function:

mysql>   
SELECT quote(text\_fld)  
  
 ->   
FROM string\_tbl;  
  
+---------------------------------------------+  
| QUOTE(text\_fld) |  
+---------------------------------------------+  
| 'This string didn\'t work, but it does now' |  
+---------------------------------------------+  
1 row in set (0.04 sec)

When retrieving data for data export, you may want to use the quote() function for all non-system-generated character columns, such as a customer\_notes column.

## Including special characters

If your application is multinational in scope, you might find yourself working with strings that include characters that do not appear on your keyboard. When working with the French and German languages, for example, you might need to include accented characters such as é and ö. The SQL Server and MySQL servers include the built-in function char() so that you can build strings from any of the 255 characters in the ASCII character set (Oracle Database users can use the chr() function). To demonstrate, the next example retrieves a typed string and its equivalent built via individual characters:

mysql>   
SELECT 'abcdefg', CHAR(97,98,99,100,101,102,103);  
  
+---------+--------------------------------+  
| abcdefg | CHAR(97,98,99,100,101,102,103) |  
+---------+--------------------------------+  
| abcdefg | abcdefg |  
+---------+--------------------------------+  
1 row in set (0.01 sec)

Thus, the 97th character in the ASCII character set is the letter a. While the characters shown in the preceding example are not special, the following examples show the location of the accented characters along with other special characters, such as currency symbols:

mysql>   
SELECT CHAR(128,129,130,131,132,133,134,135,136,137);  
  
+-----------------------------------------------+  
| CHAR(128,129,130,131,132,133,134,135,136,137) |  
+-----------------------------------------------+  
| Çüéâäàåçêë |  
+-----------------------------------------------+  
1 row in set (0.01 sec)  
  
mysql>   
SELECT CHAR(138,139,140,141,142,143,144,145,146,147);  
  
+-----------------------------------------------+  
| CHAR(138,139,140,141,142,143,144,145,146,147) |  
+-----------------------------------------------+  
| èïîìÄÅÉæÆô |  
+-----------------------------------------------+  
1 row in set (0.01 sec)  
  
mysql>   
SELECT CHAR(148,149,150,151,152,153,154,155,156,157);  
  
+-----------------------------------------------+  
| CHAR(148,149,150,151,152,153,154,155,156,157) |  
+-----------------------------------------------+  
| öòûùÿÖÜø£Ø |  
+-----------------------------------------------+  
1 row in set (0.00 sec)  
  
mysql>   
SELECT CHAR(158,159,160,161,162,163,164,165);  
  
+---------------------------------------+  
| CHAR(158,159,160,161,162,163,164,165) |  
+---------------------------------------+  
| ×ƒáíóúñÑ |  
+---------------------------------------+  
1 row in set (0.01 sec)

##### Note

I am using the utf8mb4 character set for the examples in this section. If your session is configured for a different character set, you will see a different set of characters than what is shown here. The same concepts apply, but you will need to familiarize yourself with the layout of your character set to locate specific characters.

Building strings character by character can be quite tedious, especially if only a few of the characters in the string are accented. Fortunately, you can use the concat() function to concatenate individual strings, some of which you can type while others you can generate via the char() function. For example, the following shows how to build the phrase danke schön using the concat() and char() functions:

mysql>   
SELECT CONCAT('danke sch', CHAR(148), 'n');  
  
+-------------------------------------+  
| CONCAT('danke sch', CHAR(148), 'n') |  
+-------------------------------------+  
| danke schön |  
+-------------------------------------+  
1 row in set (0.00 sec)

##### Note

Oracle Database users can use the concatenation operator (||) instead of the concat() function, as in:

SELECT 'danke sch' || CHR(148) || 'n'  
FROM dual;

SQL Server does not include a concat() function, so you will need to use the concatenation operator (+), as in:

SELECT 'danke sch' + CHAR(148) + 'n'

If you have a character and need to find its ASCII equivalent, you can use the ascii() function, which takes the leftmost character in the string and returns a number:

mysql>   
SELECT ASCII('ö');  
  
+------------+  
| ASCII('ö') |  
+------------+  
| 148 |  
+------------+  
1 row in set (0.00 sec)

Using the char(), ascii(), and concat() functions (or concatenation operators), you should be able to work with any Roman language even if you are using a keyboard that does not include accented or special characters.

## String Manipulation

Each database server includes many built-in functions for manipulating strings. This section explores two types of string functions: those that return numbers and those that return strings. Before I begin, however, I reset the data in the string\_tbl table to the following:

mysql>   
DELETE FROM string\_tbl;  
  
Query OK, 1 row affected (0.02 sec)  
  
mysql>   
INSERT INTO string\_tbl (char\_fld, vchar\_fld, text\_fld)  
  
 ->   
VALUES ('This string is 28 characters',  
  
 ->   
'This string is 28 characters',  
  
 ->   
'This string is 28 characters');  
  
Query OK, 1 row affected (0.00 sec)

## String functions that return numbers

Of the string functions that return numbers, one of the most commonly used is the length() function, which returns the number of characters in the string (SQL Server users will need to use the len() function). The following query applies the length() function to each column in the string\_tbl table:

mysql>   
SELECT LENGTH(char\_fld) char\_length,  
  
 ->   
LENGTH(vchar\_fld) varchar\_length,  
  
 ->   
LENGTH(text\_fld) text\_length  
  
 ->   
FROM string\_tbl;  
  
+-------------+----------------+-------------+  
| char\_length | varchar\_length | text\_length |  
+-------------+----------------+-------------+  
| 28 | 28 | 28 |  
+-------------+----------------+-------------+  
1 row in set (0.00 sec)

While the lengths of the varchar and text columns are as expected, you might have expected the length of the char column to be 30, since I told you that strings stored in char columns are right-padded with spaces. The MySQL server removes trailing spaces from char data when it is retrieved, however, so you will see the same results from all string functions regardless of the type of column in which the strings are stored.

Along with finding the length of a string, you might want to find the location of a substring within a string. For example, if you want to find the position at which the string 'characters' appears in the vchar\_fld column, you could use the position() function, as demonstrated by the following:

mysql>   
SELECT POSITION('characters' IN vchar\_fld)  
  
 ->   
FROM string\_tbl;  
  
+-------------------------------------+  
| POSITION('characters' IN vchar\_fld) |  
+-------------------------------------+  
| 19 |  
+-------------------------------------+  
1 row in set (0.12 sec)

If the substring cannot be found, the position() function returns 0.

Warning

For those of you who program in a language such as C or C++, where the first element of an array is at position 0, remember when working with databases that the first character in a string is at position 1. A return value of 0 from instr() indicates that the substring could not be found, not that the substring was found at the first position in the string.

If you want to start your search at something other than the first character of your target string, you will need to use the locate() function, which is similar to the position() function except that it allows an optional third parameter, which is used to define the search’s start position. The locate() function is also proprietary, whereas the position() function is part of the SQL:2003 standard. Here’s an example asking for the position of the string 'is' starting at the fifth character in the vchar\_fld column:

mysql>   
SELECT LOCATE('is', vchar\_fld, 5)  
  
 ->   
FROM string\_tbl;  
  
+----------------------------+  
| LOCATE('is', vchar\_fld, 5) |  
+----------------------------+  
| 13 |  
+----------------------------+  
1 row in set (0.02 sec)

##### Note

Oracle Database does not include the position() or locate() function, but it does include the instr() function, which mimics the position() function when provided with two arguments and mimics the locate() function when provided with three arguments. SQL Server also doesn’t include a position() or locate() function, but it does include the charindx() function, which also accepts either two or three arguments similar to Oracle’s instr() function.

Another function that takes strings as arguments and returns numbers is the string comparison function strcmp(). strcmp(), which is implemented only by MySQL and has no analog in Oracle Database or SQL Server, takes two strings as arguments and returns one of the following:

* −1 if the first string comes before the second string in sort order
* 0 if the strings are identical
* 1 if the first string comes after the second string in sort order

To illustrate how the function works, I first show the sort order of five strings using a query and then show how the strings compare to one another using strcmp(). Here are the five strings that I insert into the string\_tbl table:

mysql>   
DELETE FROM string\_tbl;  
  
Query OK, 1 row affected (0.00 sec)  
  
mysql> INSERT INTO string\_tbl(vchar\_fld)  
    -> VALUES ('abcd'),  
    ->        ('xyz'),  
    ->        ('QRSTUV'),  
    ->        ('qrstuv'),  
    ->        ('12345');  
Query OK, 5 rows affected (0.05 sec)  
Records: 5  Duplicates: 0  Warnings: 0

Here are the five strings in their sort order:

mysql>   
SELECT vchar\_fld  
  
 ->   
FROM string\_tbl  
  
 ->   
ORDER BY vchar\_fld;  
  
+-----------+  
| vchar\_fld |  
+-----------+  
| 12345 |  
| abcd |  
| QRSTUV |  
| qrstuv |  
| xyz |  
+-----------+  
5 rows in set (0.00 sec)

The next query makes six comparisons among the five different strings:

mysql>   
SELECT STRCMP('12345','12345') 12345\_12345,  
  
 ->   
STRCMP('abcd','xyz') abcd\_xyz,  
  
 ->   
STRCMP('abcd','QRSTUV') abcd\_QRSTUV,  
  
 ->   
STRCMP('qrstuv','QRSTUV') qrstuv\_QRSTUV,  
  
 ->   
STRCMP('12345','xyz') 12345\_xyz,  
  
 ->   
STRCMP('xyz','qrstuv') xyz\_qrstuv;  
  
+-------------+----------+-------------+---------------+-----------+------------+  
| 12345\_12345 | abcd\_xyz | abcd\_QRSTUV | qrstuv\_QRSTUV | 12345\_xyz | xyz\_qrstuv |  
+-------------+----------+-------------+---------------+-----------+------------+  
| 0 | −1 | −1 | 0 | −1 | 1 |  
+-------------+----------+-------------+---------------+-----------+------------+  
1 row in set (0.00 sec)

The first comparison yields 0, which is to be expected since I compared a string to itself. The fourth comparison also yields 0, which is a bit surprising, since the strings are composed of the same letters, with one string all uppercase and the other all lowercase. The reason for this result is that MySQL’s strcmp() function is case-insensitive, which is something to remember when using the function. The other four comparisons yield either −1 or 1 depending on whether the first string comes before or after the second string in sort order. For example, strcmp('abcd','xyz') yields −1, since the string 'abcd' comes before the string 'xyz'.

Along with the strcmp() function, MySQL also allows you to use the like and regexp operators to compare strings in the select clause. Such comparisons will yield 1 (for true) or 0 (for false). Therefore, these operators allow you to build expressions that return a number, much like the functions described in this section. Here’s an example using like:

mysql> SELECT name, name LIKE '%y' ends\_in\_y  
    -> FROM category;  
+-------------+-----------+  
| name        | ends\_in\_y |  
+-------------+-----------+  
| Action      |         0 |  
| Animation   |         0 |  
| Children    |         0 |  
| Classics    |         0 |  
| Comedy      |         1 |  
| Documentary |         1 |  
| Drama       |         0 |  
| Family      |         1 |  
| Foreign     |         0 |  
| Games       |         0 |  
| Horror      |         0 |  
| Music       |         0 |  
| New         |         0 |  
| Sci-Fi      |         0 |  
| Sports      |         0 |  
| Travel      |         0 |  
+-------------+-----------+  
16 rows in set (0.00 sec)

This example retrieves all the category names, along with an expression that returns 1 if the name ends in “y” or 0 otherwise. If you want to perform more complex pattern matches, you can use the regexp operator, as demonstrated by the following:

mysql> SELECT name, name REGEXP 'y$' ends\_in\_y  
    -> FROM category;  
+-------------+-----------+  
| name        | ends\_in\_y |  
+-------------+-----------+  
| Action      |         0 |  
| Animation   |         0 |  
| Children    |         0 |  
| Classics    |         0 |  
| Comedy      |         1 |  
| Documentary |         1 |  
| Drama       |         0 |  
| Family      |         1 |  
| Foreign     |         0 |  
| Games       |         0 |  
| Horror      |         0 |  
| Music       |         0 |  
| New         |         0 |  
| Sci-Fi      |         0 |  
| Sports      |         0 |  
| Travel      |         0 |  
+-------------+-----------+  
16 rows in set (0.00 sec)

The second column of this query returns 1 if the value stored in the name column matches the given regular expression.

##### Note

Microsoft SQL Server and Oracle Database users can achieve similar results by building case expressions, which I describe in detail in [Chapter 11](#Chapter_11__Conditional_Logic__I_2).

## String functions that return strings

In some cases, you will need to modify existing strings, either by extracting part of the string or by adding additional text to the string. Every database server includes multiple functions to help with these tasks. Before I begin, I once again reset the data in the string\_tbl table:

mysql>   
DELETE FROM string\_tbl;  
  
Query OK, 5 rows affected (0.00 sec)  
  
mysql>   
INSERT INTO string\_tbl (text\_fld)  
  
 ->   
VALUES ('This string was 29 characters');  
  
Query OK, 1 row affected (0.01 sec)

Earlier in the chapter, I demonstrated the use of the concat() function to help build words that include accented characters. The concat() function is useful in many other situations, including when you need to append additional characters to a stored string. For instance, the following example modifies the string stored in the text\_fld column by tacking an additional phrase on the end:

mysql>   
UPDATE string\_tbl  
  
 ->   
SET text\_fld = CONCAT(text\_fld, ', but now it is longer');  
  
Query OK, 1 row affected (0.03 sec)  
Rows matched: 1 Changed: 1 Warnings: 0

The contents of the text\_fld column are now as follows:

mysql>   
SELECT text\_fld  
  
 ->   
FROM string\_tbl;  
  
+-----------------------------------------------------+  
| text\_fld |  
+-----------------------------------------------------+  
| This string was 29 characters, but now it is longer |  
+-----------------------------------------------------+  
1 row in set (0.00 sec)

Thus, like all functions that return a string, you can use concat() to replace the data stored in a character column.

Another common use for the concat() function is to build a string from individual pieces of data. For example, the following query generates a narrative string for each customer:

mysql> SELECT concat(first\_name, ' ', last\_name,  
    ->   ' has been a customer since ', date(create\_date)) cust\_narrative  
    -> FROM customer;  
+---------------------------------------------------------+  
| cust\_narrative                                        |  
+---------------------------------------------------------+  
| MARY SMITH has been a customer since 2006-02-14       |  
| PATRICIA JOHNSON has been a customer since 2006-02-14 |  
| LINDA WILLIAMS has been a customer since 2006-02-14   |  
| BARBARA JONES has been a customer since 2006-02-14    |  
| ELIZABETH BROWN has been a customer since 2006-02-14  |  
| JENNIFER DAVIS has been a customer since 2006-02-14   |  
| MARIA MILLER has been a customer since 2006-02-14     |  
| SUSAN WILSON has been a customer since 2006-02-14     |  
| MARGARET MOORE has been a customer since 2006-02-14   |  
| DOROTHY TAYLOR has been a customer since 2006-02-14   |  
...  
| RENE MCALISTER has been a customer since 2006-02-14     |  
| EDUARDO HIATT has been a customer since 2006-02-14      |  
| TERRENCE GUNDERSON has been a customer since 2006-02-14 |  
| ENRIQUE FORSYTHE has been a customer since 2006-02-14   |  
| FREDDIE DUGGAN has been a customer since 2006-02-14     |  
| WADE DELVALLE has been a customer since 2006-02-14      |  
| AUSTIN CINTRON has been a customer since 2006-02-14     |  
+---------------------------------------------------------+  
599 rows in set (0.00 sec)

The concat() function can handle any expression that returns a string and will even convert numbers and dates to string format, as evidenced by the date column (create\_date) used as an argument. Although Oracle Database includes the concat() function, it will accept only two string arguments, so the previous query will not work on Oracle. Instead, you would need to use the concatenation operator (||) rather than a function call, as in:

SELECT first\_name || ' ' || last\_name ||  
  ' has been a customer since ' || date(create\_date)) cust\_narrative  
FROM customer;

SQL Server does not include a concat() function, so you would need to use the same approach as the previous query, except that you would use SQL Server’s concatenation operator (+) instead of ||.

While concat() is useful for adding characters to the beginning or end of a string, you may also have a need to add or replace characters in the middle of a string. All three database servers provide functions for this purpose, but all of them are different, so I demonstrate the MySQL function and then show the functions from the other two servers.

MySQL includes the insert() function, which takes four arguments: the original string, the position at which to start, the number of characters to replace, and the replacement string. Depending on the value of the third argument, the function may be used to either insert or replace characters in a string. With a value of 0 for the third argument, the replacement string is inserted, and any trailing characters are pushed to the right, as in:

mysql>   
SELECT INSERT('goodbye world', 9, 0, 'cruel ') string;  
  
+---------------------+  
| string |  
+---------------------+  
| goodbye cruel world |  
+---------------------+  
1 row in set (0.00 sec)

In this example, all characters starting from position 9 are pushed to the right, and the string 'cruel' is inserted. If the third argument is greater than zero, then that number of characters is replaced with the replacement string, as in:

mysql>   
SELECT INSERT('goodbye world', 1, 7, 'hello') string;  
  
+-------------+  
| string |  
+-------------+  
| hello world |  
+-------------+  
1 row in set (0.00 sec)

For this example, the first seven characters are replaced with the string 'hello'. Oracle Database does not provide a single function with the flexibility of MySQL’s insert() function, but Oracle does provide the replace() function, which is useful for replacing one substring with another. Here’s the previous example reworked to use replace():

SELECT REPLACE('goodbye world', 'goodbye', 'hello')  
FROM dual;

All instances of the string 'goodbye' will be replaced with the string 'hello', resulting in the string 'hello world'. The replace() function will replace every instance of the search string with the replacement string, so you need to be careful that you don’t end up with more replacements than you anticipated.

SQL Server also includes a replace() function with the same functionality as Oracle’s, but SQL Server also includes a function called stuff() with similar functionality to MySQL’s insert() function. Here’s an example:

SELECT STUFF('hello world', 1, 5, 'goodbye cruel')

When executed, five characters are removed starting at position 1, and then the string 'goodbye cruel' is inserted at the starting position, resulting in the string 'goodbye cruel world'.

Along with inserting characters into a string, you may have a need to extract a substring from a string. For this purpose, all three servers include the substring() function (although Oracle Database’s version is called substr()), which extracts a specified number of characters starting at a specified position. The following example extracts five characters from a string starting at the ninth position:

mysql>   
SELECT SUBSTRING('goodbye cruel world', 9, 5);  
  
+----------------------------------------+  
| SUBSTRING('goodbye cruel world', 9, 5) |  
+----------------------------------------+  
| cruel |  
+----------------------------------------+  
1 row in set (0.00 sec)

Along with the functions demonstrated here, all three servers include many more built-in functions for manipulating string data. While many of them are designed for very specific purposes, such as generating the string equivalent of octal or hexadecimal numbers, there are many other general-purpose functions as well, such as functions that remove or add trailing spaces. For more information, consult your server’s SQL reference guide, or a general-purpose SQL reference guide such as [SQL in a Nutshell](http://shop.oreilly.com/product/9780596518851.do) (O’Reilly).

# Working with Numeric Data

Unlike string data (and temporal data, as you will see shortly), numeric data generation is quite straightforward. You can type a number, retrieve it from another column, or generate it via a calculation. All the usual arithmetic operators (+, -, \*, /) are available for performing calculations, and parentheses may be used to dictate precedence, as in:

mysql>   
SELECT (37 \* 59) / (78 - (8 \* 6));  
  
+----------------------------+  
| (37 \* 59) / (78 - (8 \* 6)) |  
+----------------------------+  
| 72.77 |  
+----------------------------+  
1 row in set (0.00 sec)

As I mentioned in [Chapter 2](#Chapter_2__Creating_and_Populati_2), the main concern when storing numeric data is that numbers might be rounded if they are larger than the specified size for a numeric column. For example, the number 9.96 will be rounded to 10.0 if stored in a column defined as float(3,1).

## Performing Arithmetic Functions

Most of the built-in numeric functions are used for specific arithmetic purposes, such as determining the square root of a number. [Table 7-1](#Table_7_1__Single_argument_numer) lists some of the common numeric functions that take a single numeric argument and return a number.

|  |  |
| --- | --- |
| Table 7-1. Single-argument numeric functions  Function name | Description |

|  |  |
| --- | --- |
| acos( x ) | Calculates the arc cosine of x |

|  |  |
| --- | --- |
| asin( x ) | Calculates the arc sine of x |

|  |  |
| --- | --- |
| atan( x ) | Calculates the arc tangent of x |

|  |  |
| --- | --- |
| cos( x ) | Calculates the cosine of x |

|  |  |
| --- | --- |
| cot( x ) | Calculates the cotangent of x |

|  |  |
| --- | --- |
| exp( x ) | Calculates ex |

|  |  |
| --- | --- |
| ln( x ) | Calculates the natural log of x |

|  |  |
| --- | --- |
| sin( x ) | Calculates the sine of x |

|  |  |
| --- | --- |
| sqrt( x ) | Calculates the square root of x |

|  |  |
| --- | --- |
| tan( x ) | Calculates the tangent of x |

These functions perform very specific tasks, and I refrain from showing examples for these functions (if you don’t recognize a function by name or description, then you probably don’t need it). Other numeric functions used for calculations, however, are a bit more flexible and deserve some explanation.

For example, the modulo operator, which calculates the remainder when one number is divided into another number, is implemented in MySQL and Oracle Database via the mod() function. The following example calculates the remainder when 10 is divided by 4:

mysql>   
SELECT MOD(10,4);  
  
+-----------+  
| MOD(10,4) |  
+-----------+  
| 2 |  
+-----------+  
1 row in set (0.02 sec)

While the mod() function is typically used with integer arguments, with MySQL you can also use real numbers, as in:

mysql>   
SELECT MOD(22.75, 5);  
  
+---------------+  
| MOD(22.75, 5) |  
+---------------+  
| 2.75 |  
+---------------+  
1 row in set (0.02 sec)

##### Note

SQL Server does not have a mod() function. Instead, the operator % is used for finding remainders. The expression 10 % 4 will therefore yield the value 2.

Another numeric function that takes two numeric arguments is the pow() function (or power() if you are using Oracle Database or SQL Server), which returns one number raised to the power of a second number, as in:

mysql>   
SELECT POW(2,8);  
  
+----------+  
| POW(2,8) |  
+----------+  
| 256 |  
+----------+  
1 row in set (0.03 sec)

Thus, pow(2,8) is the MySQL equivalent of specifying 28. Since computer memory is allocated in chunks of 2x bytes, the pow() function can be a handy way to determine the exact number of bytes in a certain amount of memory:

mysql>   
SELECT POW(2,10) kilobyte, POW(2,20) megabyte,  
  
 ->   
POW(2,30) gigabyte, POW(2,40) terabyte;  
  
+----------+----------+------------+---------------+  
| kilobyte | megabyte | gigabyte | terabyte |  
+----------+----------+------------+---------------+  
| 1024 | 1048576 | 1073741824 | 1099511627776 |  
+----------+----------+------------+---------------+  
1 row in set (0.00 sec)

I don’t know about you, but I find it easier to remember that a gigabyte is 230 bytes than to remember the number 1,073,741,824.

## Controlling Number Precision

When working with floating-point numbers, you may not always want to interact with or display a number with its full precision. For example, you may store monetary transaction data with a precision to six decimal places, but you might want to round to the nearest hundredth for display purposes. Four functions are useful when limiting the precision of floating-point numbers: ceil(), floor(), round(), and truncate(). All three servers include these functions, although Oracle Database includes trunc() instead of truncate(), and SQL Server includes ceiling() instead of ceil().

The ceil() and floor() functions are used to round either up or down to the closest integer, as demonstrated by the following:

mysql>   
SELECT CEIL(72.445), FLOOR(72.445);  
  
+--------------+---------------+  
| CEIL(72.445) | FLOOR(72.445) |  
+--------------+---------------+  
| 73 | 72 |  
+--------------+---------------+  
1 row in set (0.06 sec)

Thus, any number between 72 and 73 will be evaluated as 73 by the ceil() function and 72 by the floor() function. Remember that ceil() will round up even if the decimal portion of a number is very small, and floor() will round down even if the decimal portion is quite significant, as in:

mysql>   
SELECT CEIL(72.000000001), FLOOR(72.999999999);  
  
+--------------------+---------------------+  
| CEIL(72.000000001) | FLOOR(72.999999999) |  
+--------------------+---------------------+  
| 73 | 72 |  
+--------------------+---------------------+  
1 row in set (0.00 sec)

If this is a bit too severe for your application, you can use the round() function to round up or down from the midpoint between two integers, as in:

mysql>   
SELECT ROUND(72.49999), ROUND(72.5), ROUND(72.50001);  
  
+-----------------+-------------+-----------------+  
| ROUND(72.49999) | ROUND(72.5) | ROUND(72.50001) |  
+-----------------+-------------+-----------------+  
| 72 | 73 | 73 |  
+-----------------+-------------+-----------------+  
1 row in set (0.00 sec)

Using round(), any number whose decimal portion is halfway or more between two integers will be rounded up, whereas the number will be rounded down if the decimal portion is anything less than halfway between the two integers.

Most of the time, you will want to keep at least some part of the decimal portion of a number rather than rounding to the nearest integer; the round() function allows an optional second argument to specify how many digits to the right of the decimal place to round to. The next example shows how you can use the second argument to round the number 72.0909 to one, two, and three decimal places:

mysql>   
SELECT ROUND(72.0909, 1), ROUND(72.0909, 2), ROUND(72.0909, 3);  
  
+-------------------+-------------------+-------------------+  
| ROUND(72.0909, 1) | ROUND(72.0909, 2) | ROUND(72.0909, 3) |  
+-------------------+-------------------+-------------------+  
| 72.1 | 72.09 | 72.091 |  
+-------------------+-------------------+-------------------+  
1 row in set (0.00 sec)

Like the round() function, the truncate() function allows an optional second argument to specify the number of digits to the right of the decimal, but truncate() simply discards the unwanted digits without rounding. The next example shows how the number 72.0909 would be truncated to one, two, and three decimal places:

mysql>   
SELECT TRUNCATE(72.0909, 1), TRUNCATE(72.0909, 2),  
  
 ->   
TRUNCATE(72.0909, 3);  
  
+----------------------+----------------------+----------------------+  
| TRUNCATE(72.0909, 1) | TRUNCATE(72.0909, 2) | TRUNCATE(72.0909, 3) |  
+----------------------+----------------------+----------------------+  
| 72.0 | 72.09 | 72.090 |  
+----------------------+----------------------+----------------------+  
1 row in set (0.00 sec)

##### Note

SQL Server does not include a truncate() function. Instead, the round() function allows for an optional third argument that, if present and nonzero, calls for the number to be truncated rather than rounded.

Both truncate() and round() also allow a negative value for the second argument, meaning that numbers to the left of the decimal place are truncated or rounded. This might seem like a strange thing to do at first, but there are valid applications. For example, you might sell a product that can be purchased only in units of 10. If a customer were to order 17 units, you could choose from one of the following methods to modify the customer’s order quantity:

mysql>   
SELECT ROUND(17, −1), TRUNCATE(17, −1);  
  
+---------------+------------------+  
| ROUND(17, −1) | TRUNCATE(17, −1) |  
+---------------+------------------+  
| 20 | 10 |  
+---------------+------------------+  
1 row in set (0.00 sec)

If the product in question is thumbtacks, then it might not make much difference to your bottom line whether you sold the customer 10 or 20 thumbtacks when only 17 were requested; if you are selling Rolex watches, however, your business may fare better by rounding.

## Handling Signed Data

If you are working with numeric columns that allow negative values (in [Chapter 2](#Chapter_2__Creating_and_Populati_2), I showed how a numeric column may be labeled unsigned, meaning that only positive numbers are allowed), several numeric functions might be of use. Let’s say, for example, that you are asked to generate a report showing the current status of a set of bank accounts using the following data from the account table:

+------------+--------------+---------+  
| account\_id | acct\_type    | balance |  
+------------+--------------+---------+  
|        123 | MONEY MARKET |  785.22 |  
|        456 | SAVINGS      |    0.00 |  
|        789 | CHECKING     | -324.22 |  
+------------+--------------+---------+

The following query returns three columns useful for generating the report:

mysql> SELECT account\_id, SIGN(balance), ABS(balance)  
    -> FROM account;  
+------------+---------------+--------------+  
| account\_id | SIGN(balance) | ABS(balance) |  
+------------+---------------+--------------+  
|        123 |             1 |       785.22 |  
|        456 |             0 |         0.00 |  
|        789 |            -1 |       324.22 |  
+------------+---------------+--------------+  
3 rows in set (0.00 sec)

The second column uses the sign() function to return −1 if the account balance is negative, 0 if the account balance is zero, and 1 if the account balance is positive. The third column returns the absolute value of the account balance via the abs() function.

# Working with Temporal Data

Of the three types of data discussed in this chapter (character, numeric, and temporal), temporal data is the most involved when it comes to data generation and manipulation. Some of the complexity of temporal data is caused by the myriad ways in which a single date and time can be described. For example, the date on which I wrote this paragraph can be described in all the following ways:

* Wednesday, June 5, 2019
* 6/05/2019 2:14:56 P.M. EST
* 6/05/2019 19:14:56 GMT
* 1562019 (Julian format)
* Star date [−4] 97026.79 14:14:56 (Star Trek format)

While some of these differences are purely a matter of formatting, most of the complexity has to do with your frame of reference, which we explore in the next section.

## Dealing with Time Zones

Because people around the world prefer that noon coincides roughly with the sun’s peak at their location, there has never been a serious attempt to coerce everyone to use a universal clock. Instead, the world has been sliced into 24 imaginary sections, called time zones; within a particular time zone, everyone agrees on the current time, whereas people in different time zones do not. While this seems simple enough, some geographic regions shift their time by one hour twice a year (implementing what is known as daylight saving time) and some do not, so the time difference between two points on Earth might be four hours for one-half of the year and five hours for the other half of the year. Even within a single time zone, different regions may or may not adhere to daylight saving time, causing different clocks in the same time zone to agree for one-half of the year but be one hour different for the rest of the year.

While the computer age has exacerbated the issue, people have been dealing with time zone differences since the early days of naval exploration. To ensure a common point of reference for timekeeping, fifteenth-century navigators set their clocks to the time of day in Greenwich, England. This became known as Greenwich Mean Time, or GMT. All other time zones can be described by the number of hours’ difference from GMT; for example, the time zone for the Eastern United States, known as Eastern Standard Time, can be described as GMT −5:00, or five hours earlier than GMT.

Today, we use a variation of GMT called Coordinated Universal Time, or UTC, which is based on an atomic clock (or, to be more precise, the average time of 200 atomic clocks in 50 locations worldwide, which is referred to as Universal Time). Both SQL Server and MySQL provide functions that will return the current UTC timestamp (getutcdate() for SQL Server and utc\_timestamp() for MySQL).

Most database servers default to the time zone setting of the server on which it resides and provide tools for modifying the time zone if needed. For example, a database used to store stock exchange transactions from around the world would generally be configured to use UTC time, whereas a database used to store transactions at a particular retail establishment might use the server’s time zone.

MySQL keeps two different time zone settings: a global time zone and a session time zone, which may be different for each user logged in to a database. You can see both settings via the following query:

mysql>   
SELECT @@global.time\_zone, @@session.time\_zone;  
  
+--------------------+---------------------+  
| @@global.time\_zone | @@session.time\_zone |  
+--------------------+---------------------+  
| SYSTEM | SYSTEM |  
+--------------------+---------------------+  
1 row in set (0.00 sec)

A value of system tells you that the server is using the time zone setting from the server on which the database resides.

If you are sitting at a computer in Zurich, Switzerland, and you open a session across the network to a MySQL server situated in New York, you may want to change the time zone setting for your session, which you can do via the following command:

mysql>   
SET time\_zone = 'Europe/Zurich';  
  
Query OK, 0 rows affected (0.18 sec)

If you check the time zone settings again, you will see the following:

mysql>   
SELECT @@global.time\_zone, @@session.time\_zone;  
  
+--------------------+---------------------+  
| @@global.time\_zone | @@session.time\_zone |  
+--------------------+---------------------+  
| SYSTEM | Europe/Zurich |  
+--------------------+---------------------+  
1 row in set (0.00 sec)

All dates displayed in your session will now conform to Zurich time.

##### Note

Oracle Database users can change the time zone setting for a session via the following command:

ALTER SESSION TIMEZONE = 'Europe/Zurich'

## Generating Temporal Data

You can generate temporal data via any of the following means:

* Copying data from an existing date, datetime, or time column
* Executing a built-in function that returns a date, datetime, or time
* Building a string representation of the temporal data to be evaluated by the server

To use the last method, you will need to understand the various components used in formatting dates.

## String representations of temporal data

[Table 2-4](#Table_2_4__MySQL_temporal_types) in [Chapter 2](#Chapter_2__Creating_and_Populati_2) presented the more popular date components; to refresh your memory, [Table 7-2](#Table_7_2__Date_format_component) shows these same components.

|  |  |  |
| --- | --- | --- |
| Table 7-2. Date format components  Component | Definition | Range |

|  |  |  |
| --- | --- | --- |
| YYYY | Year, including century | 1000 to 9999 |

|  |  |  |
| --- | --- | --- |
| MM | Month | 01 (January) to 12 (December) |

|  |  |  |
| --- | --- | --- |
| DD | Day | 01 to 31 |

|  |  |  |
| --- | --- | --- |
| HH | Hour | 00 to 23 |

|  |  |  |
| --- | --- | --- |
| HHH | Hours (elapsed) | −838 to 838 |

|  |  |  |
| --- | --- | --- |
| MI | Minute | 00 to 59 |

|  |  |  |
| --- | --- | --- |
| SS | Second | 00 to 59 |

To build a string that the server can interpret as a date, datetime, or time, you need to put the various components together in the order shown in [Table 7-3](#Table_7_3__Required_date_compone).

|  |  |
| --- | --- |
| Table 7-3. Required date components  Type | Default format |

|  |  |
| --- | --- |
| date | YYYY-MM-DD |

|  |  |
| --- | --- |
| datetime | YYYY-MM-DD HH:MI:SS |

|  |  |
| --- | --- |
| timestamp | YYYY-MM-DD HH:MI:SS |

|  |  |
| --- | --- |
| time | HHH:MI:SS |

Thus, to populate a datetime column with 3:30 P.M. on September 17, 2019, you will need to build the following string:

'2019-09-17 15:30:00'

If the server is expecting a datetime value, such as when updating a datetime column or when calling a built-in function that takes a datetime argument, you can provide a properly formatted string with the required date components, and the server will do the conversion for you. For example, here’s a statement used to modify the return date of a film rental:

UPDATE rental  
SET return\_date = '2019-09-17 15:30:00'  
WHERE rental\_id = 99999;

The server determines that the string provided in the set clause must be a datetime value, since the string is being used to populate a datetime column. Therefore, the server will attempt to convert the string for you by parsing the string into the six components (year, month, day, hour, minute, second) included in the default datetime format.

## String-to-date conversions

If the server is not expecting a datetime value or if you would like to represent the datetime using a nondefault format, you will need to tell the server to convert the string to a datetime. For example, here is a simple query that returns a datetime value using the cast() function:

mysql>   
SELECT CAST('2019-09-17 15:30:00' AS DATETIME);  
  
+-----------------------------------------+  
| CAST('2019-09-17 15:30:00' AS DATETIME) |  
+-----------------------------------------+  
| 2019-09-17 15:30:00 |  
+-----------------------------------------+  
1 row in set (0.00 sec)

We cover the cast() function at the end of this chapter. While this example demonstrates how to build datetime values, the same logic applies to the date and time types as well. The following query uses the cast() function to generate a date value and a time value:

mysql>   
SELECT CAST('2019-09-17' AS DATE) date\_field,  
  
 ->   
CAST('108:17:57' AS TIME) time\_field;  
  
+------------+------------+  
| date\_field | time\_field |  
+------------+------------+  
| 2019-09-17 | 108:17:57 |  
+------------+------------+  
1 row in set (0.00 sec)

You might, of course, explicitly convert your strings even when the server is expecting a date, datetime, or time value, rather than allowing the server to do an implicit conversion.

When strings are converted to temporal values—whether explicitly or implicitly—you must provide all the date components in the required order. While some servers are quite strict regarding the date format, the MySQL server is quite lenient about the separators used between the components. For example, MySQL will accept all of the following strings as valid representations of 3:30 P.M. on September 17, 2019:

'2019-09-17 15:30:00'  
'2019/09/17 15:30:00'  
'2019,09,17,15,30,00'  
'20190917153000'

Although this gives you a bit more flexibility, you may find yourself trying to generate a temporal value without the default date components; the next section demonstrates a built-in function that is far more flexible than the cast() function.

## Functions for generating dates

If you need to generate temporal data from a string and the string is not in the proper form to use the cast() function, you can use a built-in function that allows you to provide a format string along with the date string. MySQL includes the str\_to\_date() function for this purpose. Say, for example, that you pull the string 'September 17, 2019' from a file and need to use it to update a date column. Since the string is not in the required YYYY-MM-DD format, you can use str\_to\_date() instead of reformatting the string so that you can use the cast() function, as in:

UPDATE rental  
SET return\_date =   
STR\_TO\_DATE('September 17, 2019', '%M %d, %Y')  
  
WHERE rental\_id = 99999;

The second argument in the call to str\_to\_date() defines the format of the date string, with, in this case, a month name (%M), a numeric day (%d), and a four-digit numeric year (%Y). While there are more than 30 recognized format components, [Table 7-4](#Table_7_4__Date_format_component) defines the dozen or so of the most commonly used components.

|  |  |
| --- | --- |
| Table 7-4. Date format components  Format component | Description |

|  |  |
| --- | --- |
| %M | Month name (January to December) |

|  |  |
| --- | --- |
| %m | Month numeric (01 to 12) |

|  |  |
| --- | --- |
| %d | Day numeric (01 to 31) |

|  |  |
| --- | --- |
| %j | Day of year (001 to 366) |

|  |  |
| --- | --- |
| %W | Weekday name (Sunday to Saturday) |

|  |  |
| --- | --- |
| %Y | Year, four-digit numeric |

|  |  |
| --- | --- |
| %y | Year, two-digit numeric |

|  |  |
| --- | --- |
| %H | Hour (00 to 23) |

|  |  |
| --- | --- |
| %h | Hour (01 to 12) |

|  |  |
| --- | --- |
| %i | Minutes (00 to 59) |

|  |  |
| --- | --- |
| %s | Seconds (00 to 59) |

|  |  |
| --- | --- |
| %f | Microseconds (000000 to 999999) |

|  |  |
| --- | --- |
| %p | A.M. or P.M. |

The str\_to\_date() function returns a datetime, date, or time value depending on the contents of the format string. For example, if the format string includes only %H, %i, and %s, then a time value will be returned.

##### Note

Oracle Database users can use the to\_date() function in the same manner as MySQL’s str\_to\_date() function. SQL Server includes a convert() function that is not quite as flexible as MySQL and Oracle Database; rather than supplying a custom format string, your date string must conform to one of 21 predefined formats.

If you are trying to generate the current date/time, then you won’t need to build a string, because the following built-in functions will access the system clock and return the current date and/or time as a string for you:

mysql>   
SELECT CURRENT\_DATE(), CURRENT\_TIME(), CURRENT\_TIMESTAMP();  
  
+----------------+----------------+---------------------+  
| CURRENT\_DATE() | CURRENT\_TIME() | CURRENT\_TIMESTAMP() |  
+----------------+----------------+---------------------+  
| 2019-06-05     | 16:54:36       | 2019-06-05 16:54:36 |  
+----------------+----------------+---------------------+  
1 row in set (0.12 sec)

The values returned by these functions are in the default format for the temporal type being returned. Oracle Database will include current\_date() and current\_timestamp() but not current\_time(), and Microsoft SQL Server includes only the current\_timestamp() function.

## Manipulating Temporal Data

This section explores the built-in functions that take date arguments and return dates, strings, or numbers.

## Temporal functions that return dates

Many of the built-in temporal functions take one date as an argument and return another date. MySQL’s date\_add() function, for example, allows you to add any kind of interval (e.g., days, months, years) to a specified date to generate another date. Here’s an example that demonstrates how to add five days to the current date:

mysql>   
SELECT DATE\_ADD(CURRENT\_DATE(), INTERVAL 5 DAY);  
  
+------------------------------------------+  
| DATE\_ADD(CURRENT\_DATE(), INTERVAL 5 DAY) |  
+------------------------------------------+  
| 2019-06-10 |  
+------------------------------------------+  
1 row in set (0.06 sec)

The second argument is composed of three elements: the interval keyword, the desired quantity, and the type of interval. [Table 7-5](#Table_7_5__Common_interval_types) shows some of the commonly used interval types.

|  |  |
| --- | --- |
| Table 7-5. Common interval types  Interval name | Description |

|  |  |
| --- | --- |
| second | Number of seconds |

|  |  |
| --- | --- |
| minute | Number of minutes |

|  |  |
| --- | --- |
| hour | Number of hours |

|  |  |
| --- | --- |
| day | Number of days |

|  |  |
| --- | --- |
| month | Number of months |

|  |  |
| --- | --- |
| year | Number of years |

|  |  |
| --- | --- |
| minute\_second | Number of minutes and seconds, separated by “:” |

|  |  |
| --- | --- |
| hour\_second | Number of hours, minutes, and seconds, separated by “:” |

|  |  |
| --- | --- |
| year\_month | Number of years and months, separated by “-” |

While the first six types listed in [Table 7-5](#Table_7_5__Common_interval_types) are pretty straightforward, the last three types require a bit more explanation since they have multiple elements. For example, if you are told that a film was actually returned 3 hours, 27 minutes, and 11 seconds later than what was originally specified, you can fix it via the following:

UPDATE rental  
SET return\_date = DATE\_ADD(return\_date,   
INTERVAL '3:27:11' HOUR\_SECOND  
)  
WHERE rental\_id = 99999;

In this example, the date\_add() function takes the value in the return\_date column and adds 3 hours, 27 minutes, and 11 seconds to it. Then it uses the value that results to modify the return\_date column.

Or, if you work in HR and found out that employee ID 4789 claimed to be older than he actually is, you could add 9 years and 11 months to his birth date, as in:

UPDATE employee  
SET birth\_date = DATE\_ADD(birth\_date,   
INTERVAL '9-11' YEAR\_MONTH  
)  
WHERE emp\_id = 4789;

##### Note

SQL Server users can accomplish the previous example using the dateadd() function:

UPDATE employee  
SET birth\_date =  
 DATEADD(MONTH, 119, birth\_date)  
WHERE emp\_id = 4789

SQL Server doesn’t have combined intervals (i.e., year\_month), so I converted 9 years and 11 months to 119 months.

Oracle Database users can use the add\_months() function for this example, as in:

UPDATE employee  
SET birth\_date = ADD\_MONTHS(birth\_date, 119)  
WHERE emp\_id = 4789;

There are some cases where you want to add an interval to a date, and you know where you want to arrive but not how many days it takes to get there. For example, let’s say that a bank customer logs on to the online banking system and schedules a transfer for the end of the month. Rather than writing some code that figures out the current month and then looks up the number of days in that month, you can call the last\_day() function, which does the work for you (both MySQL and Oracle Database include the last\_day() function; SQL Server has no comparable function). If the customer asks for the transfer on September 17, 2019, you could find the last day of September via the following:

mysql>   
SELECT LAST\_DAY('2019-09-17');  
  
+------------------------+  
| LAST\_DAY('2019-09-17') |  
+------------------------+  
| 2019-09-30 |  
+------------------------+  
1 row in set (0.10 sec)

Whether you provide a date or datetime value, the last\_day() function always returns a date. Although this function may not seem like an enormous time-saver, the underlying logic can be tricky if you’re trying to find the last day of February and need to figure out whether the current year is a leap year.

## Temporal functions that return strings

Most of the temporal functions that return string values are used to extract a portion of a date or time. For example, MySQL includes the dayname() function to determine which day of the week a certain date falls on, as in:

mysql>   
SELECT DAYNAME('2019-09-18');  
  
+-----------------------+  
| DAYNAME('2019-09-18') |  
+-----------------------+  
| Wednesday             |  
+-----------------------+  
1 row in set (0.00 sec)

Many such functions are included with MySQL for extracting information from date values, but I recommend that you use the extract() function instead, since it’s easier to remember a few variations of one function than to remember a dozen different functions. Additionally, the extract() function is part of the SQL:2003 standard and has been implemented by Oracle Database as well as MySQL.

The extract() function uses the same interval types as the date\_add() function (see [Table 7-5](#Table_7_5__Common_interval_types)) to define which element of the date interests you. For example, if you want to extract just the year portion of a datetime value, you can do the following:

mysql>   
SELECT EXTRACT(YEAR FROM '2019-09-18 22:19:05');  
  
+------------------------------------------+  
| EXTRACT(YEAR FROM '2019-09-18 22:19:05') |  
+------------------------------------------+  
| 2019 |  
+------------------------------------------+  
1 row in set (0.00 sec)

##### Note

SQL Server doesn’t include an implementation of extract(), but it does include the datepart() function. Here’s how you would extract the year from a datetime value using datepart():

SELECT DATEPART(YEAR, GETDATE())

## Temporal functions that return numbers

Earlier in this chapter, I showed you a function used to add a given interval to a date value, thus generating another date value. Another common activity when working with dates is to take two date values and determine the number of intervals (days, weeks, years) between the two dates. For this purpose, MySQL includes the function datediff(), which returns the number of full days between two dates. For example, if I want to know the number of days that my kids will be out of school this summer, I can do the following:

mysql>   
SELECT DATEDIFF('2019-09-03', '2019-06-21');  
  
+--------------------------------------+  
| DATEDIFF('2019-09-03', '2019-06-21') |  
+--------------------------------------+  
|                                   74 |  
+--------------------------------------+  
1 row in set (0.00 sec)

Thus, I will have to endure 74 days of poison ivy, mosquito bites, and scraped knees before the kids are safely back at school. The datediff() function ignores the time of day in its arguments. Even if I include a time of day, setting it to one second until midnight for the first date and to one second after midnight for the second date, those times will have no effect on the calculation:

mysql>   
SELECT DATEDIFF('2019-09-03 23:59:59', '2019-06-21 00:00:01');  
  
+--------------------------------------------------------+  
| DATEDIFF('2019-09-03 23:59:59', '2019-06-21 00:00:01') |  
+--------------------------------------------------------+  
|                                                     74 |  
+--------------------------------------------------------+  
1 row in set (0.00 sec)

If I switch the arguments and have the earlier date first, datediff() will return a negative number, as in:

mysql>   
SELECT DATEDIFF('2019-06-21', '2019-09-03');  
  
+--------------------------------------+  
| DATEDIFF('2019-06-21', '2019-09-03') |  
+--------------------------------------+  
|                                  -74 |  
+--------------------------------------+  
1 row in set (0.00 sec)

##### Note

SQL Server also includes the datediff() function, but it is more flexible than the MySQL implementation in that you can specify the interval type (i.e., year, month, day, hour) instead of counting only the number of days between two dates. Here’s how SQL Server would accomplish the previous example:

SELECT DATEDIFF(DAY, '2019-06-21', '2019-09-03')

Oracle Database allows you to determine the number of days between two dates simply by subtracting one date from another.

# Conversion Functions

Earlier in this chapter, I showed you how to use the cast() function to convert a string to a datetime value. While every database server includes a number of proprietary functions used to convert data from one type to another, I recommend using the cast() function, which is included in the SQL:2003 standard and has been implemented by MySQL, Oracle Database, and Microsoft SQL Server.

To use cast(), you provide a value or expression, the as keyword, and the type to which you want the value converted. Here’s an example that converts a string to an integer:

mysql>   
SELECT CAST('1456328' AS SIGNED INTEGER);  
  
+-----------------------------------+  
| CAST('1456328' AS SIGNED INTEGER) |  
+-----------------------------------+  
| 1456328 |  
+-----------------------------------+  
1 row in set (0.01 sec)

When converting a string to a number, the cast() function will attempt to convert the entire string from left to right; if any nonnumeric characters are found in the string, the conversion halts without an error. Consider the following example:

mysql>   
SELECT CAST('999ABC111' AS UNSIGNED INTEGER);  
  
+---------------------------------------+  
| CAST('999ABC111' AS UNSIGNED INTEGER) |  
+---------------------------------------+  
| 999 |  
+---------------------------------------+  
1 row in set,   
1 warning  
 (0.08 sec)  
  
mysql> show warnings;  
+---------+------+------------------------------------------------+  
| Level | Code | Message |  
+---------+------+------------------------------------------------+  
| Warning | 1292 | Truncated incorrect INTEGER value: '999ABC111' |  
+---------+------+------------------------------------------------+  
1 row in set (0.07 sec)

In this case, the first three digits of the string are converted, whereas the rest of the string is discarded, resulting in a value of 999. The server did, however, issue a warning to let you know that not all the string was converted.

If you are converting a string to a date, time, or datetime value, then you will need to stick with the default formats for each type, since you can’t provide the cast() function with a format string. If your date string is not in the default format (i.e., YYYY-MM-DD HH:MI:SS for datetime types), then you will need to resort to using another function, such as MySQL’s str\_to\_date() function described earlier in the chapter.

# Test Your Knowledge

These exercises are designed to test your understanding of some of the built-in functions shown in this chapter. See [Appendix B](#Appendix_B__Solutions_to_Exercis_2) for the answers.

## Exercise 7-1

Write a query that returns the 17th through 25th characters of the string 'Please find the substring in this string'.

## Exercise 7-2

Write a query that returns the absolute value and sign (−1, 0, or 1) of the number −25.76823. Also return the number rounded to the nearest hundredth.

## Exercise 7-3

Write a query to return just the month portion of the current date.

# Chapter 8. Grouping and Aggregates

Data is generally stored at the lowest level of granularity needed by any of a database’s users; if Chuck in accounting needs to look at individual customer transactions, then there needs to be a table in the database that stores individual transactions. That doesn’t mean, however, that all users must deal with the data as it is stored in the database. The focus of this chapter is on how data can be grouped and aggregated to allow users to interact with it at some higher level of granularity than what is stored in the database.

# Grouping Concepts

Sometimes you will want to find trends in your data that will require the database server to cook the data a bit before you can generate the results you are looking for. For example, let’s say that you are in charge of sending coupons for free rentals to your best customers. You could issue a simple query to look at the raw data:

mysql> SELECT customer\_id FROM rental;  
+-------------+  
| customer\_id |  
+-------------+  
|           1 |  
|           1 |  
|           1 |  
|           1 |  
|           1 |  
|           1 |  
|           1 |  
...  
|         599 |  
|         599 |  
|         599 |  
|         599 |  
|         599 |  
|         599 |  
+-------------+  
16044 rows in set (0.01 sec)

With 599 customers spanning more than 16,000 rental records, it isn’t feasible to determine which customers have rented the most films by looking at the raw data. Instead, you can ask the database server to group the data for you by using the group by clause. Here’s the same query but employing a group by clause to group the rental data by customer ID:

mysql> SELECT customer\_id  
    -> FROM rental  
    -> GROUP BY customer\_id;  
+-------------+  
| customer\_id |  
+-------------+  
|           1 |  
|           2 |  
|           3 |  
|           4 |  
|           5 |  
|           6 |  
...  
|         594 |  
|         595 |  
|         596 |  
|         597 |  
|         598 |  
|         599 |  
+-------------+  
599 rows in set (0.00 sec)

The result set contains one row for each distinct value in the customer\_id column, resulting in 599 rows instead of the full 16,044 rows. The reason for the smaller result set is that some of the customers rented more than one film. To see how many films each customer rented, you can use an aggregate function in the select clause to count the number of rows in each group:

mysql> SELECT customer\_id,   
count(\*)  
  
    -> FROM rental  
    -> GROUP BY customer\_id;  
+-------------+----------+  
| customer\_id | count(\*) |  
+-------------+----------+  
|           1 |       32 |  
|           2 |       27 |  
|           3 |       26 |  
|           4 |       22 |  
|           5 |       38 |  
|           6 |       28 |  
...  
|         594 |       27 |  
|         595 |       30 |  
|         596 |       28 |  
|         597 |       25 |  
|         598 |       22 |  
|         599 |       19 |  
+-------------+----------+  
599 rows in set (0.01 sec)

The aggregate function count() counts the number of rows in each group, and the asterisk tells the server to count everything in the group. Using the combination of a group by clause and the count() aggregate function, you are able to generate exactly the data needed to answer the business question without having to look at the raw data.

Looking at the results, you can see that 32 films were rented by customer ID 1, and 25 films were rented by the customer ID 597. In order to determine which customers have rented the most films, simply add an order by clause:

mysql> SELECT customer\_id, count(\*)  
    -> FROM rental  
    -> GROUP BY customer\_id  
    ->   
ORDER BY 2 DESC  
;  
+-------------+----------+  
| customer\_id | count(\*) |  
+-------------+----------+  
|         148 |       46 |  
|         526 |       45 |  
|         236 |       42 |  
|         144 |       42 |  
|          75 |       41 |  
...  
|         248 |       15 |  
|         110 |       14 |  
|         281 |       14 |  
|          61 |       14 |  
|         318 |       12 |  
+-------------+----------+  
599 rows in set (0.01 sec)

Now that the results are sorted, you can easily see that customer ID 148 has rented the most films (46), while customer ID 318 has rented the fewest films (12).

When grouping data, you may need to filter out undesired data from your result set based on groups of data rather than based on the raw data. Since the group by clause runs after the where clause has been evaluated, you cannot add filter conditions to your where clause for this purpose. For example, here’s an attempt to filter out any customers who have rented fewer than 40 films:

mysql> SELECT customer\_id, count(\*)  
    -> FROM rental  
    ->   
WHERE count(\*) >= 40  
  
    -> GROUP BY customer\_id;  
ERROR 1111 (HY000): Invalid use of group function

You cannot refer to the aggregate function count(\*) in your where clause, because the groups have not yet been generated at the time the where clause is evaluated. Instead, you must put your group filter conditions in the having clause. Here’s what the query would look like using having:

mysql> SELECT customer\_id, count(\*)  
    -> FROM rental  
    -> GROUP BY customer\_id  
    ->   
HAVING count(\*) >= 40  
;  
+-------------+----------+  
| customer\_id | count(\*) |  
+-------------+----------+  
|          75 |       41 |  
|         144 |       42 |  
|         148 |       46 |  
|         197 |       40 |  
|         236 |       42 |  
|         469 |       40 |  
|         526 |       45 |  
+-------------+----------+  
7 rows in set (0.01 sec)

Because those groups containing fewer than 40 members have been filtered out via the having clause, the result set now contains only those customers who have rented 40 or more films.

# Aggregate Functions

Aggregate functions perform a specific operation over all rows in a group. Although every database server has its own set of specialty aggregate functions, the common aggregate functions implemented by all major servers include:

max()

Returns the maximum value within a set

min()

Returns the minimum value within a set

avg()

Returns the average value across a set

sum()

Returns the sum of the values across a set

count()

Returns the number of values in a set

Here’s a query that uses all of the common aggregate functions to analyze the data on film rental payments:

mysql> SELECT MAX(amount) max\_amt,  
    ->   MIN(amount) min\_amt,  
    ->   AVG(amount) avg\_amt,  
    ->   SUM(amount) tot\_amt,  
    ->   COUNT(\*) num\_payments  
    -> FROM payment;  
+---------+---------+----------+----------+--------------+  
| max\_amt | min\_amt | avg\_amt  | tot\_amt  | num\_payments |  
+---------+---------+----------+----------+--------------+  
|   11.99 |    0.00 | 4.200667 | 67416.51 |        16049 |  
+---------+---------+----------+----------+--------------+  
1 row in set (0.09 sec)

The results from this query tell you that, across the 16,049 rows in the payment table, the maximum amount paid to rent a film was $11.99, the minimum amount was $0, the average payment was $4.20, and the total of all rental payments was $67,416.51. Hopefully, this gives you an appreciation for the role of these aggregate functions; the next subsections further clarify how you can utilize these functions.

## Implicit Versus Explicit Groups

In the previous example, every value returned by the query is generated by an aggregate function. Since there is no group by clause, there is a single, implicit group (all rows in the payment table).

In most cases, however, you will want to retrieve additional columns along with columns generated by aggregate functions. What if, for example, you wanted to extend the previous query to execute the same five aggregate functions for each customer, instead of across all customers? For this query, you would want to retrieve the customer\_id column along with the five aggregate functions, as in:

SELECT   
customer\_id  
,  
  MAX(amount) max\_amt,  
  MIN(amount) min\_amt,  
  AVG(amount) avg\_amt,  
  SUM(amount) tot\_amt,  
  COUNT(\*) num\_payments  
FROM payment;

However, if you try to execute the query, you will receive the following error:

ERROR 1140 (42000): In aggregated query without GROUP BY,   
  expression #1 of SELECT list contains nonaggregated column

While it may be obvious to you that you want the aggregate functions applied to each customer found in the payment table, this query fails because you have not explicitly specified how the data should be grouped. Therefore, you will need to add a group by clause to specify over which group of rows the aggregate functions should be applied:

mysql> SELECT customer\_id,  
    ->   MAX(amount) max\_amt,  
    ->   MIN(amount) min\_amt,  
    ->   AVG(amount) avg\_amt,  
    ->   SUM(amount) tot\_amt,  
    ->   COUNT(\*) num\_payments  
    -> FROM payment  
    ->   
GROUP BY customer\_id  
;  
+-------------+---------+---------+----------+---------+--------------+  
| customer\_id | max\_amt | min\_amt | avg\_amt  | tot\_amt | num\_payments |  
+-------------+---------+---------+----------+---------+--------------+  
|           1 |    9.99 |    0.99 | 3.708750 |  118.68 |           32 |  
|           2 |   10.99 |    0.99 | 4.767778 |  128.73 |           27 |  
|           3 |   10.99 |    0.99 | 5.220769 |  135.74 |           26 |  
|           4 |    8.99 |    0.99 | 3.717273 |   81.78 |           22 |  
|           5 |    9.99 |    0.99 | 3.805789 |  144.62 |           38 |  
|           6 |    7.99 |    0.99 | 3.347143 |   93.72 |           28 |  
...  
|         594 |    8.99 |    0.99 | 4.841852 |  130.73 |           27 |  
|         595 |   10.99 |    0.99 | 3.923333 |  117.70 |           30 |  
|         596 |    6.99 |    0.99 | 3.454286 |   96.72 |           28 |  
|         597 |    8.99 |    0.99 | 3.990000 |   99.75 |           25 |  
|         598 |    7.99 |    0.99 | 3.808182 |   83.78 |           22 |  
|         599 |    9.99 |    0.99 | 4.411053 |   83.81 |           19 |  
+-------------+---------+---------+----------+---------+--------------+  
599 rows in set (0.04 sec)

With the inclusion of the group by clause, the server knows to group together rows having the same value in the customer\_id column first and then to apply the five aggregate functions to each of the 599 groups.

## Counting Distinct Values

When using the count() function to determine the number of members in each group, you have your choice of counting all members in the group or counting only the distinct values for a column across all members of the group.

For example, consider the following query, which uses the count() function with the customer\_id column in two different ways:

mysql> SELECT COUNT(customer\_id) num\_rows,  
    ->   COUNT(  
DISTINCT   
customer\_id) num\_customers  
    -> FROM payment;  
+----------+---------------+  
| num\_rows | num\_customers |  
+----------+---------------+  
|    16049 |           599 |  
+----------+---------------+  
1 row in set (0.01 sec)

The first column in the query simply counts the number of rows in the payment table, whereas the second column examines the values in the customer\_id column and counts only the number of unique values. By specifying distinct, therefore, the count() function examines the values of a column for each member of the group in order to find and remove duplicates, rather than simply counting the number of values in the group.

## Using Expressions

Along with using columns as arguments to aggregate functions, you can use expressions as well. For example, you may want to find the maximum number of days between when a film was rented and subsequently returned. You can achieve this via the following query:

mysql> SELECT MAX(datediff(return\_date,rental\_date))  
    -> FROM rental;  
+----------------------------------------+  
| MAX(datediff(return\_date,rental\_date)) |  
+----------------------------------------+  
|                                     10 |  
+----------------------------------------+  
1 row in set (0.01 sec)

The datediff function is used to compute the number of days between the return date and the rental date for every rental, and the max function returns the highest value, which in this case is 10 days.

While this example uses a fairly simple expression, expressions used as arguments to aggregate functions can be as complex as needed, as long as they return a number, string, or date. In [Chapter 11](#Chapter_11__Conditional_Logic__I_2), I show you how you can use case expressions with aggregate functions to determine whether a particular row should or should not be included in an aggregation.

## How Nulls Are Handled

When performing aggregations, or, indeed, any type of numeric calculation, you should always consider how null values might affect the outcome of your calculation. To illustrate, I will build a simple table to hold numeric data and populate it with the set {1, 3, 5}:

mysql>   
CREATE TABLE number\_tbl  
  
 ->   
(val SMALLINT);  
  
Query OK, 0 rows affected (0.01 sec)  
  
mysql>   
INSERT INTO number\_tbl VALUES (1);  
  
Query OK, 1 row affected (0.00 sec)  
  
mysql>   
INSERT INTO number\_tbl VALUES (3);  
  
Query OK, 1 row affected (0.00 sec)  
  
mysql>   
INSERT INTO number\_tbl VALUES (5);  
  
Query OK, 1 row affected (0.00 sec)

Consider the following query, which performs five aggregate functions on the set of numbers:

mysql>   
SELECT COUNT(\*) num\_rows,  
  
 ->   
COUNT(val) num\_vals,  
  
 ->   
SUM(val) total,  
  
 ->   
MAX(val) max\_val,  
  
 ->   
AVG(val) avg\_val  
  
 ->   
FROM number\_tbl;  
  
+----------+----------+-------+---------+---------+  
| num\_rows | num\_vals | total | max\_val | avg\_val |  
+----------+----------+-------+---------+---------+  
| 3 | 3 | 9 | 5 | 3.0000 |  
+----------+----------+-------+---------+---------+  
1 row in set (0.08 sec)

The results are as you would expect: both count(\*) and count(val) return the value 3, sum(val) returns the value 9, max(val) returns 5, and avg(val) returns 3. Next, I will add a null value to the number\_tbl table and run the query again:

mysql>   
INSERT INTO number\_tbl VALUES (NULL);  
  
Query OK, 1 row affected (0.01 sec)  
  
mysql>   
SELECT COUNT(\*) num\_rows,  
  
 ->   
COUNT(val) num\_vals,  
  
 ->   
SUM(val) total,  
  
 ->   
MAX(val) max\_val,  
  
 ->   
AVG(val) avg\_val  
  
 ->   
FROM number\_tbl;  
  
+----------+----------+-------+---------+---------+  
| num\_rows | num\_vals | total | max\_val | avg\_val |  
+----------+----------+-------+---------+---------+  
| 4 | 3 | 9 | 5 | 3.0000 |  
+----------+----------+-------+---------+---------+  
1 row in set (0.00 sec)

Even with the addition of the null value to the table, the sum(), max(), and avg() functions all return the same values, indicating that they ignore any null values encountered. The count(\*) function now returns the value 4, which is valid since the number\_tbl table contains four rows, while the count(val) function still returns the value 3. The difference is that count(\*) counts the number of rows, whereas count(val) counts the number of values contained in the val column and ignores any null values encountered.

# Generating Groups

People are rarely interested in looking at raw data; instead, people engaging in data analysis will want to manipulate the raw data to better suit their needs. Examples of common data manipulations include:

* Generating totals for a geographic region, such as total European sales
* Finding outliers, such as the top salesperson for 2020
* Determining frequencies, such as the number of films rented in each month

To answer these types of queries, you will need to ask the database server to group rows together by one or more columns or expressions. As you have seen already in several examples, the group by clause is the mechanism for grouping data within a query. In this section, you will see how to group data by one or more columns, how to group data using expressions, and how to generate rollups within groups.

## Single-Column Grouping

Single-column groups are the simplest and most-often-used type of grouping. If you want to find the number of films associated with each actor, for example, you need only group on the film\_actor.actor\_id column, as in:

mysql> SELECT actor\_id, count(\*)  
    -> FROM film\_actor  
    -> GROUP BY actor\_id;  
+----------+----------+  
| actor\_id | count(\*) |  
+----------+----------+  
|        1 |       19 |  
|        2 |       25 |  
|        3 |       22 |  
|        4 |       22 |  
...  
|      197 |       33 |  
|      198 |       40 |  
|      199 |       15 |  
|      200 |       20 |  
+----------+----------+  
200 rows in set (0.11 sec)

This query generates 200 groups, one for each actor, and then sums the number of films for each member of the group.

## Multicolumn Grouping

In some cases, you may want to generate groups that span more than one column. Expanding on the previous example, imagine that you want to find the total number of films for each film rating (G, PG, ...) for each actor. The following example shows how you can accomplish this:

mysql> SELECT fa.actor\_id, f.rating, count(\*)  
    -> FROM film\_actor fa  
    ->   INNER JOIN film f  
    ->   ON fa.film\_id = f.film\_id  
    -> GROUP BY fa.actor\_id, f.rating  
    -> ORDER BY 1,2;  
+----------+--------+----------+  
| actor\_id | rating | count(\*) |  
+----------+--------+----------+  
|        1 | G      |        4 |  
|        1 | PG     |        6 |  
|        1 | PG-13  |        1 |  
|        1 | R      |        3 |  
|        1 | NC-17  |        5 |  
|        2 | G      |        7 |  
|        2 | PG     |        6 |  
|        2 | PG-13  |        2 |  
|        2 | R      |        2 |  
|        2 | NC-17  |        8 |  
...  
|      199 | G      |        3 |  
|      199 | PG     |        4 |  
|      199 | PG-13  |        4 |  
|      199 | R      |        2 |  
|      199 | NC-17  |        2 |  
|      200 | G      |        5 |  
|      200 | PG     |        3 |  
|      200 | PG-13  |        2 |  
|      200 | R      |        6 |  
|      200 | NC-17  |        4 |  
+----------+--------+----------+  
996 rows in set (0.01 sec)

This version of the query generates 996 groups, one for each combination of actor and film rating found by joining the film\_actor table with the film table. Along with adding the rating column to the select clause, I also added it to the group by clause, since rating is retrieved from a table and is not generated via an aggregate function such as max or count.

## Grouping via Expressions

Along with using columns to group data, you can build groups based on the values generated by expressions. Consider the following query, which groups rentals by year:

mysql> SELECT extract(YEAR FROM rental\_date) year,  
    ->   COUNT(\*) how\_many  
    -> FROM rental  
    -> GROUP BY extract(YEAR FROM rental\_date);  
+------+----------+  
| year | how\_many |  
+------+----------+  
| 2005 |    15862 |  
| 2006 |      182 |  
+------+----------+  
2 rows in set (0.01 sec)

This query employs a fairly simple expression that uses the extract() function to return only the year portion of a date to group the rows in the rental table.

## Generating Rollups

In [“Multicolumn Grouping”](#Multicolumn_Grouping_____In_some), I showed an example that counts the number of films for each actor and film rating. Let’s say, however, that along with the total count for each actor/rating combination, you also want total counts for each distinct actor. You could run an additional query and merge the results, you could load the results of the query into a spreadsheet, or you could build a Python script, Java program, or some other mechanism to take that data and perform the additional calculations. Better yet, you could use the with rollup option to have the database server do the work for you. Here’s the revised query using with rollup in the group by clause:

mysql> SELECT fa.actor\_id, f.rating, count(\*)  
    -> FROM film\_actor fa  
    ->   INNER JOIN film f  
    ->   ON fa.film\_id = f.film\_id  
    -> GROUP BY fa.actor\_id, f.rating   
WITH ROLLUP  
  
    -> ORDER BY 1,2;  
+----------+--------+----------+  
| actor\_id | rating | count(\*) |  
+----------+--------+----------+  
|       
NULL   
|   
NULL     
|     5462 |  
|        1 |   
NULL     
|       19 |  
|        1 | G      |        4 |  
|        1 | PG     |        6 |  
|        1 | PG-13  |        1 |  
|        1 | R      |        3 |  
|        1 | NC-17  |        5 |  
|        2 |   
NULL     
|       25 |  
|        2 | G      |        7 |  
|        2 | PG     |        6 |  
|        2 | PG-13  |        2 |  
|        2 | R      |        2 |  
|        2 | NC-17  |        8 |  
...  
|      199 |   
NULL     
|       15 |  
|      199 | G      |        3 |  
|      199 | PG     |        4 |  
|      199 | PG-13  |        4 |  
|      199 | R      |        2 |  
|      199 | NC-17  |        2 |  
|      200 |   
NULL     
|       20 |  
|      200 | G      |        5 |  
|      200 | PG     |        3 |  
|      200 | PG-13  |        2 |  
|      200 | R      |        6 |  
|      200 | NC-17  |        4 |  
+----------+--------+----------+  
1197 rows in set (0.07 sec)

There are now 201 additional rows in the result set, one for each of the 200 distinct actors and one for the grand total (all actors combined). For the 200 actor rollups, a null value is provided for the rating column, since the rollup is being performed across all ratings. Looking at the first line for actor\_id 200, for example, you will see that a total of 20 films are associated with the actor; this equals the sum of the counts for each rating (4 NC-17 + 6 R + 2 PG-13 + 3 PG + 5 G). For the grand total row in the first line of the output, a null value is provided for both the actor\_id and rating columns; the total for the first line of output equals 5,462, which is equal to the number of rows in the film\_actor table.

##### Note

If you are using Oracle Database, you need to use a slightly different syntax to indicate that you want a rollup performed. The group by clause for the previous query would look as follows when using Oracle:

GROUP BY ROLLUP(fa.actor\_id, f.rating)

The advantage of this syntax is that it allows you to perform rollups on a subset of the columns in the group\_by clause. If you are grouping by columns a, b, and c, for example, you could indicate that the server should perform rollups on only columns b and c via the following:

GROUP BY a, ROLLUP(b, c)

If in addition to totals by actor you also want to calculate totals per rating, then you can use the with cube option, which will generate summary rows for all possible combinations of the grouping columns. Unfortunately, with cube is not available in version 8.0 of MySQL, but it is available with SQL Server and Oracle Database.

# Group Filter Conditions

In [Chapter 4](#Chapter_4__Filtering__Sometimes_2), I introduced you to various types of filter conditions and showed how you can use them in the where clause. When grouping data, you also can apply filter conditions to the data after the groups have been generated. The having clause is where you should place these types of filter conditions. Consider the following example:

mysql> SELECT fa.actor\_id, f.rating, count(\*)  
    -> FROM film\_actor fa  
    ->   INNER JOIN film f  
    ->   ON fa.film\_id = f.film\_id  
    -> WHERE f.rating IN ('G','PG')  
    -> GROUP BY fa.actor\_id, f.rating  
    -> HAVING count(\*) > 9;  
+----------+--------+----------+  
| actor\_id | rating | count(\*) |  
+----------+--------+----------+  
|      137 | PG     |       10 |  
|       37 | PG     |       12 |  
|      180 | PG     |       12 |  
|        7 | G      |       10 |  
|       83 | G      |       14 |  
|      129 | G      |       12 |  
|      111 | PG     |       15 |  
|       44 | PG     |       12 |  
|       26 | PG     |       11 |  
|       92 | PG     |       12 |  
|       17 | G      |       12 |  
|      158 | PG     |       10 |  
|      147 | PG     |       10 |  
|       14 | G      |       10 |  
|      102 | PG     |       11 |  
|      133 | PG     |       10 |  
+----------+--------+----------+  
16 rows in set (0.01 sec)

This query has two filter conditions: one in the where clause, which filters out any films rated something other than G or PG, and another in the having clause, which filters out any actors who appeared in less than 10 films. Thus, one of the filters acts on data before it is grouped, and the other filter acts on data after the groups have been created. If you mistakenly put both filters in the where clause, you will see the following error:

mysql> SELECT fa.actor\_id, f.rating, count(\*)  
    -> FROM film\_actor fa  
    ->   INNER JOIN film f  
    ->   ON fa.film\_id = f.film\_id  
    -> WHERE f.rating IN ('G','PG')  
    ->     
AND count(\*) > 9  
  
    -> GROUP BY fa.actor\_id, f.rating;  
ERROR 1111 (HY000): Invalid use of group function

This query fails because you cannot include an aggregate function in a query’s where clause. This is because the filters in the where clause are evaluated before the grouping occurs, so the server can’t yet perform any functions on groups.

Warning

When adding filters to a query that includes a group by clause, think carefully about whether the filter acts on raw data, in which case it belongs in the where clause, or on grouped data, in which case it belongs in the having clause.

# Test Your Knowledge

Work through the following exercises to test your grasp of SQL’s grouping and aggregating features. Check your work with the answers in [Appendix B](#Appendix_B__Solutions_to_Exercis_2).

## Exercise 8-1

Construct a query that counts the number of rows in the payment table.

## Exercise 8-2

Modify your query from Exercise 8-1 to count the number of payments made by each customer. Show the customer ID and the total amount paid for each customer.

## Exercise 8-3

Modify your query from Exercise 8-2 to include only those customers who have made at least 40 payments.

# Chapter 9. Subqueries

Subqueries are a powerful tool that you can use in all four SQL data statements. In this chapter, I’ll show you how subqueries can be used to filter data, generate values, and construct temporary data sets. After a little experimentation, I think you’ll agree that subqueries are one of the most powerful features of the SQL language.

# What Is a Subquery?

A subquery is a query contained within another SQL statement (which I refer to as the containing statement for the rest of this discussion). A subquery is always enclosed within parentheses, and it is usually executed prior to the containing statement. Like any query, a subquery returns a result set that may consist of:

* A single row with a single column
* Multiple rows with a single column
* Multiple rows having multiple columns

The type of result set returned by the subquery determines how it may be used and which operators the containing statement may use to interact with the data the subquery returns. When the containing statement has finished executing, the data returned by any subqueries is discarded, making a subquery act like a temporary table with statement scope (meaning that the server frees up any memory allocated to the subquery results after the SQL statement has finished execution).

You already saw several examples of subqueries in earlier chapters, but here’s a simple example to get started:

mysql> SELECT customer\_id, first\_name, last\_name  
    -> FROM customer  
    -> WHERE customer\_id =   
(SELECT MAX(customer\_id) FROM customer)  
;  
+-------------+------------+-----------+  
| customer\_id | first\_name | last\_name |  
+-------------+------------+-----------+  
|         599 | AUSTIN     | CINTRON   |  
+-------------+------------+-----------+  
1 row in set (0.27 sec)

In this example, the subquery returns the maximum value found in the customer\_id column in the customer table, and the containing statement then returns data about that customer. If you are ever confused about what a subquery is doing, you can run the subquery by itself (without the parentheses) to see what it returns. Here’s the subquery from the previous example:

mysql> SELECT MAX(customer\_id) FROM customer;  
+------------------+  
| MAX(customer\_id) |  
+------------------+  
|              599 |  
+------------------+  
1 row in set (0.00 sec)

The subquery returns a single row with a single column, which allows it to be used as one of the expressions in an equality condition (if the subquery returned two or more rows, it could be compared to something but could not be equal to anything, but more on this later). In this case, you can take the value the subquery returned and substitute it into the righthand expression of the filter condition in the containing query, as in the following:

mysql> SELECT customer\_id, first\_name, last\_name  
    -> FROM customer  
    -> WHERE customer\_id = 599;  
+-------------+------------+-----------+  
| customer\_id | first\_name | last\_name |  
+-------------+------------+-----------+  
|         599 | AUSTIN     | CINTRON   |  
+-------------+------------+-----------+  
1 row in set (0.00 sec)

The subquery is useful in this case because it allows you to retrieve information about the customer with the highest ID in a single query, rather than retrieving the maximum customer\_id using one query and then writing a second query to retrieve the desired data from the customer table. As you will see, subqueries are useful in many other situations as well and may become one of the most powerful tools in your SQL toolkit.

# Subquery Types

Along with the differences noted previously regarding the type of result set returned by a subquery (single row/column, single row/multicolumn, or multiple columns), you can use another feature to differentiate subqueries; some subqueries are completely self-contained (called noncorrelated subqueries), while others reference columns from the containing statement (called correlated subqueries). The next several sections explore these two subquery types and show the different operators that you can employ to interact with them.

# Noncorrelated Subqueries

The example from earlier in the chapter is a noncorrelated subquery; it may be executed alone and does not reference anything from the containing statement. Most subqueries that you encounter will be of this type unless you are writing update or delete statements, which frequently make use of correlated subqueries (more on this later). Along with being noncorrelated, the example from earlier in the chapter also returns a result set containing a single row and column. This type of subquery is known as a scalar subquery and can appear on either side of a condition using the usual operators (=, <>, <, >, <=, >=). The next example shows how you can use a scalar subquery in an inequality condition:

mysql> SELECT city\_id, city  
    -> FROM city  
    -> WHERE country\_id <>   
  ->   
(SELECT country\_id FROM country WHERE country = 'India')  
;  
+---------+----------------------------+  
| city\_id | city                       |  
+---------+----------------------------+  
|       1 | A Corua (La Corua)         |  
|       2 | Abha                       |  
|       3 | Abu Dhabi                  |  
|       4 | Acua                       |  
|       5 | Adana                      |  
|       6 | Addis Abeba                |  
...  
|     595 | Zapopan                    |  
|     596 | Zaria                      |  
|     597 | Zeleznogorsk               |  
|     598 | Zhezqazghan                |  
|     599 | Zhoushan                   |  
|     600 | Ziguinchor                 |  
+---------+----------------------------+  
540 rows in set (0.02 sec)

This query returns all cities that are not in India. The subquery, which is found on the last line of the statement, returns the country ID for India, and the containing query returns all cities that do not have that country ID. While the subquery in this example is quite simple, subqueries may be as complex as you need them to be, and they may utilize any and all the available query clauses (select, from, where, group by, having, and order by).

If you use a subquery in an equality condition but the subquery returns more than one row, you will receive an error. For example, if you modify the previous query such that the subquery returns all countries except for India, you will receive the following error:

mysql> SELECT city\_id, city  
    -> FROM city  
    -> WHERE country\_id <>   
  -> (SELECT country\_id FROM country WHERE country   
<>  
 'India');  
ERROR 1242 (21000):   
Subquery returns more than 1 row

If you run the subquery by itself, you will see the following results:

mysql> SELECT country\_id FROM country WHERE country <> 'India';  
+------------+  
| country\_id |  
+------------+  
|          1 |  
|          2 |  
|          3 |  
|          4 |  
...  
|        106 |  
|        107 |  
|        108 |  
|        109 |  
+------------+  
108 rows in set (0.00 sec)

The containing query fails because an expression (country\_id) cannot be equated to a set of expressions (country\_ids 1, 2, 3, ..., 109). In other words, a single thing cannot be equated to a set of things. In the next section, you will see how to fix the problem by using a different operator.

## Multiple-Row, Single-Column Subqueries

If your subquery returns more than one row, you will not be able to use it on one side of an equality condition, as the previous example demonstrated. However, there are four additional operators that you can use to build conditions with these types of subqueries.

## The in and not in operators

While you can’t equate a single value to a set of values, you can check to see whether a single value can be found within a set of values. The next example, while it doesn’t use a subquery, demonstrates how to build a condition that uses the in operator to search for a value within a set of values:

mysql> SELECT country\_id  
    -> FROM country  
    -> WHERE country IN ('Canada','Mexico');  
+------------+  
| country\_id |  
+------------+  
|         20 |  
|         60 |  
+------------+  
2 rows in set (0.00 sec)

The expression on the lefthand side of the condition is the country column, while the righthand side of the condition is a set of strings. The in operator checks to see whether either of the strings can be found in the country column; if so, the condition is met, and the row is added to the result set. You could achieve the same results using two equality conditions, as in:

mysql> SELECT country\_id  
    -> FROM country  
    -> WHERE country = 'Canada' OR country = 'Mexico';  
+------------+  
| country\_id |  
+------------+  
|         20 |  
|         60 |  
+------------+  
2 rows in set (0.00 sec)

While this approach seems reasonable when the set contains only two expressions, it is easy to see why a single condition using the in operator would be preferable if the set contained dozens (or hundreds, thousands, etc.) of values.

Although you will occasionally create a set of strings, dates, or numbers to use on one side of a condition, you are more likely to generate the set using a subquery that returns one or more rows. The following query uses the in operator with a subquery on the righthand side of the filter condition to return all cities that are in Canada or Mexico:

mysql> SELECT city\_id, city  
    -> FROM city  
    -> WHERE country\_id IN  
    ->  (SELECT country\_id  
    ->   FROM country  
    ->   WHERE country IN ('Canada','Mexico'));  
+---------+----------------------------+  
| city\_id | city                       |  
+---------+----------------------------+  
|     179 | Gatineau                   |  
|     196 | Halifax                    |  
|     300 | Lethbridge                 |  
|     313 | London                     |  
|     383 | Oshawa                     |  
|     430 | Richmond Hill              |  
|     565 | Vancouver                  |  
...  
|     452 | San Juan Bautista Tuxtepec |  
|     541 | Torren                     |  
|     556 | Uruapan                    |  
|     563 | Valle de Santiago          |  
|     595 | Zapopan                    |  
+---------+----------------------------+  
37 rows in set (0.00 sec)

Along with seeing whether a value exists within a set of values, you can check the converse using the not in operator. Here’s another version of the previous query using not in instead of in:

mysql> SELECT city\_id, city  
    -> FROM city  
    -> WHERE country\_id   
NOT IN  
  
    ->  (SELECT country\_id  
    ->   FROM country  
    ->   WHERE country IN ('Canada','Mexico'));  
+---------+----------------------------+  
| city\_id | city                       |  
+---------+----------------------------+  
|       1 | A Corua (La Corua)         |  
|       2 | Abha                       |  
|       3 | Abu Dhabi                  |  
|       5 | Adana                      |  
|       6 | Addis Abeba                |  
...  
|     596 | Zaria                      |  
|     597 | Zeleznogorsk               |  
|     598 | Zhezqazghan                |  
|     599 | Zhoushan                   |  
|     600 | Ziguinchor                 |  
+---------+----------------------------+  
563 rows in set (0.00 sec)

This query finds all cities that are not in Canada or Mexico.

## The all operator

While the in operator is used to see whether an expression can be found within a set of expressions, the all operator allows you to make comparisons between a single value and every value in a set. To build such a condition, you will need to use one of the comparison operators (=, <>, <, >, etc.) in conjunction with the all operator. For example, the next query finds all customers who have never gotten a free film rental:

mysql> SELECT first\_name, last\_name  
    -> FROM customer  
    -> WHERE customer\_id   
<> ALL  
  
    ->  (SELECT customer\_id  
    ->   FROM payment  
    ->   WHERE amount = 0);  
+-------------+--------------+  
| first\_name  | last\_name    |  
+-------------+--------------+  
| MARY        | SMITH        |  
| PATRICIA    | JOHNSON      |  
| LINDA       | WILLIAMS     |  
| BARBARA     | JONES        |  
...  
| EDUARDO     | HIATT        |  
| TERRENCE    | GUNDERSON    |  
| ENRIQUE     | FORSYTHE     |  
| FREDDIE     | DUGGAN       |  
| WADE        | DELVALLE     |  
| AUSTIN      | CINTRON      |  
+-------------+--------------+  
576 rows in set (0.01 sec)

The subquery returns the set of IDs for customers who have paid $0 for a film rental, and the containing query returns the names of all customers whose ID is not in the set returned by the subquery. If this approach seems a bit clumsy to you, you are in good company; most people would prefer to phrase the query differently and avoid using the all operator. To illustrate, the previous query generates the same results as the next example, which uses the not in operator:

SELECT first\_name, last\_name  
FROM customer  
WHERE customer\_id   
NOT IN  
  
 (SELECT customer\_id  
  FROM payment  
  WHERE amount = 0)

It’s a matter of preference, but I think that most people would find the version that uses not in to be easier to understand.

##### Note

When using not in or <> all to compare a value to a set of values, you must be careful to ensure that the set of values does not contain a null value, because the server equates the value on the lefthand side of the expression to each member of the set, and any attempt to equate a value to null yields unknown. Thus, the following query returns an empty set:

mysql> SELECT first\_name, last\_name  
    -> FROM customer  
    -> WHERE customer\_id NOT IN (122, 452,   
NULL  
);  
Empty set (0.00 sec)

Here’s another example using the all operator, but this time the subquery is in the having clause:

mysql> SELECT customer\_id, count(\*)  
    -> FROM rental  
    -> GROUP BY customer\_id  
    ->   
HAVING count(\*) > ALL  
  
    ->  (SELECT count(\*)  
    ->   FROM rental r  
    ->     INNER JOIN customer c  
    ->     ON r.customer\_id = c.customer\_id  
    ->     INNER JOIN address a  
    ->     ON c.address\_id = a.address\_id  
    ->     INNER JOIN city ct  
    ->     ON a.city\_id = ct.city\_id  
    ->     INNER JOIN country co  
    ->     ON ct.country\_id = co.country\_id  
    ->   WHERE co.country IN ('United States','Mexico','Canada')  
    ->   GROUP BY r.customer\_id  
  -> );  
+-------------+----------+  
| customer\_id | count(\*) |  
+-------------+----------+  
|         148 |       46 |  
+-------------+----------+  
1 row in set (0.01 sec)

The subquery in this example returns the total number of film rentals for all customers in North America, and the containing query returns all customers whose total number of film rentals exceeds any of the North American customers.

## The any operator

Like the all operator, the any operator allows a value to be compared to the members of a set of values; unlike all, however, a condition using the any operator evaluates to true as soon as a single comparison is favorable. This example will find all customers whose total film rental payments exceed the total payments for all customers in Bolivia, Paraguay, or Chile:

mysql> SELECT customer\_id, sum(amount)  
    -> FROM payment  
    -> GROUP BY customer\_id  
    -> HAVING sum(amount)   
> ANY  
  
    ->  (SELECT sum(p.amount)  
    ->   FROM payment p  
    ->     INNER JOIN customer c  
    ->     ON p.customer\_id = c.customer\_id  
    ->     INNER JOIN address a  
    ->     ON c.address\_id = a.address\_id  
    ->     INNER JOIN city ct  
    ->     ON a.city\_id = ct.city\_id  
    ->     INNER JOIN country co  
    ->     ON ct.country\_id = co.country\_id  
    ->   WHERE co.country IN ('Bolivia','Paraguay','Chile')  
    ->   GROUP BY co.country  
    ->  );  
+-------------+-------------+  
| customer\_id | sum(amount) |  
+-------------+-------------+  
|         137 |      194.61 |  
|         144 |      195.58 |  
|         148 |      216.54 |  
|         178 |      194.61 |  
|         459 |      186.62 |  
|         526 |      221.55 |  
+-------------+-------------+  
6 rows in set (0.03 sec)

The subquery returns the total film rental fees for all customers in Bolivia, Paraguay, and Chile, and the containing query returns all customers who outspent at least one of these three countries (if you find yourself outspending an entire country, perhaps you need to cancel your Netflix subscription and book a trip to Bolivia, Paraguay, or Chile...).

##### Note

Although most people prefer to use in, using = any is equivalent to using the in operator.

## Multicolumn Subqueries

So far, the subquery examples in this chapter have returned a single column and one or more rows. In certain situations, however, you can use subqueries that return two or more columns. To show the utility of multicolumn subqueries, it might help to look first at an example that uses multiple, single-column subqueries:

mysql> SELECT fa.actor\_id, fa.film\_id  
    -> FROM film\_actor fa  
    -> WHERE fa.actor\_id IN  
    ->  (SELECT actor\_id FROM actor WHERE last\_name = 'MONROE')  
    ->   AND fa.film\_id IN  
    ->  (SELECT film\_id FROM film WHERE rating = 'PG');  
+----------+---------+  
| actor\_id | film\_id |  
+----------+---------+  
|      120 |      63 |  
|      120 |     144 |  
|      120 |     414 |  
|      120 |     590 |  
|      120 |     715 |  
|      120 |     894 |  
|      178 |     164 |  
|      178 |     194 |  
|      178 |     273 |  
|      178 |     311 |  
|      178 |     983 |  
+----------+---------+  
11 rows in set (0.00 sec)

This query uses two subqueries to identify all actors with the last name Monroe and all films rated PG, and the containing query then uses this information to retrieve all cases where an actor named Monroe appeared in a PG film. However, you could merge the two single-column subqueries into one multicolumn subquery and compare the results to two columns in the film\_actor table. To do so, your filter condition must name both columns from the film\_actor table surrounded by parentheses and in the same order as returned by the subquery, as in:

mysql> SELECT actor\_id, film\_id  
    -> FROM film\_actor  
    -> WHERE   
(actor\_id, film\_id) IN  
  
    ->  (  
SELECT a.actor\_id, f.film\_id  
  
    ->   FROM actor a  
    ->      CROSS JOIN film f  
    ->   WHERE a.last\_name = 'MONROE'  
    ->   AND f.rating = 'PG');  
+----------+---------+  
| actor\_id | film\_id |  
+----------+---------+  
|      120 |      63 |  
|      120 |     144 |  
|      120 |     414 |  
|      120 |     590 |  
|      120 |     715 |  
|      120 |     894 |  
|      178 |     164 |  
|      178 |     194 |  
|      178 |     273 |  
|      178 |     311 |  
|      178 |     983 |  
+----------+---------+  
11 rows in set (0.00 sec)

This version of the query performs the same function as the previous example, but with a single subquery that returns two columns instead of two subqueries that each return a single column. The subquery in this version uses a type of join called a cross join, which will be explored in the next chapter. The basic idea is to return all combinations of actors named Monroe (2) and all films rated PG (194) for a total of 388 rows, 11 of which can be found in the film\_actor table.

# Correlated Subqueries

All of the subqueries shown thus far have been independent of their containing statements, meaning that you can execute them by themselves and inspect the results. A correlated subquery, on the other hand, is dependent on its containing statement from which it references one or more columns. Unlike a noncorrelated subquery, a correlated subquery is not executed once prior to execution of the containing statement; instead, the correlated subquery is executed once for each candidate row (rows that might be included in the final results). For example, the following query uses a correlated subquery to count the number of film rentals for each customer, and the containing query then retrieves those customers who have rented exactly 20 films:

mysql> SELECT c.first\_name, c.last\_name  
    -> FROM customer c  
    -> WHERE 20 =  
    ->  (SELECT count(\*) FROM rental r  
    ->   WHERE r.customer\_id =   
c.customer\_id  
);  
+------------+-------------+  
| first\_name | last\_name   |  
+------------+-------------+  
| LAUREN     | HUDSON      |  
| JEANETTE   | GREENE      |  
| TARA       | RYAN        |  
| WILMA      | RICHARDS    |  
| JO         | FOWLER      |  
| KAY        | CALDWELL    |  
| DANIEL     | CABRAL      |  
| ANTHONY    | SCHWAB      |  
| TERRY      | GRISSOM     |  
| LUIS       | YANEZ       |  
| HERBERT    | KRUGER      |  
| OSCAR      | AQUINO      |  
| RAUL       | FORTIER     |  
| NELSON     | CHRISTENSON |  
| ALFREDO    | MCADAMS     |  
+------------+-------------+  
15 rows in set (0.01 sec)

The reference to c.customer\_id at the very end of the subquery is what makes the subquery correlated; the containing query must supply values for c.customer\_id for the subquery to execute. In this case, the containing query retrieves all 599 rows from the customer table and executes the subquery once for each customer, passing in the appropriate customer ID for each execution. If the subquery returns the value 20, then the filter condition is met, and the row is added to the result set.

##### Note

One word of caution: since the correlated subquery will be executed once for each row of the containing query, the use of correlated subqueries can cause performance issues if the containing query returns a large number of rows.

Along with equality conditions, you can use correlated subqueries in other types of conditions, such as the range condition illustrated here:

mysql> SELECT c.first\_name, c.last\_name  
    -> FROM customer c  
    -> WHERE  
    ->  (SELECT sum(p.amount) FROM payment p  
    ->   WHERE p.customer\_id = c.customer\_id)  
    ->   BETWEEN 180 AND 240;  
+------------+-----------+  
| first\_name | last\_name |  
+------------+-----------+  
| RHONDA     | KENNEDY   |  
| CLARA      | SHAW      |  
| ELEANOR    | HUNT      |  
| MARION     | SNYDER    |  
| TOMMY      | COLLAZO   |  
| KARL       | SEAL      |  
+------------+-----------+  
6 rows in set (0.03 sec)

This variation on the previous query finds all customers whose total payments for all film rentals are between $180 and $240. Once again, the correlated subquery is executed 599 times (once for each customer row), and each execution of the subquery returns the total account balance for the given customer.

##### Note

Another subtle difference in the previous query is that the subquery is on the lefthand side of the condition, which may look a bit odd but is perfectly valid.

## The exists Operator

While you will often see correlated subqueries used in equality and range conditions, the most common operator used to build conditions that utilize correlated subqueries is the exists operator. You use the exists operator when you want to identify that a relationship exists without regard for the quantity; for example, the following query finds all the customers who rented at least one film prior to May 25, 2005, without regard for how many films were rented:

mysql> SELECT c.first\_name, c.last\_name  
    -> FROM customer c  
    -> WHERE   
EXISTS  
  
    ->  (SELECT 1 FROM rental r  
    ->   WHERE r.customer\_id = c.customer\_id  
    ->     AND date(r.rental\_date) < '2005-05-25');  
+------------+-------------+  
| first\_name | last\_name   |  
+------------+-------------+  
| CHARLOTTE  | HUNTER      |  
| DELORES    | HANSEN      |  
| MINNIE     | ROMERO      |  
| CASSANDRA  | WALTERS     |  
| ANDREW     | PURDY       |  
| MANUEL     | MURRELL     |  
| TOMMY      | COLLAZO     |  
| NELSON     | CHRISTENSON |  
+------------+-------------+  
8 rows in set (0.03 sec)

Using the exists operator, your subquery can return zero, one, or many rows, and the condition simply checks whether the subquery returned one or more rows. If you look at the select clause of the subquery, you will see that it consists of a single literal (1); since the condition in the containing query only needs to know how many rows have been returned, the actual data the subquery returned is irrelevant. Your subquery can return whatever strikes your fancy, as demonstrated next:

mysql> SELECT c.first\_name, c.last\_name  
    -> FROM customer c  
    -> WHERE EXISTS  
    ->  (SELECT   
r.rental\_date, r.customer\_id, 'ABCD' str, 2 \* 3 / 7 nmbr  
  
    ->   FROM rental r  
    ->   WHERE r.customer\_id = c.customer\_id  
    ->     AND date(r.rental\_date) < '2005-05-25');  
+------------+-------------+  
| first\_name | last\_name   |  
+------------+-------------+  
| CHARLOTTE  | HUNTER      |  
| DELORES    | HANSEN      |  
| MINNIE     | ROMERO      |  
| CASSANDRA  | WALTERS     |  
| ANDREW     | PURDY       |  
| MANUEL     | MURRELL     |  
| TOMMY      | COLLAZO     |  
| NELSON     | CHRISTENSON |  
+------------+-------------+  
8 rows in set (0.03 sec)

However, the convention is to specify either select 1 or select \* when using exists.

You may also use not exists to check for subqueries that return no rows, as demonstrated by the following:

mysql> SELECT a.first\_name, a.last\_name  
    -> FROM actor a  
    -> WHERE   
NOT EXISTS  
  
    ->  (SELECT 1  
    ->   FROM film\_actor fa  
    ->     INNER JOIN film f ON f.film\_id = fa.film\_id  
    ->   WHERE fa.actor\_id =   
a.actor\_id  
  
    ->     AND f.rating = 'R');  
+------------+-----------+  
| first\_name | last\_name |  
+------------+-----------+  
| JANE       | JACKMAN   |  
+------------+-----------+  
1 row in set (0.00 sec)

This query finds all actors who have never appeared in an R-rated film.

## Data Manipulation Using Correlated Subqueries

All of the examples thus far in the chapter have been select statements, but don’t think that means that subqueries aren’t useful in other SQL statements. Subqueries are used heavily in update, delete, and insert statements as well, with correlated subqueries appearing frequently in update and delete statements. Here’s an example of a correlated subquery used to modify the last\_update column in the customer table:

UPDATE customer c  
SET c.last\_update =  
 (SELECT max(r.rental\_date) FROM rental r  
  WHERE r.customer\_id = c.customer\_id);

This statement modifies every row in the customer table (since there is no where clause) by finding the latest rental date for each customer in the rental table. While it seems reasonable to expect that every customer will have at least one film rental, it would be best to check before attempting to update the last\_update column; otherwise, the column will be set to null, since the subquery would return no rows. Here’s another version of the update statement, this time employing a where clause with a second correlated subquery:

UPDATE customer c  
SET c.last\_update =  
 (SELECT max(r.rental\_date) FROM rental r  
  WHERE r.customer\_id = c.customer\_id)  
WHERE EXISTS  
 (SELECT 1 FROM rental r  
  WHERE r.customer\_id = c.customer\_id);

The two correlated subqueries are identical except for the select clauses. The subquery in the set clause, however, executes only if the condition in the update statement’s where clause evaluates to true (meaning that at least one rental was found for the customer), thus protecting the data in the last\_update column from being overwritten with a null.

Correlated subqueries are also common in delete statements. For example, you may run a data maintenance script at the end of each month that removes unnecessary data. The script might include the following statement, which removes rows from the customer table where there have been no film rentals in the past year:

DELETE FROM customer  
WHERE 365 < ALL  
 (SELECT datediff(now(), r.rental\_date) days\_since\_last\_rental  
  FROM rental r  
  WHERE r.customer\_id = customer.customer\_id);

When using correlated subqueries with delete statements in MySQL, keep in mind that, for whatever reason, table aliases are not allowed when using delete, which is why I had to use the entire table name in the subquery. With most other database servers, you could provide an alias for the customer table, such as:

DELETE FROM customer   
c  
  
WHERE 365 < ALL  
 (SELECT datediff(now(), r.rental\_date) days\_since\_last\_rental  
  FROM rental r  
  WHERE r.customer\_id =   
c  
.customer\_id);

# When to Use Subqueries

Now that you have learned about the different types of subqueries and the different operators that you can employ to interact with the data returned by subqueries, it’s time to explore the many ways in which you can use subqueries to build powerful SQL statements. The next three sections demonstrate how you may use subqueries to construct custom tables, to build conditions, and to generate column values in result sets.

## Subqueries as Data Sources

Back in [Chapter 3](#Chapter_3__Query_Primer__So_far_2), I stated that the from clause of a select statement contains the tables to be used by the query. Since a subquery generates a result set containing rows and columns of data, it is perfectly valid to include subqueries in your from clause along with tables. Although it might, at first glance, seem like an interesting feature without much practical merit, using subqueries alongside tables is one of the most powerful tools available when writing queries. Here’s a simple example:

mysql> SELECT c.first\_name, c.last\_name,   
  -> pymnt.num\_rentals, pymnt.tot\_payments  
    -> FROM customer c  
    ->   INNER JOIN  
    ->      
(  
SELECT customer\_id,   
  -> count(\*) num\_rentals, sum(amount) tot\_payments  
    ->     FROM payment  
    ->     GROUP BY customer\_id  
    ->      
) pymnt  
  
    ->   ON c.customer\_id = pymnt.customer\_id;  
+-------------+--------------+-------------+--------------+  
| first\_name  | last\_name    | num\_rentals | tot\_payments |  
+-------------+--------------+-------------+--------------+  
| MARY        | SMITH        |          32 |       118.68 |  
| PATRICIA    | JOHNSON      |          27 |       128.73 |  
| LINDA       | WILLIAMS     |          26 |       135.74 |  
| BARBARA     | JONES        |          22 |        81.78 |  
| ELIZABETH   | BROWN        |          38 |       144.62 |  
...  
| TERRENCE    | GUNDERSON    |          30 |       117.70 |  
| ENRIQUE     | FORSYTHE     |          28 |        96.72 |  
| FREDDIE     | DUGGAN       |          25 |        99.75 |  
| WADE        | DELVALLE     |          22 |        83.78 |  
| AUSTIN      | CINTRON      |          19 |        83.81 |  
+-------------+--------------+-------------+--------------+  
599 rows in set (0.03 sec)

In this example, a subquery generates a list of customer IDs along with the number of film rentals and the total payments. Here’s the result set generated by the subquery:

mysql> SELECT customer\_id, count(\*) num\_rentals, sum(amount) tot\_payments  
    -> FROM payment  
    -> GROUP BY customer\_id;  
+-------------+-------------+--------------+  
| customer\_id | num\_rentals | tot\_payments |  
+-------------+-------------+--------------+  
|           1 |          32 |       118.68 |  
|           2 |          27 |       128.73 |  
|           3 |          26 |       135.74 |  
|           4 |          22 |        81.78 |  
...  
|         596 |          28 |        96.72 |  
|         597 |          25 |        99.75 |  
|         598 |          22 |        83.78 |  
|         599 |          19 |        83.81 |  
+-------------+-------------+--------------+  
599 rows in set (0.03 sec)

The subquery is given the name pymnt and is joined to the customer table via the customer\_id column. The containing query then retrieves the customer’s name from the customer table, along with the summary columns from the pymnt subquery.

Subqueries used in the from clause must be noncorrelated;[1](#1_Actually__depending_on_which_d) they are executed first, and the data is held in memory until the containing query finishes execution. Subqueries offer immense flexibility when writing queries, because you can go far beyond the set of available tables to create virtually any view of the data that you desire and then join the results to other tables or subqueries. If you are writing reports or generating data feeds to external systems, you may be able to do things with a single query that used to demand multiple queries or a procedural language to accomplish.

## Data fabrication

Along with using subqueries to summarize existing data, you can use subqueries to generate data that doesn’t exist in any form within your database. For example, you may wish to group your customers by the amount of money spent on film rentals, but you want to use group definitions that are not stored in your database. For example, let’s say you want to sort your customers into the groups shown in [Table 9-1](#Table_9_1__Customer_payment_grou).

|  |  |  |
| --- | --- | --- |
| Table 9-1. Customer payment groups  Group name | Lower limit | Upper limit |

|  |  |  |
| --- | --- | --- |
| Small Fry | 0 | $74.99 |

|  |  |  |
| --- | --- | --- |
| Average Joes | $75 | $149.99 |

|  |  |  |
| --- | --- | --- |
| Heavy Hitters | $150 | $9,999,999.99 |

To generate these groups within a single query, you will need a way to define these three groups. The first step is to define a query that generates the group definitions:

mysql> SELECT 'Small Fry' name, 0 low\_limit, 74.99 high\_limit  
    -> UNION ALL  
    -> SELECT 'Average Joes' name, 75 low\_limit, 149.99 high\_limit  
    -> UNION ALL  
    -> SELECT 'Heavy Hitters' name, 150 low\_limit, 9999999.99 high\_limit;  
+---------------+-----------+------------+  
| name          | low\_limit | high\_limit |  
+---------------+-----------+------------+  
| Small Fry     |         0 |      74.99 |  
| Average Joes  |        75 |     149.99 |  
| Heavy Hitters |       150 | 9999999.99 |  
+---------------+-----------+------------+  
3 rows in set (0.00 sec)

I have used the set operator union all to merge the results from three separate queries into a single result set. Each query retrieves three literals, and the results from the three queries are put together to generate a result set with three rows and three columns. You now have a query to generate the desired groups, and you can place it into the from clause of another query to generate your customer groups:

mysql> SELECT pymnt\_grps.name, count(\*) num\_customers  
    -> FROM  
    ->  (SELECT customer\_id,  
    ->     count(\*) num\_rentals, sum(amount) tot\_payments  
    ->   FROM payment  
    ->   GROUP BY customer\_id  
    ->  ) pymnt  
    ->   INNER JOIN  
    ->  (SELECT 'Small Fry' name, 0 low\_limit, 74.99 high\_limit  
    ->   UNION ALL  
    ->   SELECT 'Average Joes' name, 75 low\_limit, 149.99 high\_limit  
    ->   UNION ALL  
    ->   SELECT 'Heavy Hitters' name, 150 low\_limit, 9999999.99 high\_limit  
    ->  ) pymnt\_grps  
    ->   ON pymnt.tot\_payments  
    ->     BETWEEN pymnt\_grps.low\_limit AND pymnt\_grps.high\_limit  
    -> GROUP BY pymnt\_grps.name;  
+---------------+---------------+  
| name          | num\_customers |  
+---------------+---------------+  
| Average Joes  |           515 |  
| Heavy Hitters |            46 |  
| Small Fry     |            38 |  
+---------------+---------------+  
3 rows in set (0.03 sec)

The from clause contains two subqueries; the first subquery, named pymnt, returns the total number of film rentals and total payments for each customer, while the second subquery, named pymnt\_grps, generates the three customer groupings. The two subqueries are joined by finding which of the three groups each customer belongs to, and the rows are then grouped by the group name in order to count the number of customers in each group.

Of course, you could simply decide to build a permanent (or temporary) table to hold the group definitions instead of using a subquery. Using that approach, you would find your database to be littered with small special-purpose tables after a while, and you wouldn’t remember the reason for which most of them were created. Using subqueries, however, you will be able to adhere to a policy where tables are added to a database only when there is a clear business need to store new data.

## Task-oriented subqueries

Let’s say that you want to generate a report showing each customer’s name, along with their city, the total number of rentals, and the total payment amount. You could accomplish this by joining the payment, customer, address, and city tables, and then grouping on the customer’s first and last names:

mysql> SELECT c.first\_name, c.last\_name, ct.city,  
    ->   sum(p.amount) tot\_payments, count(\*) tot\_rentals  
    -> FROM payment p  
    ->   INNER JOIN customer c  
    ->   ON p.customer\_id = c.customer\_id  
    ->   INNER JOIN address a  
    ->   ON c.address\_id = a.address\_id  
    ->   INNER JOIN city ct  
    ->   ON a.city\_id = ct.city\_id  
    -> GROUP BY c.first\_name, c.last\_name, ct.city;  
+-------------+------------+-----------------+--------------+-------------+  
| first\_name  | last\_name  | city            | tot\_payments | tot\_rentals |  
+-------------+------------+-----------------+--------------+-------------+  
| MARY        | SMITH      | Sasebo          |       118.68 |          32 |  
| PATRICIA    | JOHNSON    | San Bernardino  |       128.73 |          27 |  
| LINDA       | WILLIAMS   | Athenai         |       135.74 |          26 |  
| BARBARA     | JONES      | Myingyan        |        81.78 |          22 |  
...  
| TERRENCE    | GUNDERSON  | Jinzhou         |       117.70 |          30 |  
| ENRIQUE     | FORSYTHE   | Patras          |        96.72 |          28 |  
| FREDDIE     | DUGGAN     | Sullana         |        99.75 |          25 |  
| WADE        | DELVALLE   | Lausanne        |        83.78 |          22 |  
| AUSTIN      | CINTRON    | Tieli           |        83.81 |          19 |  
+-------------+------------+-----------------+--------------+-------------+  
599 rows in set (0.06 sec)

This query returns the desired data, but if you look at the query closely, you will see that the customer, address, and city tables are needed only for display purposes and that the payment table has everything needed to generate the groupings (customer\_id and amount). Therefore, you could separate out the task of generating the groups into a subquery and then join the other three tables to the table generated by the subquery to achieve the desired end result. Here’s the grouping subquery:

mysql> SELECT customer\_id,  
    ->   count(\*) tot\_rentals, sum(amount) tot\_payments  
    -> FROM payment  
    -> GROUP BY customer\_id;  
+-------------+-------------+--------------+  
| customer\_id | tot\_rentals | tot\_payments |  
+-------------+-------------+--------------+  
|           1 |          32 |       118.68 |  
|           2 |          27 |       128.73 |  
|           3 |          26 |       135.74 |  
|           4 |          22 |        81.78 |  
...  
|         595 |          30 |       117.70 |  
|         596 |          28 |        96.72 |  
|         597 |          25 |        99.75 |  
|         598 |          22 |        83.78 |  
|         599 |          19 |        83.81 |  
+-------------+-------------+--------------+  
599 rows in set (0.03 sec)

This is the heart of the query; the other tables are needed only to provide meaningful strings in place of the customer\_id value. The next query joins the previous data set to the other three tables:

mysql> SELECT c.first\_name, c.last\_name,  
    ->   ct.city,  
    ->   pymnt.tot\_payments, pymnt.tot\_rentals  
    -> FROM  
    ->  (SELECT customer\_id,  
    ->     count(\*) tot\_rentals, sum(amount) tot\_payments  
    ->   FROM payment  
    ->   GROUP BY customer\_id  
    ->  ) pymnt  
    ->   INNER JOIN customer c  
    ->   ON pymnt.customer\_id = c.customer\_id  
    ->   INNER JOIN address a  
    ->   ON c.address\_id = a.address\_id  
    ->   INNER JOIN city ct  
    ->   ON a.city\_id = ct.city\_id;  
+-------------+------------+-----------------+--------------+-------------+  
| first\_name  | last\_name  | city            | tot\_payments | tot\_rentals |  
+-------------+------------+-----------------+--------------+-------------+  
| MARY        | SMITH      | Sasebo          |       118.68 |          32 |  
| PATRICIA    | JOHNSON    | San Bernardino  |       128.73 |          27 |  
| LINDA       | WILLIAMS   | Athenai         |       135.74 |          26 |  
| BARBARA     | JONES      | Myingyan        |        81.78 |          22 |  
...  
| TERRENCE    | GUNDERSON  | Jinzhou         |       117.70 |          30 |  
| ENRIQUE     | FORSYTHE   | Patras          |        96.72 |          28 |  
| FREDDIE     | DUGGAN     | Sullana         |        99.75 |          25 |  
| WADE        | DELVALLE   | Lausanne        |        83.78 |          22 |  
| AUSTIN      | CINTRON    | Tieli           |        83.81 |          19 |  
+-------------+------------+-----------------+--------------+-------------+  
599 rows in set (0.06 sec)

I realize that beauty is in the eye of the beholder, but I find this version of the query to be far more satisfying than the big, flat version. This version may execute faster as well, because the grouping is being done on a single numeric column (customer\_id) instead of multiple lengthy string columns (customer.first\_name, customer.last\_name, city.city).

## Common table expressions

Common table expressions (a.k.a. CTEs), which are new to MySQL in version 8.0, have been available in other database servers for quite some time. A CTE is a named subquery that appears at the top of a query in a with clause, which can contain multiple CTEs separated by commas. Along with making queries more understandable, this feature also allows each CTE to refer to any other CTE defined above it in the same with clause. The following example includes three CTEs, where the second refers to the first, and the third refers to the second:

mysql>   
WITH actors\_s  
 AS  
    ->  (SELECT actor\_id, first\_name, last\_name  
    ->   FROM actor  
    ->   WHERE last\_name LIKE 'S%'  
    ->  ),  
    ->    
actors\_s\_pg  
 AS  
    ->  (SELECT s.actor\_id, s.first\_name, s.last\_name,  
    ->     f.film\_id, f.title  
    ->   FROM   
actors\_s  
 s  
    ->     INNER JOIN film\_actor fa  
    ->     ON s.actor\_id = fa.actor\_id  
    ->     INNER JOIN film f  
    ->     ON f.film\_id = fa.film\_id  
    ->   WHERE f.rating = 'PG'  
    ->  ),  
    ->    
actors\_s\_pg\_revenue  
 AS  
    ->  (SELECT spg.first\_name, spg.last\_name, p.amount  
    ->   FROM   
actors\_s\_pg  
 spg  
    ->     INNER JOIN inventory i  
    ->     ON i.film\_id = spg.film\_id  
    ->     INNER JOIN rental r  
    ->     ON i.inventory\_id = r.inventory\_id  
    ->     INNER JOIN payment p  
    ->     ON r.rental\_id = p.rental\_id  
    ->  ) -- end of With clause  
    -> SELECT spg\_rev.first\_name, spg\_rev.last\_name,  
    ->   sum(spg\_rev.amount) tot\_revenue  
    -> FROM   
actors\_s\_pg\_revenue  
 spg\_rev  
    -> GROUP BY spg\_rev.first\_name, spg\_rev.last\_name  
    -> ORDER BY 3 desc;  
+------------+-------------+-------------+  
| first\_name | last\_name   | tot\_revenue |  
+------------+-------------+-------------+  
| NICK       | STALLONE    |      692.21 |  
| JEFF       | SILVERSTONE |      652.35 |  
| DAN        | STREEP      |      509.02 |  
| GROUCHO    | SINATRA     |      457.97 |  
| SISSY      | SOBIESKI    |      379.03 |  
| JAYNE      | SILVERSTONE |      372.18 |  
| CAMERON    | STREEP      |      361.00 |  
| JOHN       | SUVARI      |      296.36 |  
| JOE        | SWANK       |      177.52 |  
+------------+-------------+-------------+  
9 rows in set (0.18 sec)

This query calculates the total revenues generated from PG-rated film rentals where the cast includes an actor whose last name starts with S. The first subquery (actors\_s) finds all actors whose last name starts with S, the second subquery (actors\_s\_pg) joins that data set to the film table and filters on films having a PG rating, and the third subquery (actors\_s\_pg\_revenue) joins that data set to the payment table to retrieve the amounts paid to rent any of these films. The final query simply groups the data from actors\_s\_pg\_revenue by first/last names and sums the revenues.

##### Note

Those who tend to utilize temporary tables to store query results for use in subsequent queries may find CTEs an attractive alternative.

## Subqueries as Expression Generators

For this last section of the chapter, I finish where I began: with single-column, single-row scalar subqueries. Along with being used in filter conditions, scalar subqueries may be used wherever an expression can appear, including the select and order by clauses of a query and the values clause of an insert statement.

In [“Task-oriented subqueries”](#Task_oriented_subqueries__Let_s), I showed you how to use a subquery to separate out the grouping mechanism from the rest of the query. Here’s another version of the same query that uses subqueries for the same purpose, but in a different way:

mysql> SELECT  
    ->    
(  
SELECT c.first\_name FROM customer c  
    ->   WHERE c.customer\_id = p.customer\_id  
  ->   
) first\_name  
,  
    ->    
(  
SELECT c.last\_name FROM customer c  
    ->   WHERE c.customer\_id = p.customer\_id  
    ->   
) last\_name  
,  
  ->    
(  
SELECT ct.city  
    ->   FROM customer c  
    ->   INNER JOIN address a  
    ->     ON c.address\_id = a.address\_id  
    ->   INNER JOIN city ct  
    ->     ON a.city\_id = ct.city\_id  
    ->   WHERE c.customer\_id = p.customer\_id  
  ->   
) city  
,  
    ->   sum(p.amount) tot\_payments,  
    ->   count(\*) tot\_rentals  
    -> FROM payment p  
    -> GROUP BY p.customer\_id;  
+-------------+------------+-----------------+--------------+-------------+  
| first\_name  | last\_name  | city            | tot\_payments | tot\_rentals |  
+-------------+------------+-----------------+--------------+-------------+  
| MARY        | SMITH      | Sasebo          |       118.68 |          32 |  
| PATRICIA    | JOHNSON    | San Bernardino  |       128.73 |          27 |  
| LINDA       | WILLIAMS   | Athenai         |       135.74 |          26 |  
| BARBARA     | JONES      | Myingyan        |        81.78 |          22 |  
...  
| TERRENCE    | GUNDERSON  | Jinzhou         |       117.70 |          30 |  
| ENRIQUE     | FORSYTHE   | Patras          |        96.72 |          28 |  
| FREDDIE     | DUGGAN     | Sullana         |        99.75 |          25 |  
| WADE        | DELVALLE   | Lausanne        |        83.78 |          22 |  
| AUSTIN      | CINTRON    | Tieli           |        83.81 |          19 |  
+-------------+------------+-----------------+--------------+-------------+  
599 rows in set (0.06 sec)

There are two main differences between this query and the earlier version using a subquery in the from clause:

* Instead of joining the customer, address, and city tables to the payment data, correlated scalar subqueries are used in the select clause to look up the customer’s first/last names and city.
* The customer table is accessed three times (once in each of the three subqueries) rather than just once.

The customer table is accessed three times because scalar subqueries can return only a single column and row, so if we need three columns related to the customer, it is necessary to use three different subqueries.

As previously noted, scalar subqueries can also appear in the order by clause. The following query retrieves an actor’s first and last names and sorts by the number of films in which the actor appeared:

mysql> SELECT a.actor\_id, a.first\_name, a.last\_name  
    -> FROM actor a  
    -> ORDER BY  
    ->  (SELECT count(\*) FROM film\_actor fa  
    ->   WHERE fa.actor\_id = a.actor\_id) DESC;  
+----------+-------------+--------------+  
| actor\_id | first\_name  | last\_name    |  
+----------+-------------+--------------+  
|      107 | GINA        | DEGENERES    |  
|      102 | WALTER      | TORN         |  
|      198 | MARY        | KEITEL       |  
|      181 | MATTHEW     | CARREY       |  
...  
|       71 | ADAM        | GRANT        |  
|      186 | JULIA       | ZELLWEGER    |  
|       35 | JUDY        | DEAN         |  
|      199 | JULIA       | FAWCETT      |  
|      148 | EMILY       | DEE          |  
+----------+-------------+--------------+  
200 rows in set (0.01 sec)

The query uses a correlated scalar subquery in the order by clause to return just the number of film appearances, and this value is used solely for sorting purposes.

Along with using correlated scalar subqueries in select statements, you can use noncorrelated scalar subqueries to generate values for an insert statement. For example, let’s say you are going to generate a new row in the film\_actor table, and you’ve been given the following data:

* The first and last name of the actor
* The name of the film

You have two choices for how to go about it: execute two queries to retrieve the primary key values from film and actor and place those values into an insert statement or use subqueries to retrieve the two key values from within an insert statement. Here’s an example of the latter approach:

INSERT INTO film\_actor (actor\_id, film\_id, last\_update)  
VALUES (  
 (SELECT actor\_id FROM actor  
  WHERE first\_name = 'JENNIFER' AND last\_name = 'DAVIS'),  
 (SELECT film\_id FROM film  
  WHERE title = 'ACE GOLDFINGER'),  
 now()  
 );

Using a single SQL statement, you can create a row in the film\_actor table and look up two foreign key column values at the same time.

# Subquery Wrap-Up

I covered a lot of ground in this chapter, so it might be a good idea to review it. The examples in this chapter demonstrate subqueries that:

* Return a single column and row, a single column with multiple rows, and multiple columns and rows
* Are independent of the containing statement (noncorrelated subqueries)
* Reference one or more columns from the containing statement (correlated subqueries)
* Are used in conditions that utilize comparison operators as well as the special-purpose operators in, not in, exists, and not exists
* Can be found in select, update, delete, and insert statements
* Generate result sets that can be joined to other tables (or subqueries) in a query
* Can be used to generate values to populate a table or to populate columns in a query’s result set
* Are used in the select, from, where, having, and order by clauses of queries

Obviously, subqueries are a very versatile tool, so don’t feel bad if all these concepts haven’t sunk in after reading this chapter for the first time. Keep experimenting with the various uses for subqueries, and you will soon find yourself thinking about how you might utilize a subquery every time you write a nontrivial SQL statement.

# Test Your Knowledge

These exercises are designed to test your understanding of subqueries. Please see [Appendix B](#Appendix_B__Solutions_to_Exercis_2) for the solutions.

## Exercise 9-1

Construct a query against the film table that uses a filter condition with a noncorrelated subquery against the category table to find all action films (category.name = 'Action').

## Exercise 9-2

Rework the query from Exercise 9-1 using a correlated subquery against the category and film\_category tables to achieve the same results.

## Exercise 9-3

Join the following query to a subquery against the film\_actor table to show the level of each actor:

SELECT 'Hollywood Star' level, 30 min\_roles, 99999 max\_roles  
UNION ALL  
SELECT 'Prolific Actor' level, 20 min\_roles, 29 max\_roles  
UNION ALL  
SELECT 'Newcomer' level, 1 min\_roles, 19 max\_roles

The subquery against the film\_actor table should count the number of rows for each actor using group by actor\_id, and the count should be compared to the min\_roles/max\_roles columns to determine which level each actor belongs to.

[1](#1) Actually, depending on which database server you are using, you might be able to include correlated subqueries in your from clause by using cross apply or outer apply, but these features are beyond the scope of this book.

# Chapter 10. Joins Revisited

By now, you should be comfortable with the concept of the inner join, which I introduced in [Chapter 5](#Chapter_5__Querying_Multiple_Tab_2). This chapter focuses on other ways in which you can join tables, including the outer join and the cross join.

# Outer Joins

In all the examples thus far that have included multiple tables, we haven’t been concerned that the join conditions might fail to find matches for all the rows in the tables. For example, the inventory table contains a row for every film available for rental, but of the 1,000 rows in the film table, only 958 have one or more rows in the inventory table. The other 42 films are not available for rental (perhaps they are new releases due to arrive in a few days), so these film IDs cannot be found in the inventory table. The following query counts the number of available copies of each film by joining these two tables:

mysql> SELECT f.film\_id, f.title, count(\*) num\_copies  
    -> FROM film f  
    ->   INNER JOIN inventory i  
    ->   ON f.film\_id = i.film\_id  
    -> GROUP BY f.film\_id, f.title;  
+---------+-----------------------------+------------+  
| film\_id | title                       | num\_copies |  
+---------+-----------------------------+------------+  
|       1 | ACADEMY DINOSAUR            |          8 |  
|       2 | ACE GOLDFINGER              |          3 |  
|       3 | ADAPTATION HOLES            |          4 |  
|       4 | AFFAIR PREJUDICE            |          7 |  
...  
|      13 | ALI FOREVER                 |          4 |  
|      15 | ALIEN CENTER                |          6 |  
...  
|     997 | YOUTH KICK                  |          2 |  
|     998 | ZHIVAGO CORE                |          2 |  
|     999 | ZOOLANDER FICTION           |          5 |  
|    1000 | ZORRO ARK                   |          8 |  
+---------+-----------------------------+------------+  
958  
 rows in set (0.02 sec)

While you may have expected 1,000 rows to be returned (one for each film), the query returns only 958 rows. This is because the query uses an inner join, which only returns rows that satisfy the join condition. The film Alice Fantasia (film\_id 14) doesn’t appear in the results, for example, because it doesn’t have any rows in the inventory table.

If you want the query to return all 1,000 films, regardless of whether or not there are rows in the inventory table, you can use an outer join, which essentially makes the join condition optional:

mysql> SELECT f.film\_id, f.title,   
count(i.inventory\_id  
) num\_copies  
    -> FROM film f  
    ->     
LEFT OUTER JOIN  
 inventory i  
    ->   ON f.film\_id = i.film\_id  
    -> GROUP BY f.film\_id, f.title;  
+---------+-----------------------------+------------+  
| film\_id | title                       | num\_copies |  
+---------+-----------------------------+------------+  
|       1 | ACADEMY DINOSAUR            |          8 |  
|       2 | ACE GOLDFINGER              |          3 |  
|       3 | ADAPTATION HOLES            |          4 |  
|       4 | AFFAIR PREJUDICE            |          7 |  
...  
|      13 | ALI FOREVER                 |          4 |  
|      14 | ALICE FANTASIA              |          0 |  
  
|      15 | ALIEN CENTER                |          6 |  
...  
|     997 | YOUTH KICK                  |          2 |  
|     998 | ZHIVAGO CORE                |          2 |  
|     999 | ZOOLANDER FICTION           |          5 |  
|    1000 | ZORRO ARK                   |          8 |  
+---------+-----------------------------+------------+  
1000   
rows in set (0.01 sec)

As you can see, the query now returns all 1,000 rows from the film table, and 42 of the rows (including Alice Fantasia) have a value of 0 in the num\_copies column, which indicates that there are no copies in inventory.

Here’s a description of the changes from the prior version of the query:

* The join definition was changed from inner to left outer, which instructs the server to include all rows from the table on the left side of the join (film, in this case) and then include columns from the table on the right side of the join (inventory) if the join is successful.
* The num\_copies column definition was changed from count(\*) to count(i.inventory\_id), which will count the number of non-null values of the inventory.inventory\_id column.

Next, let’s remove the group by clause and filter out most of the rows in order to clearly see the differences between inner and outer joins. Here’s a query using an inner join and a filter condition to return rows for just a few films:

mysql> SELECT f.film\_id, f.title, i.inventory\_id  
    -> FROM film f  
    ->   INNER JOIN inventory i  
    ->   ON f.film\_id = i.film\_id  
    -> WHERE f.film\_id BETWEEN 13 AND 15;  
+---------+--------------+--------------+  
| film\_id | title        | inventory\_id |  
+---------+--------------+--------------+  
|      13 | ALI FOREVER  |           67 |  
|      13 | ALI FOREVER  |           68 |  
|      13 | ALI FOREVER  |           69 |  
|      13 | ALI FOREVER  |           70 |  
|      15 | ALIEN CENTER |           71 |  
|      15 | ALIEN CENTER |           72 |  
|      15 | ALIEN CENTER |           73 |  
|      15 | ALIEN CENTER |           74 |  
|      15 | ALIEN CENTER |           75 |  
|      15 | ALIEN CENTER |           76 |  
+---------+--------------+--------------+  
10 rows in set (0.00 sec)

The results show that there are four copies of Ali Forever and six copies of Alien Center in inventory. Here’s the same query, but using an outer join:

mysql> SELECT f.film\_id, f.title, i.inventory\_id  
    -> FROM film f  
    ->     
LEFT OUTER  
 JOIN inventory i  
    ->   ON f.film\_id = i.film\_id  
    -> WHERE f.film\_id BETWEEN 13 AND 15;  
+---------+----------------+--------------+  
| film\_id | title          | inventory\_id |  
+---------+----------------+--------------+  
|      13 | ALI FOREVER    |           67 |  
|      13 | ALI FOREVER    |           68 |  
|      13 | ALI FOREVER    |           69 |  
|      13 | ALI FOREVER    |           70 |  
|      14 | ALICE FANTASIA |         NULL |  
  
|      15 | ALIEN CENTER   |           71 |  
|      15 | ALIEN CENTER   |           72 |  
|      15 | ALIEN CENTER   |           73 |  
|      15 | ALIEN CENTER   |           74 |  
|      15 | ALIEN CENTER   |           75 |  
|      15 | ALIEN CENTER   |           76 |  
+---------+----------------+--------------+  
11 rows in set (0.00 sec)

The results are the same for Ali Forever and Alien Center, but there’s one new row for Alice Fantasia, with a null value for the inventory.inventory\_id column. This example illustrates how an outer join will add column values without restricting the number of rows returned by the query. If the join condition fails (as in the case of Alice Fantasia), any columns retrieved from the outer-joined table will be null.

## Left Versus Right Outer Joins

In each of the outer join examples in the previous section, I specified left outer join. The keyword left indicates that the table on the left side of the join is responsible for determining the number of rows in the result set, whereas the table on the right side is used to provide column values whenever a match is found. However, you may also specify a right outer join, in which case the table on the right side of the join is responsible for determining the number of rows in the result set, whereas the table on the left side is used to provide column values.

Here’s the last query from the previous section rearranged to use a right outer join instead of a left outer join:

mysql> SELECT f.film\_id, f.title, i.inventory\_id  
    -> FROM inventory i  
    ->     
RIGHT OUTER JOIN  
 film f  
    ->   ON f.film\_id = i.film\_id  
    -> WHERE f.film\_id BETWEEN 13 AND 15;  
+---------+----------------+--------------+  
| film\_id | title          | inventory\_id |  
+---------+----------------+--------------+  
|      13 | ALI FOREVER    |           67 |  
|      13 | ALI FOREVER    |           68 |  
|      13 | ALI FOREVER    |           69 |  
|      13 | ALI FOREVER    |           70 |  
|      14 | ALICE FANTASIA |         NULL |  
|      15 | ALIEN CENTER   |           71 |  
|      15 | ALIEN CENTER   |           72 |  
|      15 | ALIEN CENTER   |           73 |  
|      15 | ALIEN CENTER   |           74 |  
|      15 | ALIEN CENTER   |           75 |  
|      15 | ALIEN CENTER   |           76 |  
+---------+----------------+--------------+  
11 rows in set (0.00 sec)

Keep in mind that both versions of the query are performing outer joins; the keywords left and right are there just to tell the server which table is allowed to have gaps in the data. If you want to outer-join tables A and B and you want all rows from A with additional columns from B whenever there is matching data, you can specify either A left outer join B or B right outer join A.

##### Note

Since you will rarely (if ever) encounter right outer joins, and since not all database servers support them, I recommend that you always use left outer joins. The outer keyword is optional, so you may opt for A left join B instead, but I recommend including outer for the sake of clarity.

## Three-Way Outer Joins

In some cases, you may want to outer-join one table with two other tables. For example, the query from a prior section can be expanded to include data from the rental table:

mysql> SELECT f.film\_id, f.title, i.inventory\_id,   
r.rental\_date  
  
    -> FROM film f  
    ->   LEFT OUTER JOIN inventory i  
    ->   ON f.film\_id = i.film\_id  
    ->     
LEFT OUTER JOIN rental r  
  
    ->     
ON i.inventory\_id = r.inventory\_id  
  
    -> WHERE f.film\_id BETWEEN 13 AND 15;  
+---------+----------------+--------------+---------------------+  
| film\_id | title          | inventory\_id | rental\_date         |  
+---------+----------------+--------------+---------------------+  
|      13 | ALI FOREVER    |           67 | 2005-07-31 18:11:17 |  
|      13 | ALI FOREVER    |           67 | 2005-08-22 21:59:29 |  
|      13 | ALI FOREVER    |           68 | 2005-07-28 15:26:20 |  
|      13 | ALI FOREVER    |           68 | 2005-08-23 05:02:31 |  
|      13 | ALI FOREVER    |           69 | 2005-08-01 23:36:10 |  
|      13 | ALI FOREVER    |           69 | 2005-08-22 02:12:44 |  
|      13 | ALI FOREVER    |           70 | 2005-07-12 10:51:09 |  
|      13 | ALI FOREVER    |           70 | 2005-07-29 01:29:51 |  
|      13 | ALI FOREVER    |           70 | 2006-02-14 15:16:03 |  
|      14 | ALICE FANTASIA |         NULL | NULL                |  
  
|      15 | ALIEN CENTER   |           71 | 2005-05-28 02:06:37 |  
|      15 | ALIEN CENTER   |           71 | 2005-06-17 16:40:03 |  
|      15 | ALIEN CENTER   |           71 | 2005-07-11 05:47:08 |  
|      15 | ALIEN CENTER   |           71 | 2005-08-02 13:58:55 |  
|      15 | ALIEN CENTER   |           71 | 2005-08-23 05:13:09 |  
|      15 | ALIEN CENTER   |           72 | 2005-05-27 22:49:27 |  
|      15 | ALIEN CENTER   |           72 | 2005-06-19 13:29:28 |  
|      15 | ALIEN CENTER   |           72 | 2005-07-07 23:05:53 |  
|      15 | ALIEN CENTER   |           72 | 2005-08-01 05:55:13 |  
|      15 | ALIEN CENTER   |           72 | 2005-08-20 15:11:48 |  
|      15 | ALIEN CENTER   |           73 | 2005-07-06 15:51:58 |  
|      15 | ALIEN CENTER   |           73 | 2005-07-30 14:48:24 |  
|      15 | ALIEN CENTER   |           73 | 2005-08-20 22:32:11 |  
|      15 | ALIEN CENTER   |           74 | 2005-07-27 00:15:18 |  
|      15 | ALIEN CENTER   |           74 | 2005-08-23 19:21:22 |  
|      15 | ALIEN CENTER   |           75 | 2005-07-09 02:58:41 |  
|      15 | ALIEN CENTER   |           75 | 2005-07-29 23:52:01 |  
|      15 | ALIEN CENTER   |           75 | 2005-08-18 21:55:01 |  
|      15 | ALIEN CENTER   |           76 | 2005-06-15 08:01:29 |  
|      15 | ALIEN CENTER   |           76 | 2005-07-07 18:31:50 |  
|      15 | ALIEN CENTER   |           76 | 2005-08-01 01:49:36 |  
|      15 | ALIEN CENTER   |           76 | 2005-08-17 07:26:47 |  
+---------+----------------+--------------+---------------------+  
32 rows in set (0.01 sec)

The results include all rentals of all films in inventory, but the film Alice Fantasia has null values for the columns from both outer-joined tables.

# Cross Joins

Back in [Chapter 5](#Chapter_5__Querying_Multiple_Tab_2), I introduced the concept of a Cartesian product, which is essentially the result of joining multiple tables without specifying any join conditions. Cartesian products are used fairly frequently by accident (e.g., forgetting to add the join condition to the from clause) but are not so common otherwise. If, however, you do intend to generate the Cartesian product of two tables, you should specify a cross join, as in:

mysql> SELECT c.name category\_name, l.name language\_name  
    -> FROM category c  
    ->   CROSS JOIN language l;  
+---------------+---------------+  
| category\_name | language\_name |  
+---------------+---------------+  
| Action        | English       |  
| Action        | Italian       |  
| Action        | Japanese      |  
| Action        | Mandarin      |  
| Action        | French        |  
| Action        | German        |  
| Animation     | English       |  
| Animation     | Italian       |  
| Animation     | Japanese      |  
| Animation     | Mandarin      |  
| Animation     | French        |  
| Animation     | German        |  
...  
| Sports        | English       |  
| Sports        | Italian       |  
| Sports        | Japanese      |  
| Sports        | Mandarin      |  
| Sports        | French        |  
| Sports        | German        |  
| Travel        | English       |  
| Travel        | Italian       |  
| Travel        | Japanese      |  
| Travel        | Mandarin      |  
| Travel        | French        |  
| Travel        | German        |  
+---------------+---------------+  
96 rows in set (0.00 sec)

This query generates the Cartesian product of the category and language tables, resulting in 96 rows (16 category rows × 6 language rows). But now that you know what a cross join is and how to specify it, what is it used for? Most SQL books will describe what a cross join is and then tell you that it is seldom useful, but I would like to share with you a situation in which I find the cross join to be quite helpful.

In [Chapter 9](#Chapter_9__Subqueries__Subquerie_2), I discussed how to use subqueries to fabricate tables. The example I used showed how to build a three-row table that could be joined to other tables. Here’s the fabricated table from the example:

mysql> SELECT 'Small Fry' name, 0 low\_limit, 74.99 high\_limit  
    -> UNION ALL  
    -> SELECT 'Average Joes' name, 75 low\_limit, 149.99 high\_limit  
    -> UNION ALL  
    -> SELECT 'Heavy Hitters' name, 150 low\_limit, 9999999.99 high\_limit;  
+---------------+-----------+------------+  
| name          | low\_limit | high\_limit |  
+---------------+-----------+------------+  
| Small Fry     |         0 |      74.99 |  
| Average Joes  |        75 |     149.99 |  
| Heavy Hitters |       150 | 9999999.99 |  
+---------------+-----------+------------+  
3 rows in set (0.00 sec)

While this table was exactly what was needed for placing customers into three groups based on their total film payments, this strategy of merging single-row tables using the set operator union all doesn’t work very well if you need to fabricate a large table.

Say, for example, that you want to create a query that generates a row for every day in the year 2020 but you don’t have a table in your database that contains a row for every day. Using the strategy from the example in [Chapter 9](#Chapter_9__Subqueries__Subquerie_2), you could do something like the following:

SELECT '2020-01-01' dt  
UNION ALL  
SELECT '2020-01-02' dt  
UNION ALL  
SELECT '2020-01-03' dt  
UNION ALL  
...  
...  
...  
SELECT '2020-12-29' dt  
UNION ALL  
SELECT '2020-12-30' dt  
UNION ALL  
SELECT '2020-12-31' dt

Building a query that merges together the results of 366 queries is a bit tedious, so maybe a different strategy is needed. What if you generate a table with 366 rows (2020 is a leap year) with a single column containing a number between 0 and 366 and then add that number of days to January 1, 2020? Here’s one possible method to generate such a table:

mysql> SELECT ones.num + tens.num + hundreds.num  
 -> FROM  
 -> (SELECT 0 num UNION ALL  
 -> SELECT 1 num UNION ALL  
 -> SELECT 2 num UNION ALL  
 -> SELECT 3 num UNION ALL  
 -> SELECT 4 num UNION ALL  
 -> SELECT 5 num UNION ALL  
 -> SELECT 6 num UNION ALL  
 -> SELECT 7 num UNION ALL  
 -> SELECT 8 num UNION ALL  
 -> SELECT 9 num) ones  
 -> CROSS JOIN  
 -> (SELECT 0 num UNION ALL  
 -> SELECT 10 num UNION ALL  
 -> SELECT 20 num UNION ALL  
 -> SELECT 30 num UNION ALL  
 -> SELECT 40 num UNION ALL  
 -> SELECT 50 num UNION ALL  
 -> SELECT 60 num UNION ALL  
 -> SELECT 70 num UNION ALL  
 -> SELECT 80 num UNION ALL  
 -> SELECT 90 num) tens  
 -> CROSS JOIN  
 -> (SELECT 0 num UNION ALL  
 -> SELECT 100 num UNION ALL  
 -> SELECT 200 num UNION ALL  
 -> SELECT 300 num) hundreds;  
+------------------------------------+  
| ones.num + tens.num + hundreds.num |  
+------------------------------------+  
| 0 |  
| 1 |  
| 2 |  
| 3 |  
| 4 |  
| 5 |  
| 6 |  
| 7 |  
| 8 |  
| 9 |  
| 10 |  
| 11 |  
| 12 |  
...  
...  
...  
| 391 |  
| 392 |  
| 393 |  
| 394 |  
| 395 |  
| 396 |  
| 397 |  
| 398 |  
| 399 |  
+------------------------------------+  
400 rows in set (0.00 sec)

If you take the Cartesian product of the three sets {0, 1, 2, 3, 4, 5, 6, 7, 8, 9}, {0, 10, 20, 30, 40, 50, 60, 70, 80, 90}, and {0, 100, 200, 300} and add the values in the three columns, you get a 400-row result set containing all numbers between 0 and 399. While this is more than the 366 rows needed to generate the set of days in 2020, it’s easy enough to get rid of the excess rows, and I’ll show you how shortly.

The next step is to convert the set of numbers to a set of dates. To do this, I will use the date\_add() function to add each number in the result set to January 1, 2020. Then I’ll add a filter condition to throw away any dates that venture into 2021:

mysql> SELECT DATE\_ADD('2020-01-01',  
    ->   INTERVAL (ones.num + tens.num + hundreds.num) DAY) dt  
    -> FROM  
    ->  (SELECT 0 num UNION ALL  
    ->   SELECT 1 num UNION ALL  
    ->   SELECT 2 num UNION ALL  
    ->   SELECT 3 num UNION ALL  
    ->   SELECT 4 num UNION ALL  
    ->   SELECT 5 num UNION ALL  
    ->   SELECT 6 num UNION ALL  
    ->   SELECT 7 num UNION ALL  
    ->   SELECT 8 num UNION ALL  
    ->   SELECT 9 num) ones  
    ->   CROSS JOIN  
    ->  (SELECT 0 num UNION ALL  
    ->   SELECT 10 num UNION ALL  
    ->   SELECT 20 num UNION ALL  
    ->   SELECT 30 num UNION ALL  
    ->   SELECT 40 num UNION ALL  
    ->   SELECT 50 num UNION ALL  
    ->   SELECT 60 num UNION ALL  
    ->   SELECT 70 num UNION ALL  
    ->   SELECT 80 num UNION ALL  
    ->   SELECT 90 num) tens  
    ->   CROSS JOIN  
    ->  (SELECT 0 num UNION ALL  
    ->   SELECT 100 num UNION ALL  
    ->   SELECT 200 num UNION ALL  
    ->   SELECT 300 num) hundreds  
    -> WHERE DATE\_ADD('2020-01-01',  
    ->   INTERVAL (ones.num + tens.num + hundreds.num) DAY) < '2021-01-01'  
    -> ORDER BY 1;  
+------------+  
| dt         |  
+------------+  
| 2020-01-01 |  
| 2020-01-02 |  
| 2020-01-03 |  
| 2020-01-04 |  
| 2020-01-05 |  
| 2020-01-06 |  
| 2020-01-07 |  
| 2020-01-08 |  
...  
...  
...  
| 2020-02-26 |  
| 2020-02-27 |  
| 2020-02-28 |  
| 2020-02-29 |  
  
| 2020-03-01 |  
| 2020-03-02 |  
| 2020-03-03 |  
...  
...  
...  
| 2020-12-24 |  
| 2020-12-25 |  
| 2020-12-26 |  
| 2020-12-27 |  
| 2020-12-28 |  
| 2020-12-29 |  
| 2020-12-30 |  
| 2020-12-31 |  
+------------+  
366 rows in set (0.03 sec)

The nice thing about this approach is that the result set automatically includes the extra leap day (February 29) without your intervention, since the database server figures it out when it adds 59 days to January 1, 2020.

Now that you have a mechanism for fabricating all the days in 2020, what should you do with it? Well, you might be asked to generate a report that shows every day in 2020 along with the number of film rentals on that day. The report needs to include every day of the year, including days when no films are rented. Here’s what the query might look like (using the year 2005 to match the data in the rental table):

mysql> SELECT days.dt, COUNT(r.rental\_id) num\_rentals  
    -> FROM rental r  
    ->   RIGHT OUTER JOIN  
    ->  (SELECT DATE\_ADD('2005-01-01',  
    ->     INTERVAL (ones.num + tens.num + hundreds.num) DAY) dt  
    ->   FROM  
    ->    (SELECT 0 num UNION ALL  
    ->     SELECT 1 num UNION ALL  
    ->     SELECT 2 num UNION ALL  
    ->     SELECT 3 num UNION ALL  
    ->     SELECT 4 num UNION ALL  
    ->     SELECT 5 num UNION ALL  
    ->     SELECT 6 num UNION ALL  
    ->     SELECT 7 num UNION ALL  
    ->     SELECT 8 num UNION ALL  
    ->     SELECT 9 num) ones  
    ->     CROSS JOIN  
    ->    (SELECT 0 num UNION ALL  
    ->     SELECT 10 num UNION ALL  
    ->     SELECT 20 num UNION ALL  
    ->     SELECT 30 num UNION ALL  
    ->     SELECT 40 num UNION ALL  
    ->     SELECT 50 num UNION ALL  
    ->     SELECT 60 num UNION ALL  
    ->     SELECT 70 num UNION ALL  
    ->     SELECT 80 num UNION ALL  
    ->     SELECT 90 num) tens  
    ->     CROSS JOIN  
    ->    (SELECT 0 num UNION ALL  
    ->     SELECT 100 num UNION ALL  
    ->     SELECT 200 num UNION ALL  
    ->     SELECT 300 num) hundreds  
    ->   WHERE DATE\_ADD('2005-01-01',  
    ->     INTERVAL (ones.num + tens.num + hundreds.num) DAY)   
  -> < '2006-01-01'  
    ->  ) days  
    ->   ON days.dt = date(r.rental\_date)  
    -> GROUP BY days.dt  
    -> ORDER BY 1;  
+------------+-------------+  
| dt         | num\_rentals |  
+------------+-------------+  
| 2005-01-01 |           0 |  
| 2005-01-02 |           0 |  
| 2005-01-03 |           0 |  
| 2005-01-04 |           0 |  
...  
| 2005-05-23 |           0 |  
| 2005-05-24 |           8 |  
| 2005-05-25 |         137 |  
| 2005-05-26 |         174 |  
| 2005-05-27 |         166 |  
| 2005-05-28 |         196 |  
| 2005-05-29 |         154 |  
| 2005-05-30 |         158 |  
| 2005-05-31 |         163 |  
| 2005-06-01 |           0 |  
...  
| 2005-06-13 |           0 |  
| 2005-06-14 |          16 |  
| 2005-06-15 |         348 |  
| 2005-06-16 |         324 |  
| 2005-06-17 |         325 |  
| 2005-06-18 |         344 |  
| 2005-06-19 |         348 |  
| 2005-06-20 |         331 |  
| 2005-06-21 |         275 |  
| 2005-06-22 |           0 |  
...  
| 2005-12-27 |           0 |  
| 2005-12-28 |           0 |  
| 2005-12-29 |           0 |  
| 2005-12-30 |           0 |  
| 2005-12-31 |           0 |  
+------------+-------------+  
365 rows in set (8.99 sec)

This is one of the more interesting queries thus far in the book, in that it includes cross joins, outer joins, a date function, grouping, set operations (union all), and an aggregate function (count()). It is also not the most elegant solution to the given problem, but it should serve as an example of how, with a little creativity and a firm grasp on the language, you can make even a seldom-used feature like cross joins a potent tool in your SQL toolkit.

# Natural Joins

If you are lazy (and aren’t we all), you can choose a join type that allows you to name the tables to be joined but lets the database server determine what the join conditions need to be. Known as the natural join, this join type relies on identical column names across multiple tables to infer the proper join conditions. For example, the rental table includes a column named customer\_id, which is the foreign key to the customer table, whose primary key is also named customer\_id. Thus, you could try to write a query that uses natural join to join the two tables:

mysql> SELECT c.first\_name, c.last\_name, date(r.rental\_date)  
    -> FROM customer c  
    ->   NATURAL JOIN rental r;  
Empty set (0.04 sec)

Because you specified a natural join, the server inspected the table definitions and added the join condition r.customer\_id = c.customer\_id to join the two tables. This would have worked fine, but in the Sakila schema all of the tables include the column last\_update to show when each row was last modified, so the server is also adding the join condition r.last\_update = c.last\_update, which causes the query to return no data.

The only way around this issue is to use a subquery to restrict the columns for at least one of the tables:

mysql> SELECT cust.first\_name, cust.last\_name, date(r.rental\_date)  
    -> FROM  
    ->  (SELECT customer\_id, first\_name, last\_name  
    ->   FROM customer  
    ->  ) cust  
    ->     
NATURAL JOIN  
 rental r;  
+------------+-----------+---------------------+  
| first\_name | last\_name | date(r.rental\_date) |  
+------------+-----------+---------------------+  
| MARY       | SMITH     | 2005-05-25          |  
| MARY       | SMITH     | 2005-05-28          |  
| MARY       | SMITH     | 2005-06-15          |  
| MARY       | SMITH     | 2005-06-15          |  
| MARY       | SMITH     | 2005-06-15          |  
| MARY       | SMITH     | 2005-06-16          |  
| MARY       | SMITH     | 2005-06-18          |  
| MARY       | SMITH     | 2005-06-18          |  
...  
| AUSTIN     | CINTRON   | 2005-08-21          |  
| AUSTIN     | CINTRON   | 2005-08-21          |  
| AUSTIN     | CINTRON   | 2005-08-21          |  
| AUSTIN     | CINTRON   | 2005-08-23          |  
| AUSTIN     | CINTRON   | 2005-08-23          |  
| AUSTIN     | CINTRON   | 2005-08-23          |  
+------------+-----------+---------------------+  
16044 rows in set (0.03 sec)

So, is the reduced wear and tear on the old fingers from not having to type the join condition worth the trouble? Absolutely not; you should avoid this join type and use inner joins with explicit join conditions.

# Test Your Knowledge

The following exercises test your understanding of outer and cross joins. Please see [Appendix B](#Appendix_B__Solutions_to_Exercis_2) for solutions.

## Exercise 10-1

Using the following table definitions and data, write a query that returns each customer name along with their total payments:

Customer:  
Customer\_id Name  
----------- ---------------  
1 John Smith  
2 Kathy Jones  
3 Greg Oliver  
  
 Payment:  
Payment\_id Customer\_id Amount  
---------- ----------- --------  
101 1 8.99  
102 3 4.99  
103 1 7.99

Include all customers, even if no payment records exist for that customer.

## Exercise 10-2

Reformulate your query from Exercise 10-1 to use the other outer join type (e.g., if you used a left outer join in Exercise 10-1, use a right outer join this time) such that the results are identical to Exercise 10-1.

## Exercise 10-3 (Extra Credit)

Devise a query that will generate the set {1, 2, 3, ..., 99, 100}. (Hint: use a cross join with at least two from clause subqueries.)

# Chapter 11. Conditional Logic

In certain situations, you may want your SQL logic to branch in one direction or another depending on the values of certain columns or expressions. This chapter focuses on how to write statements that can behave differently depending on the data encountered during statement execution. The mechanism used for conditional logic in SQL statements is the case expression, which can be utilized in select, insert, update, and delete statements.

# What Is Conditional Logic?

Conditional logic is simply the ability to take one of several paths during program execution. For example, when querying customer information, you might want to include the customer.active column, which stores 1 to indicate active and 0 to indicate inactive. If the query results are being used to generate a report, you may want to translate the value to improve readability. While every database includes built-in functions for these types of situations, there are no standards, so you would need to remember which functions are used by which database. Fortunately, every database’s SQL implementation includes the case expression, which is useful in many situations, including simple translations:

mysql> SELECT first\_name, last\_name,  
    ->     
CASE  
  
    ->       
WHEN active = 1 THEN 'ACTIVE'  
  
    ->       
ELSE 'INACTIVE'  
  
    ->     
END   
activity\_type  
    -> FROM customer;  
+-------------+--------------+---------------+  
| first\_name  | last\_name    | activity\_type |  
+-------------+--------------+---------------+  
| MARY        | SMITH        | ACTIVE        |  
| PATRICIA    | JOHNSON      | ACTIVE        |  
| LINDA       | WILLIAMS     | ACTIVE        |  
| BARBARA     | JONES        | ACTIVE        |  
| ELIZABETH   | BROWN        | ACTIVE        |  
| JENNIFER    | DAVIS        | ACTIVE        |  
...  
| KENT        | ARSENAULT    | ACTIVE        |  
| TERRANCE    | ROUSH        | INACTIVE      |  
| RENE        | MCALISTER    | ACTIVE        |  
| EDUARDO     | HIATT        | ACTIVE        |  
| TERRENCE    | GUNDERSON    | ACTIVE        |  
| ENRIQUE     | FORSYTHE     | ACTIVE        |  
| FREDDIE     | DUGGAN       | ACTIVE        |  
| WADE        | DELVALLE     | ACTIVE        |  
| AUSTIN      | CINTRON      | ACTIVE        |  
+-------------+--------------+---------------+  
599 rows in set (0.00 sec)

This query includes a case expression to generate a value for the activity\_type column, which returns the string “ACTIVE” or “INACTIVE” depending on the value of the customer.active column.

# The case Expression

All of the major database servers include built-in functions designed to mimic the if-then-else statement found in most programming languages (examples include Oracle’s decode() function, MySQL’s if() function, and SQL Server’s coalesce() function). case expressions are also designed to facilitate if-then-else logic but enjoy two advantages over built-in functions:

* The case expression is part of the SQL standard (SQL92 release) and has been implemented by Oracle Database, SQL Server, MySQL, PostgreSQL, IBM UDB, and others.
* case expressions are built into the SQL grammar and can be included in select, insert, update, and delete statements.

The next two subsections introduce the two different types of case expressions. This is followed by some examples of case expressions in action.

## Searched case Expressions

The case expression demonstrated earlier in the chapter is an example of a searched case expression, which has the following syntax:

CASE  
 WHEN C1 THEN E1  
 WHEN C2 THEN E2  
 ...  
 WHEN CN THEN EN  
 [ELSE ED]  
END

In the previous definition, the symbols C1, C2, ..., CN represent conditions, and the symbols E1, E2, ..., EN represent expressions to be returned by the case expression. If the condition in a when clause evaluates to true, then the case expression returns the corresponding expression. Additionally, the ED symbol represents the default expression, which the case expression returns if none of the conditions C1, C2, ..., CN evaluate to true (the else clause is optional, which is why it is enclosed in square brackets). All the expressions returned by the various when clauses must evaluate to the same type (e.g., date, number, varchar).

Here’s an example of a searched case expression:

CASE  
 WHEN category.name IN ('Children','Family','Sports','Animation')  
 THEN 'All Ages'  
 WHEN category.name = 'Horror'  
 THEN 'Adult'  
 WHEN category.name IN ('Music','Games')  
    THEN 'Teens'  
 ELSE 'Other'  
END

This case expression returns a string that can be used to classify films depending on their category. When the case expression is evaluated, the when clauses are evaluated in order from top to bottom; as soon as one of the conditions in a when clause evaluates to true, the corresponding expression is returned, and any remaining when clauses are ignored. If none of the when clause conditions evaluates to true, then the expression in the else clause is returned.

Although the previous example returns string expressions, keep in mind that case expressions may return any type of expression, including subqueries. Here’s another version of the query from earlier in the chapter that uses a subquery to return the number of rentals, but only for active customers:

mysql> SELECT c.first\_name, c.last\_name,  
    ->   CASE  
    ->     WHEN active = 0 THEN 0  
    ->       
ELSE  
  
    ->        
(SELECT count(\*) FROM rental r  
  
    ->         
WHERE r.customer\_id = c.customer\_id)  
  
    ->   END num\_rentals  
    -> FROM customer c;  
+-------------+--------------+-------------+  
| first\_name  | last\_name    | num\_rentals |  
+-------------+--------------+-------------+  
| MARY        | SMITH        |          32 |  
| PATRICIA    | JOHNSON      |          27 |  
| LINDA       | WILLIAMS     |          26 |  
| BARBARA     | JONES        |          22 |  
| ELIZABETH   | BROWN        |          38 |  
| JENNIFER    | DAVIS        |          28 |  
...  
| TERRANCE    | ROUSH        |           0 |  
| RENE        | MCALISTER    |          26 |  
| EDUARDO     | HIATT        |          27 |  
| TERRENCE    | GUNDERSON    |          30 |  
| ENRIQUE     | FORSYTHE     |          28 |  
| FREDDIE     | DUGGAN       |          25 |  
| WADE        | DELVALLE     |          22 |  
| AUSTIN      | CINTRON      |          19 |  
+-------------+--------------+-------------+  
599 rows in set (0.01 sec)

This version of the query uses a correlated subquery to retrieve the number of rentals for each active customer. Depending on the percentage of active customers, using this approach may be more efficient than joining the customer and rental tables and grouping on the customer\_id column.

## Simple case Expressions

The simple case expression is quite similar to the searched case expression but is a bit less flexible. Here’s the syntax:

CASE V0  
 WHEN V1 THEN E1  
 WHEN V2 THEN E2  
 ...  
 WHEN VN THEN EN  
 [ELSE ED]  
END

In the preceding definition, V0 represents a value, and the symbols V1, V2, ..., VN represent values that are to be compared to V0. The symbols E1, E2, ..., EN represent expressions to be returned by the case expression, and ED represents the expression to be returned if none of the values in the set V1, V2, ..., VN matches the V0 value.

Here’s an example of a simple case expression:

CASE category.name  
  WHEN 'Children' THEN 'All Ages'  
  WHEN 'Family' THEN 'All Ages'  
  WHEN 'Sports' THEN 'All Ages'  
  WHEN 'Animation' THEN 'All Ages'  
  WHEN 'Horror' THEN 'Adult'  
  WHEN 'Music' THEN 'Teens'  
  WHEN 'Games' THEN 'Teens'  
  ELSE 'Other'  
END

Simple case expressions are less flexible than searched case expressions because you can’t specify your own conditions, whereas searched case expressions may include range conditions, inequality conditions, and multipart conditions using and/or/not, so I would recommend using searched case expressions for all but the simplest logic.

# Examples of case Expressions

The following sections present a variety of examples illustrating the utility of conditional logic in SQL statements.

## Result Set Transformations

You may have run into a situation where you are performing aggregations over a finite set of values, such as days of the week, but you want the result set to contain a single row with one column per value instead of one row per value. As an example, let’s say you have been asked to write a query that shows the number of film rentals for May, June, and July of 2005:

mysql> SELECT monthname(rental\_date) rental\_month,  
    ->   count(\*) num\_rentals  
    -> FROM rental  
    -> WHERE rental\_date BETWEEN '2005-05-01' AND '2005-08-01'  
    -> GROUP BY monthname(rental\_date);  
+--------------+-------------+  
| rental\_month | num\_rentals |  
+--------------+-------------+  
| May          |        1156 |  
| June         |        2311 |  
| July         |        6709 |  
+--------------+-------------+  
3 rows in set (0.01 sec)

However, you have also been instructed to return a single row of data with three columns (one for each of the three months). To transform this result set into a single row, you will need to create three columns and, within each column, sum only those rows pertaining to the month in question:

mysql> SELECT  
    ->   SUM(CASE WHEN monthname(rental\_date) = '  
May  
' THEN 1  
    ->         ELSE 0 END) May\_rentals,  
    ->   SUM(CASE WHEN monthname(rental\_date) = '  
June  
' THEN 1  
    ->         ELSE 0 END) June\_rentals,  
    ->   SUM(CASE WHEN monthname(rental\_date) = '  
July  
' THEN 1  
    ->         ELSE 0 END) July\_rentals  
    -> FROM rental  
    -> WHERE rental\_date BETWEEN '2005-05-01' AND '2005-08-01';  
+-------------+--------------+--------------+  
| May\_rentals | June\_rentals | July\_rentals |  
+-------------+--------------+--------------+  
|        1156 |         2311 |         6709 |  
+-------------+--------------+--------------+  
1 row in set (0.01 sec)

Each of the three columns in the previous query are identical, except for the month value. When the monthname() function returns the desired value for that column, the case expression returns the value 1; otherwise, it returns a 0. When summed over all rows, each column returns the number of accounts opened for that month. Obviously, such transformations are practical for only a small number of values; generating one column for each year since 1905 would quickly become tedious.

##### Note

Although it is a bit advanced for this book, it is worth pointing out that both SQL Server and Oracle Database include pivot clauses specifically for these types of queries.

## Checking for Existence

Sometimes you will want to determine whether a relationship exists between two entities without regard for the quantity. For example, you might want to know whether an actor has appeared in at least one G-rated film, without regard for the actual number of films. Here’s a query that uses multiple case expressions to generate three output columns, one to show whether the actor has appeared in G-rated films, another for PG-rated films, and a third for NC-17-rated films:

mysql> SELECT a.first\_name, a.last\_name,  
    ->   CASE  
    ->     WHEN EXISTS (SELECT 1 FROM film\_actor fa  
    ->                    INNER JOIN film f ON fa.film\_id = f.film\_id  
    ->                  WHERE fa.actor\_id = a.actor\_id  
    ->                    AND f.rating = 'G') THEN 'Y'  
    ->     ELSE 'N'  
    ->   END g\_actor,  
    ->   CASE  
    ->     WHEN EXISTS (SELECT 1 FROM film\_actor fa  
    ->                    INNER JOIN film f ON fa.film\_id = f.film\_id  
    ->                  WHERE fa.actor\_id = a.actor\_id  
    ->                    AND f.rating = 'PG') THEN 'Y'  
    ->     ELSE 'N'  
    ->   END pg\_actor,  
    ->   CASE  
    ->     WHEN EXISTS (SELECT 1 FROM film\_actor fa  
    ->                    INNER JOIN film f ON fa.film\_id = f.film\_id  
    ->                  WHERE fa.actor\_id = a.actor\_id  
    ->                    AND f.rating = 'NC-17') THEN 'Y'  
    ->     ELSE 'N'  
    ->   END nc17\_actor  
    -> FROM actor a  
    -> WHERE a.last\_name LIKE 'S%' OR a.first\_name LIKE 'S%';  
+------------+-------------+---------+----------+------------+  
| first\_name | last\_name   | g\_actor | pg\_actor | nc17\_actor |  
+------------+-------------+---------+----------+------------+  
| JOE        | SWANK       | Y       | Y        | Y          |  
| SANDRA     | KILMER      | Y       | Y        | Y          |  
| CAMERON    | STREEP      | Y       | Y        | Y          |  
| SANDRA     | PECK        | Y       | Y        | Y          |  
| SISSY      | SOBIESKI    | Y       | Y        |   
N  
          |  
| NICK       | STALLONE    | Y       | Y        | Y          |  
| SEAN       | WILLIAMS    | Y       | Y        | Y          |  
| GROUCHO    | SINATRA     | Y       | Y        | Y          |  
| SCARLETT   | DAMON       | Y       | Y        | Y          |  
| SPENCER    | PECK        | Y       | Y        | Y          |  
| SEAN       | GUINESS     | Y       | Y        | Y          |  
| SPENCER    | DEPP        | Y       | Y        | Y          |  
| SUSAN      | DAVIS       | Y       | Y        | Y          |  
| SIDNEY     | CROWE       | Y       | Y        | Y          |  
| SYLVESTER  | DERN        | Y       | Y        | Y          |  
| SUSAN      | DAVIS       | Y       | Y        | Y          |  
| DAN        | STREEP      | Y       | Y        | Y          |  
| SALMA      | NOLTE       | Y       |   
N  
        | Y          |  
| SCARLETT   | BENING      | Y       | Y        | Y          |  
| JEFF       | SILVERSTONE | Y       | Y        | Y          |  
| JOHN       | SUVARI      | Y       | Y        | Y          |  
| JAYNE      | SILVERSTONE | Y       | Y        | Y          |  
+------------+-------------+---------+----------+------------+  
22 rows in set (0.00 sec)

Each case expression includes a correlated subquery against the film\_actor and film tables; one looks for films with a G rating, the second for films with a PG rating, and the third for films with a NC-17 rating. Since each when clause uses the exists operator, the conditions evaluate to true as long as the actor has appeared in at least one film with the proper rating.

In other cases, you may care how many rows are encountered, but only up to a point. For example, the next query uses a simple case expression to count the number of copies in inventory for each film and then returns either 'Out Of Stock', 'Scarce', 'Available', or 'Common':

mysql> SELECT f.title,  
    ->   CASE (SELECT count(\*) FROM inventory i   
  -> WHERE i.film\_id = f.film\_id)  
    ->     WHEN 0 THEN 'Out Of Stock'  
    ->     WHEN 1 THEN 'Scarce'  
    ->     WHEN 2 THEN 'Scarce'  
    ->     WHEN 3 THEN 'Available'  
    ->     WHEN 4 THEN 'Available'  
    ->     ELSE 'Common'  
    ->   END film\_availability  
    -> FROM film f  
    -> ;  
+-----------------------------+-------------------+  
| title                       | film\_availability |  
+-----------------------------+-------------------+  
| ACADEMY DINOSAUR            | Common            |  
| ACE GOLDFINGER              | Available         |  
| ADAPTATION HOLES            | Available         |  
| AFFAIR PREJUDICE            | Common            |  
| AFRICAN EGG                 | Available         |  
| AGENT TRUMAN                | Common            |  
| AIRPLANE SIERRA             | Common            |  
| AIRPORT POLLOCK             | Available         |  
| ALABAMA DEVIL               | Common            |  
| ALADDIN CALENDAR            | Common            |  
| ALAMO VIDEOTAPE             | Common            |  
| ALASKA PHANTOM              | Common            |  
| ALI FOREVER                 | Available         |  
| ALICE FANTASIA              | Out Of Stock      |  
...  
| YOUNG LANGUAGE              | Scarce            |  
| YOUTH KICK                  | Scarce            |  
| ZHIVAGO CORE                | Scarce            |  
| ZOOLANDER FICTION           | Common            |  
| ZORRO ARK                   | Common            |  
+-----------------------------+-------------------+  
1000 rows in set (0.01 sec)

For this query, I stopped counting after 5, since every other number greater than 5 will be given the 'Common' label.

## Division-by-Zero Errors

When performing calculations that include division, you should always take care to ensure that the denominators are never equal to zero. Whereas some database servers, such as Oracle Database, will throw an error when a zero denominator is encountered, MySQL simply sets the result of the calculation to null, as demonstrated by the following:

mysql>   
SELECT 100 / 0;  
  
+---------+  
| 100 / 0 |  
+---------+  
| NULL |  
+---------+  
1 row in set (0.00 sec)

To safeguard your calculations from encountering errors or, even worse, from being mysteriously set to null, you should wrap all denominators in conditional logic, as demonstrated by the following:

mysql> SELECT c.first\_name, c.last\_name,  
    ->   sum(p.amount) tot\_payment\_amt,  
    ->   count(p.amount) num\_payments,  
    ->   sum(p.amount)   
/  
  
    ->       
CASE WHEN count(p.amount) = 0 THEN 1  
  
    ->         
ELSE count(p.amount)  
  
    ->       
END  
 avg\_payment  
    -> FROM customer c  
    ->   LEFT OUTER JOIN payment p  
    ->   ON c.customer\_id = p.customer\_id  
    -> GROUP BY c.first\_name, c.last\_name;  
+------------+------------+-----------------+--------------+-------------+  
| first\_name | last\_name  | tot\_payment\_amt | num\_payments | avg\_payment |  
+------------+------------+-----------------+--------------+-------------+  
| MARY       | SMITH      |          118.68 |           32 |    3.708750 |  
| PATRICIA   | JOHNSON    |          128.73 |           27 |    4.767778 |  
| LINDA      | WILLIAMS   |          135.74 |           26 |    5.220769 |  
| BARBARA    | JONES      |           81.78 |           22 |    3.717273 |  
| ELIZABETH  | BROWN      |          144.62 |           38 |    3.805789 |  
...  
| EDUARDO    | HIATT      |          130.73 |           27 |    4.841852 |  
| TERRENCE   | GUNDERSON  |          117.70 |           30 |    3.923333 |  
| ENRIQUE    | FORSYTHE   |           96.72 |           28 |    3.454286 |  
| FREDDIE    | DUGGAN     |           99.75 |           25 |    3.990000 |  
| WADE       | DELVALLE   |           83.78 |           22 |    3.808182 |  
| AUSTIN     | CINTRON    |           83.81 |           19 |    4.411053 |  
+------------+------------+-----------------+--------------+-------------+  
599 rows in set (0.07 sec)

This query computes the average payment amount for each customer. Since some customers may be new and have yet to rent a film, it is best to include the case expression to ensure that the denominator is never zero.

## Conditional Updates

When updating rows in a table, you sometimes need conditional logic to generate a value for a column. For example, let’s say that you run a job every week that will set the customer.active column to 0 for any customers who haven’t rented a film in the last 90 days. Here’s a statement that will set the value to either 0 or 1 for every customer:

UPDATE customer  
SET active =  
  CASE  
    WHEN 90 <= (SELECT datediff(now(), max(rental\_date))  
                FROM rental r  
                WHERE r.customer\_id = customer.customer\_id)  
      THEN 0  
    ELSE 1  
  END  
WHERE active = 1;

This statement uses a correlated subquery to determine the number of days since the last rental date for each customer and compares the value to 90; if the number returned by the subquery is 90 or higher, the customer is marked as inactive.

## Handling Null Values

While null values are the appropriate thing to store in a table if the value for a column is unknown, it is not always appropriate to retrieve null values for display or to take part in expressions. For example, you might want to display the word unknown on a data entry screen rather than leaving a field blank. When retrieving the data, you can use a case expression to substitute the string if the value is null, as in:

SELECT c.first\_name, c.last\_name,  
  CASE  
    WHEN a.address IS NULL THEN 'Unknown'  
    ELSE a.address  
  END address,  
  CASE  
    WHEN ct.city IS NULL THEN 'Unknown'  
    ELSE ct.city  
  END city,  
  CASE  
    WHEN cn.country IS NULL THEN 'Unknown'  
    ELSE cn.country  
  END country  
FROM customer c  
  LEFT OUTER JOIN address a  
  ON c.address\_id = a.address\_id  
  LEFT OUTER JOIN city ct  
  ON a.city\_id = ct.city\_id  
  LEFT OUTER JOIN country cn  
  ON ct.country\_id = cn.country\_id;

For calculations, null values often cause a null result, as demonstrated by the following example:

mysql>   
SELECT (7 \* 5) / ((3 + 14) \* null);  
  
+-----------------------------+  
| (7 \* 5) / ((3 + 14) \* null) |  
+-----------------------------+  
| NULL |  
+-----------------------------+  
1 row in set (0.08 sec)

When performing calculations, case expressions are useful for translating a null value into a number (usually 0 or 1) that will allow the calculation to yield a non-null value.

# Test Your Knowledge

Challenge your ability to work through conditional logic problems with the examples that follow. When you’re done, compare your solutions with those in [Appendix B](#Appendix_B__Solutions_to_Exercis_2).

## Exercise 11-1

Rewrite the following query, which uses a simple case expression, so that the same results are achieved using a searched case expression. Try to use as few when clauses as possible.

SELECT name,  
 CASE name  
 WHEN 'English' THEN 'latin1'  
 WHEN 'Italian' THEN 'latin1'  
 WHEN 'French' THEN 'latin1'  
 WHEN 'German' THEN 'latin1'  
 WHEN 'Japanese' THEN 'utf8'  
 WHEN 'Mandarin' THEN 'utf8'  
 ELSE 'Unknown'  
 END character\_set  
FROM language;

## Exercise 11-2

Rewrite the following query so that the result set contains a single row with five columns (one for each rating). Name the five columns G, PG, PG\_13, R, and NC\_17.

mysql> SELECT rating, count(\*)  
    -> FROM film  
    -> GROUP BY rating;  
+--------+----------+  
| rating | count(\*) |  
+--------+----------+  
| PG     |      194 |  
| G      |      178 |  
| NC-17  |      210 |  
| PG-13  |      223 |  
| R      |      195 |  
+--------+----------+  
5 rows in set (0.00 sec)

# Chapter 12. Transactions

All of the examples thus far in this book have been individual, independent SQL statements. While this may be the norm for ad hoc reporting or data maintenance scripts, application logic will frequently include multiple SQL statements that need to execute together as a logical unit of work. This chapter explores transactions, which are the mechanism used to group a set of SQL statements together such that either all or none of the statements succeed.

# Multiuser Databases

Database management systems allow a single user to query and modify data, but in today’s world there may be thousands of people making changes to a database simultaneously. If every user is only executing queries, such as might be the case with a data warehouse during normal business hours, then there are very few issues for the database server to deal with. If some of the users are adding and/or modifying data, however, the server must handle quite a bit more bookkeeping.

Let’s say, for example, that you are running a report that sums up the current week’s film rental activity. At the same time you are running the report, however, the following activities are occurring:

* A customer rents a film.
* A customer returns a film after the due date and pays a late fee.
* Five new films are added to inventory.

While your report is running, therefore, multiple users are modifying the underlying data, so what numbers should appear on the report? The answer depends somewhat on how your server handles locking, which is described in the next section.

## Locking

Locks are the mechanism the database server uses to control simultaneous use of data resources. When some portion of the database is locked, any other users wishing to modify (or possibly read) that data must wait until the lock has been released. Most database servers use one of two locking strategies:

* Database writers must request and receive from the server a write lock to modify data, and database readers must request and receive from the server a read lock to query data. While multiple users can read data simultaneously, only one write lock is given out at a time for each table (or portion thereof), and read requests are blocked until the write lock is released.
* Database writers must request and receive from the server a write lock to modify data, but readers do not need any type of lock to query data. Instead, the server ensures that a reader sees a consistent view of the data (the data seems the same even though other users may be making modifications) from the time her query begins until her query has finished. This approach is known as versioning.

There are pros and cons to both approaches. The first approach can lead to long wait times if there are many concurrent read and write requests, and the second approach can be problematic if there are long-running queries while data is being modified. Of the three servers discussed in this book, Microsoft SQL Server uses the first approach, Oracle Database uses the second approach, and MySQL uses both approaches (depending on your choice of storage engine, which we’ll discuss a bit later in the chapter).

## Lock Granularities

There are also a number of different strategies that you may employ when deciding how to lock a resource. The server may apply a lock at one of three different levels, or granularities:

Table locks

Keep multiple users from modifying data in the same table simultaneously

Page locks

Keep multiple users from modifying data on the same page (a page is a segment of memory generally in the range of 2 KB to 16 KB) of a table simultaneously

Row locks

Keep multiple users from modifying the same row in a table simultaneously

Again, there are pros and cons to these approaches. It takes very little bookkeeping to lock entire tables, but this approach quickly yields unacceptable wait times as the number of users increases. On the other hand, row locking takes quite a bit more bookkeeping, but it allows many users to modify the same table as long as they are interested in different rows. Of the three servers discussed in this book, Microsoft SQL Server uses page, row, and table locking, Oracle Database uses only row locking, and MySQL uses table, page, or row locking (depending, again, on your choice of storage engine). SQL Server will, under certain circumstances, escalate locks from row to page, and from page to table, whereas Oracle Database will never escalate locks.

To get back to your report, the data that appears on the pages of the report will mirror either the state of the database when your report started (if your server uses a versioning approach) or the state of the database when the server issues the reporting application a read lock (if your server uses both read and write locks).

# What Is a Transaction?

If database servers enjoyed 100% uptime, if users always allowed programs to finish executing, and if applications always completed without encountering fatal errors that halt execution, then there would be nothing left to discuss regarding concurrent database access. However, we can rely on none of these things, so one more element is necessary to allow multiple users to access the same data.

This extra piece of the concurrency puzzle is the transaction, which is a device for grouping together multiple SQL statements such that either all or none of the statements succeed (a property known as atomicity). If you attempt to transfer $500 from your savings account to your checking account, you would be a bit upset if the money were successfully withdrawn from your savings account but never made it to your checking account. Whatever the reason for the failure (the server was shut down for maintenance, the request for a page lock on the account table timed out, etc.), you want your $500 back.

To protect against this kind of error, the program that handles your transfer request would first begin a transaction, then issue the SQL statements needed to move the money from your savings to your checking account, and, if everything succeeds, end the transaction by issuing the commit command. If something unexpected happens, however, the program would issue a rollback command, which instructs the server to undo all changes made since the transaction began. The entire process might look something like the following:

START TRANSACTION;  
  
 /\* withdraw money from first account, making sure balance is sufficient \*/  
UPDATE account SET avail\_balance = avail\_balance - 500  
WHERE account\_id = 9988  
 AND avail\_balance > 500;  
  
IF <exactly one row was updated by the previous statement> THEN  
 /\* deposit money into second account \*/  
 UPDATE account SET avail\_balance = avail\_balance + 500  
 WHERE account\_id = 9989;  
  
 IF <exactly one row was updated by the previous statement> THEN  
 /\* everything worked, make the changes permanent \*/  
 COMMIT;  
 ELSE  
 /\* something went wrong, undo all changes in this transaction \*/  
 ROLLBACK;  
 END IF;  
ELSE  
 /\* insufficient funds, or error encountered during update \*/  
 ROLLBACK;  
END IF;

##### Note

While the previous code block may look similar to one of the procedural languages provided by the major database companies, such as Oracle’s PL/SQL or Microsoft’s Transact-SQL, it is written in pseudocode and does not attempt to mimic any particular language.

The previous code block begins by starting a transaction and then attempts to remove $500 from the checking account and add it to the savings account. If all goes well, the transaction is committed; if anything goes awry, however, the transaction is rolled back, meaning that all data changes since the beginning of the transaction are undone.

By using a transaction, the program ensures that your $500 either stays in your savings account or moves to your checking account, without the possibility of it falling into a crack. Regardless of whether the transaction was committed or was rolled back, all resources acquired (e.g., write locks) during the execution of the transaction are released when the transaction completes.

Of course, if the program manages to complete both update statements but the server shuts down before a commit or rollback can be executed, then the transaction will be rolled back when the server comes back online. (One of the tasks that a database server must complete before coming online is to find any incomplete transactions that were underway when the server shut down and roll them back.) Additionally, if your program finishes a transaction and issues a commit but the server shuts down before the changes have been applied to permanent storage (i.e., the modified data is sitting in memory but has not been flushed to disk), then the database server must reapply the changes from your transaction when the server is restarted (a property known as durability).

## Starting a Transaction

Database servers handle transaction creation in one of two ways:

* An active transaction is always associated with a database session, so there is no need or method to explicitly begin a transaction. When the current transaction ends, the server automatically begins a new transaction for your session.
* Unless you explicitly begin a transaction, individual SQL statements are automatically committed independently of one another. To begin a transaction, you must first issue a command.

Of the three servers, Oracle Database takes the first approach, while Microsoft SQL Server and MySQL take the second approach. One of the advantages of Oracle’s approach to transactions is that, even if you are issuing only a single SQL command, you have the ability to roll back the changes if you don’t like the outcome or if you change your mind. Thus, if you forget to add a where clause to your delete statement, you will have the opportunity to undo the damage (assuming you’ve had your morning coffee and realize that you didn’t mean to delete all 125,000 rows in your table). With MySQL and SQL Server, however, once you press the Enter key, the changes brought about by your SQL statement will be permanent (unless your DBA can retrieve the original data from a backup or from some other means).

The SQL:2003 standard includes a start transaction command to be used when you want to explicitly begin a transaction. While MySQL conforms to the standard, SQL Server users must instead issue the command begin transaction. With both servers, until you explicitly begin a transaction, you are in what is known as autocommit mode, which means that individual statements are automatically committed by the server. You can, therefore, decide that you want to be in a transaction and issue a start/begin transaction command, or you can simply let the server commit individual statements.

Both MySQL and SQL Server allow you to turn off autocommit mode for individual sessions, in which case the servers will act just like Oracle Database regarding transactions. With SQL Server, you issue the following command to disable autocommit mode:

SET IMPLICIT\_TRANSACTIONS ON

MySQL allows you to disable autocommit mode via the following:

SET AUTOCOMMIT=0

Once you have left autocommit mode, all SQL commands take place within the scope of a transaction and must be explicitly committed or rolled back.

##### Note

A word of advice: shut off autocommit mode each time you log in, and get in the habit of running all of your SQL statements within a transaction. If nothing else, it may save you the embarrassment of having to ask your DBA to reconstruct data that you have inadvertently deleted.

## Ending a Transaction

Once a transaction has begun, whether explicitly via the start transaction command or implicitly by the database server, you must explicitly end your transaction for your changes to become permanent. You do this by way of the commit command, which instructs the server to mark the changes as permanent and release any resources (i.e., page or row locks) used during the transaction.

If you decide that you want to undo all the changes made since starting the transaction, you must issue the rollback command, which instructs the server to return the data to its pre-transaction state. After the rollback has been completed, any resources used by your session are released.

Along with issuing either the commit or rollback command, there are several other scenarios by which your transaction can end, either as an indirect result of your actions or as a result of something outside your control:

* The server shuts down, in which case your transaction will be rolled back automatically when the server is restarted.
* You issue an SQL schema statement, such as alter table, which will cause the current transaction to be committed and a new transaction to be started.
* You issue another start transaction command, which will cause the previous transaction to be committed.
* The server prematurely ends your transaction because the server detects a deadlock and decides that your transaction is the culprit. In this case, the transaction will be rolled back, and you will receive an error message.

Of these four scenarios, the first and third are fairly straightforward, but the other two merit some discussion. As far as the second scenario is concerned, alterations to a database, whether it be the addition of a new table or index or the removal of a column from a table, cannot be rolled back, so commands that alter your schema must take place outside a transaction. If a transaction is currently underway, therefore, the server will commit your current transaction, execute the SQL schema statement command(s), and then automatically start a new transaction for your session. The server will not inform you of what has happened, so you should be careful that the statements that comprise a unit of work are not inadvertently broken up into multiple transactions by the server.

The fourth scenario deals with deadlock detection. A deadlock occurs when two different transactions are waiting for resources that the other transaction currently holds. For example, transaction A might have just updated the account table and is waiting for a write lock on the transaction table, while transaction B has inserted a row into the transaction table and is waiting for a write lock on the account table. If both transactions happen to be modifying the same page or row (depending on the lock granularity in use by the database server), then they will each wait forever for the other transaction to finish and free up the needed resource. Database servers must always be on the lookout for these situations so that throughput doesn’t grind to a halt; when a deadlock is detected, one of the transactions is chosen (either arbitrarily or by some criteria) to be rolled back so that the other transaction may proceed. Most of the time, the terminated transaction can be restarted and will succeed without encountering another deadlock situation.

Unlike the second scenario discussed earlier, the database server will raise an error to inform you that your transaction has been rolled back due to deadlock detection. With MySQL, for example, you will receive error 1213, which carries the following message:

Message: Deadlock found when trying to get lock; try restarting transaction

As the error message suggests, it is a reasonable practice to retry a transaction that has been rolled back due to deadlock detection. However, if deadlocks become fairly common, then you may need to modify the applications that access the database to decrease the probability of deadlocks (one common strategy is to ensure that data resources are always accessed in the same order, such as always modifying account data before inserting transaction data).

## Transaction Savepoints

In some cases, you may encounter an issue within a transaction that requires a rollback, but you may not want to undo all of the work that has transpired. For these situations, you can establish one or more savepoints within a transaction and use them to roll back to a particular location within your transaction rather than rolling all the way back to the start of the transaction.

#### Choosing a Storage Engine

When using Oracle Database or Microsoft SQL Server, a single set of code is responsible for low-level database operations, such as retrieving a particular row from a table based on primary key value. The MySQL server, however, has been designed so that multiple storage engines may be utilized to provide low-level database functionality, including resource locking and transaction management. As of version 8.0, MySQL includes the following storage engines:

MyISAM

A nontransactional engine employing table locking

MEMORY

A nontransactional engine used for in-memory tables

CSV

A transactional engine that stores data in comma-separated files

InnoDB

A transactional engine employing row-level locking

Merge

A specialty engine used to make multiple identical MyISAM tables appear as a single table (a.k.a. table partitioning)

Archive

A specialty engine used to store large amounts of unindexed data, mainly for archival purposes

Although you might think that you would be forced to choose a single storage engine for your database, MySQL is flexible enough to allow you to choose a storage engine on a table-by-table basis. For any tables that might take part in transactions, however, you should choose the InnoDB engine, which uses row-level locking and versioning to provide the highest level of concurrency across the different storage engines.

You may explicitly specify a storage engine when creating a table, or you can change an existing table to use a different engine. If you do not know what engine is assigned to a table, you can use the show table command, as demonstrated by the following:

mysql> show table status like 'customer' \G;  
\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 1. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*  
           Name: customer  
           
Engine: InnoDB  
  
        Version: 10  
     Row\_format: Dynamic  
           Rows: 599  
 Avg\_row\_length: 136  
    Data\_length: 81920  
Max\_data\_length: 0  
   Index\_length: 49152  
      Data\_free: 0  
 Auto\_increment: 599  
    Create\_time: 2019-03-12 14:24:46  
    Update\_time: NULL  
     Check\_time: NULL  
      Collation: utf8\_general\_ci  
       Checksum: NULL  
 Create\_options:  
        Comment:  
1 row in set (0.16 sec)

Looking at the second item, you can see that the customer table is already using the InnoDB engine. If it were not, you could assign the InnoDB engine to the transaction table via the following command:

ALTER TABLE customer ENGINE = INNODB;

All savepoints must be given a name, which allows you to have multiple savepoints within a single transaction. To create a savepoint named my\_savepoint, you can do the following:

SAVEPOINT my\_savepoint;

To roll back to a particular savepoint, you simply issue the rollback command followed by the keywords to savepoint and the name of the savepoint, as in:

ROLLBACK TO SAVEPOINT my\_savepoint;

Here’s an example of how savepoints may be used:

START TRANSACTION;  
  
UPDATE product  
SET date\_retired = CURRENT\_TIMESTAMP()  
WHERE product\_cd = 'XYZ';  
  
SAVEPOINT before\_close\_accounts;  
  
UPDATE account  
SET status = 'CLOSED', close\_date = CURRENT\_TIMESTAMP(),  
 last\_activity\_date = CURRENT\_TIMESTAMP()  
WHERE product\_cd = 'XYZ';  
  
ROLLBACK TO SAVEPOINT before\_close\_accounts;  
COMMIT;

The net effect of this transaction is that the mythical XYZ product is retired but none of the accounts are closed.

When using savepoints, remember the following:

* Despite the name, nothing is saved when you create a savepoint. You must eventually issue a commit if you want your transaction to be made permanent.
* If you issue a rollback without naming a savepoint, all savepoints within the transaction will be ignored, and the entire transaction will be undone.

If you are using SQL Server, you will need to use the proprietary command save transaction to create a savepoint and rollback transaction to roll back to a savepoint, with each command being followed by the savepoint name.

# Test Your Knowledge

Test your understanding of transactions by working through the following exercise. When you’re done, compare your solution with that in [Appendix B](#Appendix_B__Solutions_to_Exercis_2).

## Exercise 12-1

Generate a unit of work to transfer $50 from account 123 to account 789. You will need to insert two rows into the transaction table and update two rows in the account table. Use the following table definitions/data:

Account:  
account\_id avail\_balance last\_activity\_date  
---------- ------------- ------------------  
123 500 2019-07-10 20:53:27  
789 75 2019-06-22 15:18:35  
  
 Transaction:  
txn\_id txn\_date account\_id txn\_type\_cd amount  
--------- ------------ ----------- ----------- --------  
1001 2019-05-15 123 C 500  
1002 2019-06-01 789 C 75

Use txn\_type\_cd = 'C' to indicate a credit (addition), and use txn\_type\_cd = 'D' to indicate a debit (subtraction).

# Chapter 13. Indexes and Constraints

Because the focus of this book is on programming techniques, the first 12 chapters concentrated on elements of the SQL language that you can use to craft powerful select, insert, update, and delete statements. However, other database features indirectly affect the code you write. This chapter focuses on two of those features: indexes and constraints.

# Indexes

When you insert a row into a table, the database server does not attempt to put the data in any particular location within the table. For example, if you add a row to the customer table, the server doesn’t place the row in numeric order via the customer\_id column or in alphabetical order via the last\_name column. Instead, the server simply places the data in the next available location within the file (the server maintains a list of free space for each table). When you query the customer table, therefore, the server will need to inspect every row of the table to answer the query. For example, let’s say that you issue the following query:

mysql> SELECT first\_name, last\_name  
    -> FROM customer  
    -> WHERE last\_name LIKE 'Y%';  
+------------+-----------+  
| first\_name | last\_name |  
+------------+-----------+  
| LUIS       | YANEZ     |  
| MARVIN     | YEE       |  
| CYNTHIA    | YOUNG     |  
+------------+-----------+  
3 rows in set (0.09 sec)

To find all customers whose last name begins with Y, the server must visit each row in the customer table and inspect the contents of the last\_name column; if the last name begins with Y, then the row is added to the result set. This type of access is known as a table scan.

While this method works fine for a table with only three rows, imagine how long it might take to answer the query if the table contains three million rows. At some number of rows larger than three and smaller than three million, a line is crossed where the server cannot answer the query within a reasonable amount of time without additional help. This help comes in the form of one or more indexes on the customer table.

Even if you have never heard of a database index, you are certainly aware of what an index is (e.g., this book has one). An index is simply a mechanism for finding a specific item within a resource. Each technical publication, for example, includes an index at the end that allows you to locate a specific word or phrase within the publication. The index lists these words and phrases in alphabetical order, allowing the reader to move quickly to a particular letter within the index, find the desired entry, and then find the page or pages on which the word or phrase may be found.

In the same way that a person uses an index to find words within a publication, a database server uses indexes to locate rows in a table. Indexes are special tables that, unlike normal data tables, are kept in a specific order. Instead of containing all of the data about an entity, however, an index contains only the column (or columns) used to locate rows in the data table, along with information describing where the rows are physically located. Therefore, the role of indexes is to facilitate the retrieval of a subset of a table’s rows and columns without the need to inspect every row in the table.

## Index Creation

Returning to the customer table, you might decide to add an index on the email column to speed up any queries that specify a value for this column, as well as any update or delete operations that specify a customer’s email address. Here’s how you can add such an index to a MySQL database:

mysql> ALTER TABLE customer  
    -> ADD INDEX idx\_email (email);  
Query OK, 0 rows affected (1.87 sec)  
Records: 0  Duplicates: 0  Warnings: 0

This statement creates an index (a B-tree index to be precise, but more on this shortly) on the customer.email column; furthermore, the index is given the name idx\_email. With the index in place, the query optimizer (which we discussed in [Chapter 3](#Chapter_3__Query_Primer__So_far_2)) can choose to use the index if it is deemed beneficial to do so. If there is more than one index on a table, the optimizer must decide which index will be the most beneficial for a particular SQL statement.

##### Note

MySQL treats indexes as optional components of a table, which is why in earlier versions you would use the alter table command to add or remove an index. Other database servers, including SQL Server and Oracle Database, treat indexes as independent schema objects. For both SQL Server and Oracle, therefore, you would generate an index using the create index command, as in:

CREATE INDEX idx\_email  
ON customer (email);

As of MySQL version 5, a create index command is available, although it is mapped to the alter table command. You must still use the alter table command to create primary key indexes, however.

All database servers allow you to look at the available indexes. MySQL users can use the show command to see all of the indexes on a specific table, as in:

mysql> SHOW INDEX FROM customer \G;  
\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 1. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*  
        Table: customer  
   Non\_unique: 0  
     Key\_name: PRIMARY  
 Seq\_in\_index: 1  
  Column\_name: customer\_id  
    Collation: A  
  Cardinality: 599  
     Sub\_part: NULL  
       Packed: NULL  
         Null:  
   Index\_type: BTREE  
...  
\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 2. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*  
        Table: customer  
   Non\_unique: 1  
     Key\_name: idx\_fk\_store\_id  
 Seq\_in\_index: 1  
  Column\_name: store\_id  
    Collation: A  
  Cardinality: 2  
     Sub\_part: NULL  
       Packed: NULL  
         Null:  
   Index\_type: BTREE  
...  
\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 3. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*  
        Table: customer  
   Non\_unique: 1  
     Key\_name: idx\_fk\_address\_id  
 Seq\_in\_index: 1  
  Column\_name: address\_id  
    Collation: A  
  Cardinality: 599  
     Sub\_part: NULL  
       Packed: NULL  
         Null:  
   Index\_type: BTREE  
...  
\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 4. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*  
        Table: customer  
   Non\_unique: 1  
     Key\_name: idx\_last\_name  
 Seq\_in\_index: 1  
  Column\_name: last\_name  
    Collation: A  
  Cardinality: 599  
     Sub\_part: NULL  
       Packed: NULL  
         Null:  
   Index\_type: BTREE  
...  
\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 5. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*  
        Table: customer  
   Non\_unique: 1  
     Key\_name: idx\_email  
 Seq\_in\_index: 1  
  Column\_name: email  
    Collation: A  
  Cardinality: 599  
     Sub\_part: NULL  
       Packed: NULL  
         Null: YES  
   Index\_type: BTREE  
...  
5 rows in set (0.06 sec)

The output shows that there are five indexes on the customer table: one on the customer\_id column called PRIMARY, and four others on the store\_id, address\_id, last\_name, and email columns. If you are wondering where these indexes came from, I created the index on the email column, and the rest were installed as part of the sample Sakila database. Here’s the statement used to create the table:

CREATE TABLE customer (  
  customer\_id SMALLINT UNSIGNED NOT NULL AUTO\_INCREMENT,  
  store\_id TINYINT UNSIGNED NOT NULL,  
  first\_name VARCHAR(45) NOT NULL,  
  last\_name VARCHAR(45) NOT NULL,  
  email VARCHAR(50) DEFAULT NULL,  
  address\_id SMALLINT UNSIGNED NOT NULL,  
  active BOOLEAN NOT NULL DEFAULT TRUE,  
  create\_date DATETIME NOT NULL,  
  last\_update TIMESTAMP DEFAULT CURRENT\_TIMESTAMP,  
    
PRIMARY KEY  (customer\_id),  
  KEY idx\_fk\_store\_id (store\_id),  
  KEY idx\_fk\_address\_id (address\_id),  
  KEY idx\_last\_name (last\_name),  
  
  ...

When the table was created, the MySQL server automatically generated an index on the primary key column, which in this case is customer\_id, and gave the index the name PRIMARY. This is a special type of index used with a primary key constraint, but I will cover constraints later in this chapter.

If, after creating an index, you decide that the index is not proving useful, you can remove it via the following:

mysql> ALTER TABLE customer  
    -> DROP INDEX idx\_email;  
Query OK, 0 rows affected (0.50 sec)  
Records: 0  Duplicates: 0  Warnings: 0

##### Note

SQL Server and Oracle Database users must use the drop index command to remove an index, as in:

DROP INDEX idx\_email; (Oracle)  
  
DROP INDEX idx\_email ON customer; (SQL Server)

MySQL now also supports the drop index command, although it is also mapped to the alter table command.

## Unique indexes

When designing a database, it is important to consider which columns are allowed to contain duplicate data and which are not. For example, it is allowable to have two customers named John Smith in the customer table since each row will have a different identifier (customer\_id), email, and address to help tell them apart. You would not, however, want to allow two different customers to have the same email address. You can enforce a rule against duplicate values by creating a unique index on the customer.email column.

A unique index plays multiple roles; along with providing all the benefits of a regular index, it also serves as a mechanism for disallowing duplicate values in the indexed column. Whenever a row is inserted or when the indexed column is modified, the database server checks the unique index to see whether the value already exists in another row in the table. Here’s how you would create a unique index on the customer.email column:

mysql> ALTER TABLE customer  
    -> ADD   
UNIQUE  
 idx\_email (email);  
Query OK, 0 rows affected (0.64 sec)  
Records: 0  Duplicates: 0  Warnings: 0

##### Note

SQL Server and Oracle Database users need only add the unique keyword when creating an index, as in:

CREATE UNIQUE INDEX idx\_email  
ON customer (email);

With the index in place, you will receive an error if you try to add a new customer with an email address that already exists:

mysql> INSERT INTO customer  
    ->  (store\_id, first\_name, last\_name, email, address\_id, active)  
    -> VALUES  
    ->  (1,'ALAN','KAHN', 'ALAN.KAHN@sakilacustomer.org', 394, 1);  
ERROR 1062 (23000): Duplicate entry 'ALAN.KAHN@sakilacustomer.org'   
  for key 'idx\_email'

You should not build unique indexes on your primary key column(s), since the server already checks uniqueness for primary key values. You may, however, create more than one unique index on the same table if you feel that it is warranted.

## Multicolumn indexes

Along with the single-column indexes demonstrated thus far, you may also build indexes that span multiple columns. If, for example, you find yourself searching for customers by first and last names, you can build an index on both columns together, as in:

mysql> ALTER TABLE customer  
    -> ADD INDEX idx\_full\_name (last\_name, first\_name);  
Query OK, 0 rows affected (0.35 sec)  
Records: 0  Duplicates: 0  Warnings: 0

This index will be useful for queries that specify the first and last names or just the last name, but it would not be useful for queries that specify only the customer’s first name. To understand why, consider how you would find a person’s phone number; if you know the person’s first and last names, you can use a phone book to find the number quickly, since a phone book is organized by last name and then by first name. If you know only the person’s first name, you would need to scan every entry in the phone book to find all the entries with the specified first name.

When building multiple-column indexes, therefore, you should think carefully about which column to list first, which column to list second, and so on, to help make the index as useful as possible. Keep in mind, however, that there is nothing stopping you from building multiple indexes using the same set of columns but in a different order if you feel that it is needed to ensure adequate response time.

## Types of Indexes

Indexing is a powerful tool, but since there are many different types of data, a single indexing strategy doesn’t always do the job. The following sections illustrate the different types of indexing available from various servers.

## B-tree indexes

All the indexes shown thus far are balanced-tree indexes, which are more commonly known as B-tree indexes. MySQL, Oracle Database, and SQL Server all default to B-tree indexing, so you will get a B-tree index unless you explicitly ask for another type. As you might expect, B-tree indexes are organized as trees, with one or more levels of branch nodes leading to a single level of leaf nodes. Branch nodes are used for navigating the tree, while leaf nodes hold the actual values and location information. For example, a B-tree index built on the customer.last\_name column might look something like [Figure 13-1](#Figure_13_1__B_tree_example).

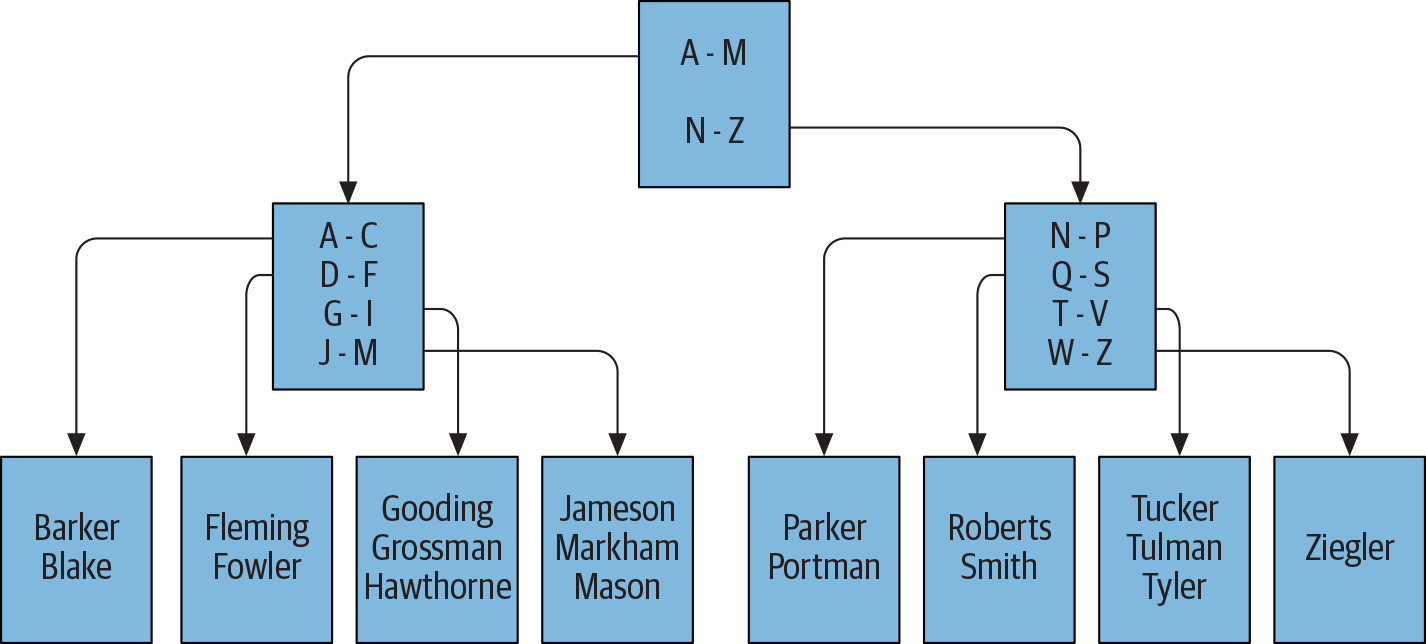


Figure 13-1. B-tree example

If you were to issue a query to retrieve all customers whose last name starts with G, the server would look at the top branch node (called the root node) and follow the link to the branch node that handles last names beginning with A through M. This branch node would, in turn, direct the server to a leaf node containing last names beginning with G through I. The server then starts reading the values in the leaf node until it encounters a value that doesn’t begin with G (which, in this case, is Hawthorne).

As rows are inserted, updated, and deleted from the customer table, the server will attempt to keep the tree balanced so that there aren’t far more branch/leaf nodes on one side of the root node than the other. The server can add or remove branch nodes to redistribute the values more evenly and can even add or remove an entire level of branch nodes. By keeping the tree balanced, the server is able to traverse quickly to the leaf nodes to find the desired values without having to navigate through many levels of branch nodes.

## Bitmap indexes

Although B-tree indexes are great at handling columns that contain many different values, such as a customer’s first/last names, they can become unwieldy when built on a column that allows only a small number of values. For example, you may decide to generate an index on the customer.active column so that you can quickly retrieve all active or inactive accounts. Because there are only two different values (stored as 1 for active and 0 for inactive), however, and because there are far more active customers, it can be difficult to maintain a balanced B-tree index as the number of customers grows.

For columns that contain only a small number of values across a large number of rows (known as low-cardinality data), a different indexing strategy is needed. To handle this situation more efficiently, Oracle Database includes bitmap indexes, which generate a bitmap for each value stored in the column. If you were to build a bitmap index on the customer.active column, the index would maintain two bitmaps: one for the value 0 and another for the value 1. When you write a query to retrieve all inactive customers, the database server can traverse the 0 bitmap and quickly retrieve the desired rows.

Bitmap indexes are a nice, compact indexing solution for low-cardinality data, but this indexing strategy breaks down if the number of values stored in the column climbs too high in relation to the number of rows (known as high-cardinality data), since the server would need to maintain too many bitmaps. For example, you would never build a bitmap index on your primary key column, since this represents the highest possible cardinality (a different value for every row).

Oracle users can generate bitmap indexes by simply adding the bitmap keyword to the create index statement, as in:

CREATE BITMAP INDEX idx\_active ON customer (active);

Bitmap indexes are commonly used in data warehousing environments, where large amounts of data are generally indexed on columns containing relatively few values (e.g., sales quarters, geographic regions, products, salespeople).

## Text indexes

If your database stores documents, you may need to allow users to search for words or phrases in the documents. You certainly don’t want the server to peruse each document and scan for the desired text each time a search is requested, but traditional indexing strategies don’t work for this situation. To handle this situation, MySQL, SQL Server, and Oracle Database include specialized indexing and search mechanisms for documents; both SQL Server and MySQL include what they call full-text indexes, and Oracle Database includes a powerful set of tools known as Oracle Text. Document searches are specialized enough that it is not practical to show an example, but it is useful to at least know what is available.

## How Indexes Are Used

Indexes are generally used by the server to quickly locate rows in a particular table, after which the server visits the associated table to extract the additional information requested by the user. Consider the following query:

mysql> SELECT customer\_id, first\_name, last\_name  
    -> FROM customer  
    -> WHERE first\_name LIKE 'S%' AND last\_name LIKE 'P%';  
+-------------+------------+-----------+  
| customer\_id | first\_name | last\_name |  
+-------------+------------+-----------+  
|          84 | SARA       | PERRY     |  
|         197 | SUE        | PETERS    |  
|         167 | SALLY      | PIERCE    |  
+-------------+------------+-----------+  
3 rows in set (0.00 sec)

For this query, the server can employ any of the following strategies:

* Scan all rows in the customer table.
* Use the index on the last\_name column to find all customers whose last name starts with P; then visit each row of the customer table to find only rows whose first name starts with S.
* Use the index on the last\_name and first\_name columns to find all customers whose last name starts with P and whose first name starts with S.

The third choice seems to be the best option, since the index will yield all of the rows needed for the result set, without the need to revisit the table. But how do you know which of the three options will be utilized? To see how MySQL’s query optimizer decides to execute the query, I use the explain statement to ask the server to show the execution plan for the query rather than executing the query:

mysql>   
EXPLAIN  
  
    -> SELECT customer\_id, first\_name, last\_name  
    -> FROM customer  
    -> WHERE first\_name LIKE 'S%' AND last\_name LIKE 'P%' \G;  
\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 1. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*  
           id: 1  
  select\_type: SIMPLE  
        table: customer  
   partitions: NULL  
         type: range  
possible\_keys: idx\_last\_name,idx\_full\_name  
          key:   
idx\_full\_name  
  
      key\_len: 274  
          ref: NULL  
         rows: 28  
     filtered: 11.11  
        Extra: Using where;   
Using index  
  
1 row in set, 1 warning (0.00 sec)

##### Note

Each database server includes tools to allow you to see how the query optimizer handles your SQL statement. SQL Server allows you to see an execution plan by issuing the statement set showplan\_text on before running your SQL statement. Oracle Database includes the explain plan statement, which writes the execution plan to a special table called plan\_table.

Looking at the query results, the possible\_keys column tells you that the server could decide to use either the idx\_last\_name or the idx\_full\_name index, and the key column tells you that the idx\_full\_name index was chosen. Furthermore, the type column tells you that a range scan will be utilized, meaning that the database server will be looking for a range of values in the index, rather than expecting to retrieve a single row.

##### Note

The process that I just led you through is an example of query tuning. Tuning involves looking at an SQL statement and determining the resources available to the server to execute the statement. You can decide to modify the SQL statement, to adjust the database resources, or to do both in order to make a statement run more efficiently. Tuning is a detailed topic, and I strongly urge you to either read your server’s tuning guide or pick up a good tuning book so that you can see all the different approaches available for your server.

## The Downside of Indexes

If indexes are so great, why not index everything? Well, the key to understanding why more indexes are not necessarily a good thing is to keep in mind that every index is a table (a special type of table but still a table). Therefore, every time a row is added to or removed from a table, all indexes on that table must be modified. When a row is updated, any indexes on the column or columns that were affected need to be modified as well. Therefore, the more indexes you have, the more work the server needs to do to keep all schema objects up-to-date, which tends to slow things down.

Indexes also require disk space as well as some amount of care from your administrators, so the best strategy is to add an index when a clear need arises. If you need an index for only special purposes, such as a monthly maintenance routine, you can always add the index, run the routine, and then drop the index until you need it again. In the case of data warehouses, where indexes are crucial during business hours as users run reports and ad hoc queries but are problematic when data is being loaded into the warehouse overnight, it is a common practice to drop the indexes before data is loaded and then re-create them before the warehouse opens for business.

In general, you should strive to have neither too many indexes nor too few. If you aren’t sure how many indexes you should have, you can use this strategy as a default:

* Make sure all primary key columns are indexed (most servers automatically create unique indexes when you create primary key constraints). For multicolumn primary keys, consider building additional indexes on a subset of the primary key columns or on all the primary key columns but in a different order than the primary key constraint definition.
* Build indexes on all columns that are referenced in foreign key constraints. Keep in mind that the server checks to make sure there are no child rows when a parent is deleted, so it must issue a query to search for a particular value in the column. If there’s no index on the column, the entire table must be scanned.
* Index any columns that will frequently be used to retrieve data. Most date columns are good candidates, along with short (2- to 50-character) string columns.

After you have built your initial set of indexes, try to capture actual queries against your tables, look at the server’s execution plan, and modify your indexing strategy to fit the most common access paths.

# Constraints

A constraint is simply a restriction placed on one or more columns of a table. There are several different types of constraints, including:

Primary key constraints

Identify the column or columns that guarantee uniqueness within a table

Foreign key constraints

Restrict one or more columns to contain only values found in another table’s primary key columns (may also restrict the allowable values in other tables if update cascade or delete cascade rules are established)

Unique constraints

Restrict one or more columns to contain unique values within a table (primary key constraints are a special type of unique constraint)

Check constraints

Restrict the allowable values for a column

Without constraints, a database’s consistency is suspect. For example, if the server allows you to change a customer’s ID in the customer table without changing the same customer ID in the rental table, then you will end up with rental data that no longer points to valid customer records (known as orphaned rows). With primary and foreign key constraints in place, however, the server will either raise an error if an attempt is made to modify or delete data that is referenced by other tables or propagate the changes to other tables for you (more on this shortly).

##### Note

If you want to use foreign key constraints with the MySQL server, you must use the InnoDB storage engine for your tables.

## Constraint Creation

Constraints are generally created at the same time as the associated table via the create table statement. To illustrate, here’s an example from the schema generation script for the Sakila sample database:

CREATE TABLE customer (  
  customer\_id SMALLINT UNSIGNED NOT NULL AUTO\_INCREMENT,  
  store\_id TINYINT UNSIGNED NOT NULL,  
  first\_name VARCHAR(45) NOT NULL,  
  last\_name VARCHAR(45) NOT NULL,  
  email VARCHAR(50) DEFAULT NULL,  
  address\_id SMALLINT UNSIGNED NOT NULL,  
  active BOOLEAN NOT NULL DEFAULT TRUE,  
  create\_date DATETIME NOT NULL,  
  last\_update TIMESTAMP DEFAULT CURRENT\_TIMESTAMP   
  ON UPDATE CURRENT\_TIMESTAMP,  
    
PRIMARY KEY (customer\_id)  
,  
  KEY idx\_fk\_store\_id (store\_id),  
  KEY idx\_fk\_address\_id (address\_id),  
  KEY idx\_last\_name (last\_name),  
    
CONSTRAINT fk\_customer\_address FOREIGN KEY  
   
(address\_id)   
  REFERENCES address (address\_id)  
 ON DELETE RESTRICT ON UPDATE CASCADE,  
    
CONSTRAINT fk\_customer\_store FOREIGN KEY  
   
(store\_id)   
  REFERENCES store (store\_id)  
 ON DELETE RESTRICT ON UPDATE CASCADE  
)ENGINE=InnoDB DEFAULT CHARSET=utf8;

The customer table includes three constraints: one to specify that the customer\_id column serves as the primary key for the table, and two more to specify that the address\_id and store\_id columns serve as foreign keys to the address and store table. Alternatively, you could create the customer table without foreign key constraints and add the foreign key constraints later via alter table statements:

ALTER TABLE customer  
ADD CONSTRAINT fk\_customer\_address FOREIGN KEY (address\_id)  
REFERENCES address (address\_id) ON DELETE RESTRICT ON UPDATE CASCADE;  
  
ALTER TABLE customer  
ADD CONSTRAINT fk\_customer\_store FOREIGN KEY (store\_id)  
REFERENCES store (store\_id) ON DELETE RESTRICT ON UPDATE CASCADE;

Both of these statements include several on clauses:

* on delete restrict, which will cause the server to raise an error if a row is deleted in the parent table (address or store) that is referenced in the child table (customer)
* on update cascade, which will cause the server to propagate a change to the primary key value of a parent table (address or store) to the child table (customer)

The on delete restrict clause protects against orphaned records when rows are deleted from the parent table. To illustrate, let’s pick a row in the address table and show the data from both the address and customer tables that share this value:

mysql> SELECT c.first\_name, c.last\_name,   
c.address\_id  
, a.address  
    -> FROM customer c  
    ->   INNER JOIN address a  
    ->   ON c.address\_id = a.address\_id  
    -> WHERE a.address\_id =   
123  
;  
+------------+-----------+------------+----------------------------------+  
| first\_name | last\_name | address\_id | address                          |  
+------------+-----------+------------+----------------------------------+  
| SHERRY     | MARSHALL  |          
123   
| 1987 Coacalco de Berriozbal Loop |  
+------------+-----------+------------+----------------------------------+  
1 row in set (0.00 sec)

The results show that there is a single customer row (for Sherry Marshall) whose address\_id column contains the value 123.

Here’s what happens if you try to remove this row from the parent (address) table:

mysql> DELETE FROM address WHERE address\_id = 123;  
ERROR 1451 (23000): Cannot delete or update a parent row:   
  a foreign key constraint fails (`sakila`.`customer`,   
  CONSTRAINT `fk\_customer\_address` FOREIGN KEY (`address\_id`)   
  REFERENCES `address` (`address\_id`)   
  ON DELETE RESTRICT ON UPDATE CASCADE)

Because at least one row in the child table contains the value 123 in the address\_id column, the on delete restrict clause of the foreign key constraint caused the statement to fail.

The on update cascade clause also protects against orphaned records when a primary key value is updated in the parent table using a different strategy. Here’s what happens if you modify a value in the address.address\_id column:

mysql> UPDATE address  
    -> SET address\_id =   
9999  
  
    -> WHERE address\_id =   
123  
;  
Query OK, 1 row affected (0.37 sec)  
Rows matched: 1  Changed: 1  Warnings: 0

The statement executed without error, and one row was modified. But what happened to Sherry Marshall’s row in the customer table? Does it still point to address ID 123, which no longer exists? To find out, let’s run the last query again, but substitute the new value 9999 for the previous value of 123:

mysql> SELECT c.first\_name, c.last\_name,   
c.address\_id  
, a.address  
    -> FROM customer c  
    ->   INNER JOIN address a  
    ->   ON c.address\_id = a.address\_id  
    -> WHERE a.address\_id =   
9999  
;  
+------------+-----------+------------+----------------------------------+  
| first\_name | last\_name | address\_id | address                          |  
+------------+-----------+------------+----------------------------------+  
| SHERRY     | MARSHALL  |         
9999   
| 1987 Coacalco de Berriozbal Loop |  
+------------+-----------+------------+----------------------------------+  
1 row in set (0.00 sec)

As you can see, the same results are returned as before (other than the new address ID value), which means that the value 9999 was automatically updated in the customer table. This is known as a cascade, and it’s the second mechanism used to protect against orphaned rows.

Along with restrict and cascade, you can also choose set null, which will set the foreign key value to null in the child table when a row is deleted or updated in the parent table. Altogether, there are six different options to choose from when defining foreign key constraints:

* on delete restrict
* on delete cascade
* on delete set null
* on update restrict
* on update cascade
* on update set null

These are optional, so you can choose zero, one, or two (one on delete and one on update) of these when defining your foreign key constraints.

Finally, if you want to remove a primary or foreign key constraint, you can use the alter table statement again, except that you specify drop instead of add. While it is unusual to drop a primary key constraint, foreign key constraints are sometimes dropped during certain maintenance operations and then reestablished.

# Test Your Knowledge

Work through the following exercises to test your knowledge of indexes and constraints. When you’re done, compare your solutions with those in [Appendix B](#Appendix_B__Solutions_to_Exercis_2).

## Exercise 13-1

Generate an alter table statement for the rental table so that an error will be raised if a row having a value found in the rental.customer\_id column is deleted from the customer table.

## Exercise 13-2

Generate a multicolumn index on the payment table that could be used by both of the following queries:

SELECT customer\_id, payment\_date, amount  
FROM payment  
WHERE payment\_date > cast('2019-12-31 23:59:59' as datetime);  
  
SELECT customer\_id, payment\_date, amount  
FROM payment  
​WHERE payment\_date > cast('2019-12-31 23:59:59' as datetime)  
 AND amount < 5;

# Chapter 14. Views

Well-designed applications generally expose a public interface while keeping implementation details private, thereby enabling future design changes without impacting end users. When designing your database, you can achieve a similar result by keeping your tables private and allowing your users to access data only through a set of views. This chapter strives to define what views are, how they are created, and when and how you might want to use them.

# What Are Views?

A view is simply a mechanism for querying data. Unlike tables, views do not involve data storage; you won’t need to worry about views filling up your disk space. You create a view by assigning a name to a select statement and then storing the query for others to use. Other users can then use your view to access data just as though they were querying tables directly (in fact, they may not even know they are using a view).

As a simple example, let’s say that you want to partially obscure the email address in the customer table. The marketing department, for example, may need access to email addresses in order to advertise promotions, but otherwise your company’s privacy policy dictates that this data be kept secure. Therefore, instead of allowing direct access to the customer table, you define a view called customer\_vw and mandate that all nonmarketing personnel use it to access customer data. Here’s the view definition:

CREATE VIEW customer\_vw  
 (customer\_id,  
 first\_name,  
 last\_name,  
 email   
 )  
AS  
SELECT   
  customer\_id,  
  first\_name,  
  last\_name,  
 concat(substr(email,1,2), '\*\*\*\*\*', substr(email, -4)) email  
FROM customer;

The first part of the statement lists the view’s column names, which may be different from those of the underlying table. The second part of the statement is a select statement, which must contain one expression for each column in the view. The email column is generated by taking the first two characters of the email address, concatenated with '\*\*\*\*\*', and then concatenated with the last four characters of the email address.

When the create view statement is executed, the database server simply stores the view definition for future use; the query is not executed, and no data is retrieved or stored. Once the view has been created, users can query it just like they would a table, as in:

mysql> SELECT first\_name, last\_name, email  
    -> FROM   
customer\_vw  
;  
+-------------+--------------+-------------+  
| first\_name  | last\_name    | email       |  
+-------------+--------------+-------------+  
| MARY        | SMITH        | MA\*\*\*\*\*.org |  
| PATRICIA    | JOHNSON      | PA\*\*\*\*\*.org |  
| LINDA       | WILLIAMS     | LI\*\*\*\*\*.org |  
| BARBARA     | JONES        | BA\*\*\*\*\*.org |  
| ELIZABETH   | BROWN        | EL\*\*\*\*\*.org |  
...  
| ENRIQUE     | FORSYTHE     | EN\*\*\*\*\*.org |  
| FREDDIE     | DUGGAN       | FR\*\*\*\*\*.org |  
| WADE        | DELVALLE     | WA\*\*\*\*\*.org |  
| AUSTIN      | CINTRON      | AU\*\*\*\*\*.org |  
+-------------+--------------+-------------+  
599 rows in set (0.00 sec)

Even though the customer\_vw view definition includes four columns of the customer table, the previous query retrieves only three of the four. As you’ll see later in the chapter, this is an important distinction if some of the columns in your view are attached to functions or subqueries.

From the user’s standpoint, a view looks exactly like a table. If you want to know what columns are available in a view, you can use MySQL’s (or Oracle’s) describe command to examine it:

mysql> describe customer\_vw;  
+-------------+----------------------+------+-----+---------+-------+  
| Field       | Type                 | Null | Key | Default | Extra |  
+-------------+----------------------+------+-----+---------+-------+  
| customer\_id | smallint(5) unsigned | NO   |     | 0       |       |  
| first\_name  | varchar(45)          | NO   |     | NULL    |       |  
| last\_name   | varchar(45)          | NO   |     | NULL    |       |  
| email       | varchar(11)          | YES  |     | NULL    |       |  
+-------------+----------------------+------+-----+---------+-------+  
4 rows in set (0.00 sec)

You are free to use any clauses of the select statement when querying through a view, including group by, having, and order by. Here’s an example:

mysql> SELECT first\_name, count(\*), min(last\_name), max(last\_name)  
    -> FROM customer\_vw  
    -> WHERE first\_name LIKE 'J%'  
    -> GROUP BY first\_name  
    -> HAVING count(\*) > 1  
    -> ORDER BY 1;  
+------------+----------+----------------+----------------+  
| first\_name | count(\*) | min(last\_name) | max(last\_name) |  
+------------+----------+----------------+----------------+  
| JAMIE      |        2 | RICE           | WAUGH          |  
| JESSIE     |        2 | BANKS          | MILAM          |  
+------------+----------+----------------+----------------+  
2 rows in set (0.00 sec)

In addition, you can join views to other tables (or even to other views) within a query, as in:

mysql> SELECT cv.first\_name, cv.last\_name, p.amount  
    -> FROM customer\_vw cv  
    ->   INNER JOIN payment p  
    ->   ON cv.customer\_id = p.customer\_id  
    -> WHERE p.amount >= 11;  
+------------+-----------+--------+  
| first\_name | last\_name | amount |  
+------------+-----------+--------+  
| KAREN      | JACKSON   |  11.99 |  
| VICTORIA   | GIBSON    |  11.99 |  
| VANESSA    | SIMS      |  11.99 |  
| ALMA       | AUSTIN    |  11.99 |  
| ROSEMARY   | SCHMIDT   |  11.99 |  
| TANYA      | GILBERT   |  11.99 |  
| RICHARD    | MCCRARY   |  11.99 |  
| NICHOLAS   | BARFIELD  |  11.99 |  
| KENT       | ARSENAULT |  11.99 |  
| TERRANCE   | ROUSH     |  11.99 |  
+------------+-----------+--------+  
10 rows in set (0.01 sec)

This query joins the customer\_vw view to the payment table in order to find customers who have paid $11 or more for a film rental.

# Why Use Views?

In the previous section, I demonstrated a simple view whose sole purpose was to mask the contents of the customer.email column. While views are often employed for this purpose, there are many reasons for using views, as detailed in the following subsections.

## Data Security

If you create a table and allow users to query it, they will be able to access every column and every row in the table. As I pointed out earlier, however, your table may include some columns that contain sensitive data, such as identification numbers or credit card numbers; not only is it a bad idea to expose such data to all users, but also it might violate your company’s privacy policies, or even state or federal laws, to do so.

The best approach for these situations is to keep the table private (i.e., don’t grant select permission to any users) and then to create one or more views that either omit or obscure (such as the '\*\*\*\*\*' approach taken with the customer\_vw.email column) the sensitive columns. You may also constrain which rows a set of users may access by adding a where clause to your view definition. For example, the next view definition excludes inactive customers:

CREATE VIEW active\_customer\_vw  
 (customer\_id,  
  first\_name,  
  last\_name,  
  email  
 )  
AS  
SELECT  
  customer\_id,  
  first\_name,  
  last\_name,  
  concat(substr(email,1,2), '\*\*\*\*\*', substr(email, -4)) email  
FROM customer  
WHERE active = 1  
;

If you provide this view to your marketing department, they will be able to avoid sending information to inactive customers, because the condition in the view’s where clause will always be included in their queries.

##### Note

Oracle Database users have another option for securing both rows and columns of a table: Virtual Private Database (VPD). VPD allows you to attach policies to your tables, after which the server will modify a user’s query as necessary to enforce the policies. For example, if you enact a policy that members of the sales and marketing departments can see only active customers, then the condition active = 1 will be added to all of their queries against the customer table.

## Data Aggregation

Reporting applications generally require aggregated data, and views are a great way to make it appear as though data is being preaggregated and stored in the database. As an example, let’s say that an application generates a report each month showing the total sales for each film category so that the managers can decide what new films to add to inventory. Rather than allowing the application developers to write queries against the base tables, you could provide them with the following view:[1](#1_This_view_definition_is_includ)

CREATE VIEW sales\_by\_film\_category  
AS  
SELECT  
  c.name AS category,  
  SUM(p.amount) AS total\_sales  
FROM payment AS p  
  INNER JOIN rental AS r ON p.rental\_id = r.rental\_id  
  INNER JOIN inventory AS i ON r.inventory\_id = i.inventory\_id  
  INNER JOIN film AS f ON i.film\_id = f.film\_id  
  INNER JOIN film\_category AS fc ON f.film\_id = fc.film\_id  
  INNER JOIN category AS c ON fc.category\_id = c.category\_id  
GROUP BY c.name  
ORDER BY total\_sales DESC;

Using this approach gives you a great deal of flexibility as a database designer. If you decide at some point in the future that query performance would improve dramatically if the data were preaggregated in a table rather than summed using a view, you could create a film\_category\_sales table, load it with aggregated data, and modify the sales\_by\_film\_category view definition to retrieve data from this table. Afterward, all queries that use the sales\_by\_film\_category view will retrieve data from the new film\_category\_sales table, meaning that users will see a performance improvement without needing to modify their queries.

## Hiding Complexity

One of the most common reasons for deploying views is to shield end users from complexity. For example, let’s say that a report is created each month showing information about all of the films, along with the film category, the number of actors appearing in the film, the total number of copies in inventory, and the number of rentals for each film. Rather than expecting the report designer to navigate six different tables to gather the necessary data, you could provide a view that looks as follows:

CREATE VIEW film\_stats  
AS  
SELECT f.film\_id, f.title, f.description, f.rating,  
 (SELECT c.name  
  FROM category c  
    INNER JOIN film\_category fc  
    ON c.category\_id = fc.category\_id  
  WHERE fc.film\_id = f.film\_id) category\_name,  
 (SELECT count(\*)  
  FROM film\_actor fa  
  WHERE fa.film\_id = f.film\_id  
 ) num\_actors,  
 (SELECT count(\*)  
  FROM inventory i  
  WHERE i.film\_id = f.film\_id  
 ) inventory\_cnt,  
 (SELECT count(\*)  
  FROM inventory i  
    INNER JOIN rental r  
    ON i.inventory\_id = r.inventory\_id  
  WHERE i.film\_id = f.film\_id  
 ) num\_rentals  
FROM film f;

This view definition is interesting because even though data from six different tables can be retrieved through the view, the from clause of the query has only one table (film). Data from the other five tables is generated using scalar subqueries. If someone uses this view but does not reference the category\_name, num\_actors, inventory\_cnt, or num\_rentals column, then none of the subqueries will be executed. This approach allows the view to be used for supplying descriptive information from the film table without unnecessarily joining five other tables.

## Joining Partitioned Data

Some database designs break large tables into multiple pieces in order to improve performance. For example, if the payment table became large, the designers may decide to break it into two tables: payment\_current, which holds the latest six months of data, and payment\_historic, which holds all data up to six months ago. If a customer wants to see all the payments for a particular customer, you would need to query both tables. By creating a view that queries both tables and combines the results together, however, you can make it look like all payment data is stored in a single table. Here’s the view definition:

CREATE VIEW payment\_all  
 (payment\_id,  
  customer\_id,  
  staff\_id,  
  rental\_id,  
  amount,  
  payment\_date,  
  last\_update  
 )  
AS  
SELECT payment\_id, customer\_id, staff\_id, rental\_id,  
  amount, payment\_date, last\_update  
FROM payment\_historic  
UNION ALL  
SELECT payment\_id, customer\_id, staff\_id, rental\_id,  
  amount, payment\_date, last\_update  
FROM payment\_current;

Using a view in this case is a good idea because it allows the designers to change the structure of the underlying data without the need to force all database users to modify their queries.

# Updatable Views

If you provide users with a set of views to use for data retrieval, what should you do if the users also need to modify the same data? It might seem a bit strange, for example, to force the users to retrieve data using a view but then allow them to directly modify the underlying table using update or insert statements. For this purpose, MySQL, Oracle Database, and SQL Server all allow you to modify data through a view, as long as you abide by certain restrictions. In the case of MySQL, a view is updatable if the following conditions are met:

* No aggregate functions are used (max(), min(), avg(), etc.).
* The view does not employ group by or having clauses.
* No subqueries exist in the select or from clause, and any subqueries in the where clause do not refer to tables in the from clause.
* The view does not utilize union, union all, or distinct.
* The from clause includes at least one table or updatable view.
* The from clause uses only inner joins if there is more than one table or view.

To demonstrate the utility of updatable views, it might be best to start with a simple view definition and then to move to a more complex view.

## Updating Simple Views

The view at the beginning of the chapter is about as simple as it gets, so let’s start there:

CREATE VIEW customer\_vw  
 (customer\_id,  
  first\_name,  
  last\_name,  
  email  
 )  
AS  
SELECT  
  customer\_id,  
  first\_name,  
  last\_name,  
  concat(substr(email,1,2), '\*\*\*\*\*', substr(email, -4)) email  
FROM customer;

The customer\_vw view queries a single table, and only one of the four columns is derived via an expression. This view definition doesn’t violate any of the restrictions listed earlier, so you can use it to modify data in the customer table. Let’s use the view to update Mary Smith’s last name to Smith-Allen:

mysql> UPDATE customer\_vw  
    -> SET last\_name = 'SMITH-ALLEN'  
    -> WHERE customer\_id = 1;  
Query OK, 1 row affected (0.11 sec)  
Rows matched: 1  Changed: 1  Warnings: 0

As you can see, the statement claims to have modified one row, but let’s check the underlying customer table just to be sure:

mysql> SELECT first\_name, last\_name, email  
    -> FROM customer  
    -> WHERE customer\_id = 1;  
+------------+-------------+-------------------------------+  
| first\_name | last\_name   | email                         |  
+------------+-------------+-------------------------------+  
| MARY       |   
SMITH-ALLEN  
 | MARY.SMITH@sakilacustomer.org |  
+------------+-------------+-------------------------------+  
1 row in set (0.00 sec)

While you can modify most of the columns in the view in this fashion, you will not be able to modify the email column, since it is derived from an expression:

mysql> UPDATE customer\_vw  
    -> SET email = 'MARY.SMITH-ALLEN@sakilacustomer.org'  
    -> WHERE customer\_id = 1;  
ERROR 1348 (HY000):   
Column 'email' is not updatable

In this case, it may not be a bad thing, since the main reason for creating the view was to obscure the email addresses.

If you want to insert data using the customer\_vw view, you are out of luck; views that contain derived columns cannot be used for inserting data, even if the derived columns are not included in the statement. For example, the next statement attempts to populate only the customer\_id, first\_name, and last\_name columns using the customer\_vw view:

mysql> INSERT INTO customer\_vw  
    ->  (customer\_id,  
    ->   first\_name,  
    ->   last\_name)  
    -> VALUES (99999,'ROBERT','SIMPSON');  
ERROR 1471 (HY000): The target table customer\_vw of the INSERT   
is not insertable-into

Now that you have seen the limitations of simple views, the next section will demonstrate the use of a view that joins multiple tables.

## Updating Complex Views

While single-table views are certainly common, many of the views that you come across will include multiple tables in the from clause of the underlying query. The next view, for example, joins the customer, address, city, and country tables so that all the data for customers can be easily queried:

CREATE VIEW customer\_details  
AS  
SELECT c.customer\_id,  
  c.store\_id,  
  c.first\_name,  
  c.last\_name,  
  c.address\_id,  
  c.active,  
  c.create\_date,  
  a.address,  
  ct.city,  
  cn.country,  
  a.postal\_code  
FROM customer c  
  INNER JOIN address a  
  ON c.address\_id = a.address\_id  
  INNER JOIN city ct  
  ON a.city\_id = ct.city\_id  
  INNER JOIN country cn  
  ON ct.country\_id = cn.country\_id;

You may use this view to update data in either the customer or address table, as the following statements demonstrate:

mysql> UPDATE customer\_details  
    -> SET last\_name = 'SMITH-ALLEN', active = 0  
    -> WHERE customer\_id = 1;  
Query OK, 1 row affected (0.10 sec)  
Rows matched: 1  Changed: 1  Warnings: 0  
  
mysql> UPDATE customer\_details  
    -> SET address = '999 Mockingbird Lane'  
    -> WHERE customer\_id = 1;  
Query OK, 1 row affected (0.06 sec)  
Rows matched: 1  Changed: 1  Warnings: 0

The first statement modifies the customer.last\_name and customer.active columns, whereas the second statement modifies the address.address column. You might be wondering what happens if you try to update columns from both tables in a single statement, so let’s find out:

mysql> UPDATE customer\_details  
    -> SET last\_name = 'SMITH-ALLEN',  
    ->   active = 0,  
    ->   address = '999 Mockingbird Lane'  
    -> WHERE customer\_id = 1;  
ERROR 1393 (HY000): Can not modify more than one base table   
  through a join view 'sakila.customer\_details'

As you can see, you are allowed to modify both of the underlying tables separately, but not within a single statement. Next, let’s try to insert data into both tables for some new customers (customer\_id = 9998 and 9999):

mysql> INSERT INTO customer\_details  
    ->  (customer\_id, store\_id, first\_name, last\_name,  
    ->   address\_id, active, create\_date)  
    -> VALUES (9998, 1, 'BRIAN', 'SALAZAR', 5, 1, now());  
Query OK, 1 row affected (0.23 sec)

This statement, which only populates columns from the customer table, works fine. Let’s see what happens if we expand the column list to also include a column from the address table:

mysql> INSERT INTO customer\_details  
    ->  (customer\_id, store\_id, first\_name, last\_name,  
    ->   address\_id, active, create\_date,   
address  
)  
    -> VALUES (9999, 2, 'THOMAS', 'BISHOP', 7, 1, now(),  
    ->    
'999 Mockingbird Lane'  
);  
ERROR 1393 (HY000): Can not modify more than one base table   
  through a join view 'sakila.customer\_details'

This version, which includes columns spanning two different tables, raises an exception. In order to insert data through a complex view, you would need to know from where each column is sourced. Since many views are created to hide complexity from end users, this seems to defeat the purpose if the users need to have explicit knowledge of the view definition.

##### Note

Oracle Database and SQL Server also allow data to be inserted and updated through views, but, like MySQL, there are many restrictions. If you are willing to write some PL/SQL or Transact-SQL, however, you can use a feature called instead-of triggers, which allows you to essentially intercept insert, update, and delete statements against a view and write custom code to incorporate the changes. Without this type of feature, there are usually too many restrictions to make updating through views a feasible strategy for nontrivial applications.

# Test Your Knowledge

Test your understanding of views by working through the following exercises. When you’re done, compare your solutions with those in [Appendix B](#Appendix_B__Solutions_to_Exercis_2).

## Exercise 14-1

Create a view definition that can be used by the following query to generate the given results:

SELECT title, category\_name, first\_name, last\_name  
FROM   
film\_ctgry\_actor  
  
WHERE last\_name = 'FAWCETT';   
  
+---------------------+---------------+------------+-----------+  
| title               | category\_name | first\_name | last\_name |  
+---------------------+---------------+------------+-----------+  
| ACE GOLDFINGER      | Horror        | BOB        | FAWCETT   |  
| ADAPTATION HOLES    | Documentary   | BOB        | FAWCETT   |  
| CHINATOWN GLADIATOR | New           | BOB        | FAWCETT   |  
| CIRCUS YOUTH        | Children      | BOB        | FAWCETT   |  
| CONTROL ANTHEM      | Comedy        | BOB        | FAWCETT   |  
| DARES PLUTO         | Animation     | BOB        | FAWCETT   |  
| DARN FORRESTER      | Action        | BOB        | FAWCETT   |  
| DAZED PUNK          | Games         | BOB        | FAWCETT   |  
| DYNAMITE TARZAN     | Classics      | BOB        | FAWCETT   |  
| HATE HANDICAP       | Comedy        | BOB        | FAWCETT   |  
| HOMICIDE PEACH      | Family        | BOB        | FAWCETT   |  
| JACKET FRISCO       | Drama         | BOB        | FAWCETT   |  
| JUMANJI BLADE       | New           | BOB        | FAWCETT   |  
| LAWLESS VISION      | Animation     | BOB        | FAWCETT   |  
| LEATHERNECKS DWARFS | Travel        | BOB        | FAWCETT   |  
| OSCAR GOLD          | Animation     | BOB        | FAWCETT   |  
| PELICAN COMFORTS    | Documentary   | BOB        | FAWCETT   |  
| PERSONAL LADYBUGS   | Music         | BOB        | FAWCETT   |  
| RAGING AIRPLANE     | Sci-Fi        | BOB        | FAWCETT   |  
| RUN PACIFIC         | New           | BOB        | FAWCETT   |  
| RUNNER MADIGAN      | Music         | BOB        | FAWCETT   |  
| SADDLE ANTITRUST    | Comedy        | BOB        | FAWCETT   |  
| SCORPION APOLLO     | Drama         | BOB        | FAWCETT   |  
| SHAWSHANK BUBBLE    | Travel        | BOB        | FAWCETT   |  
| TAXI KICK           | Music         | BOB        | FAWCETT   |  
| BERETS AGENT        | Action        | JULIA      | FAWCETT   |  
| BOILED DARES        | Travel        | JULIA      | FAWCETT   |  
| CHISUM BEHAVIOR     | Family        | JULIA      | FAWCETT   |  
| CLOSER BANG         | Comedy        | JULIA      | FAWCETT   |  
| DAY UNFAITHFUL      | New           | JULIA      | FAWCETT   |  
| HOPE TOOTSIE        | Classics      | JULIA      | FAWCETT   |  
| LUKE MUMMY          | Animation     | JULIA      | FAWCETT   |  
| MULAN MOON          | Comedy        | JULIA      | FAWCETT   |  
| OPUS ICE            | Foreign       | JULIA      | FAWCETT   |  
| POLLOCK DELIVERANCE | Foreign       | JULIA      | FAWCETT   |  
| RIDGEMONT SUBMARINE | New           | JULIA      | FAWCETT   |  
| SHANGHAI TYCOON     | Travel        | JULIA      | FAWCETT   |  
| SHAWSHANK BUBBLE    | Travel        | JULIA      | FAWCETT   |  
| THEORY MERMAID      | Animation     | JULIA      | FAWCETT   |  
| WAIT CIDER          | Animation     | JULIA      | FAWCETT   |  
+---------------------+---------------+------------+-----------+  
40 rows in set (0.00 sec)

## Exercise 14-2

The film rental company manager would like to have a report that includes the name of every country, along with the total payments for all customers who live in each country. Generate a view definition that queries the country table and uses a scalar subquery to calculate a value for a column named tot\_payments.

[1](#1_1) This view definition is included in the Sakila sample database, along with six others, several of which will be used in upcoming examples.

# Chapter 15. Metadata

Along with storing all of the data that various users insert into a database, a database server also needs to store information about all of the database objects (tables, views, indexes, etc.) that were created to store this data. The database server stores this information, not surprisingly, in a database. This chapter discusses how and where this information, known as metadata, is stored, how you can access it, and how you can use it to build flexible systems.

# Data About Data

Metadata is essentially data about data. Every time you create a database object, the database server needs to record various pieces of information. For example, if you were to create a table with multiple columns, a primary key constraint, three indexes, and a foreign key constraint, the database server would need to store all the following information:

* Table name
* Table storage information (tablespace, initial size, etc.)
* Storage engine
* Column names
* Column data types
* Default column values
* not null column constraints
* Primary key columns
* Primary key name
* Name of primary key index
* Index names
* Index types (B-tree, bitmap)
* Indexed columns
* Index column sort order (ascending or descending)
* Index storage information
* Foreign key name
* Foreign key columns
* Associated table/columns for foreign keys

This data is collectively known as the data dictionary or system catalog. The database server needs to store this data persistently, and it needs to be able to quickly retrieve this data in order to verify and execute SQL statements. Additionally, the database server must safeguard this data so that it can be modified only via an appropriate mechanism, such as the alter table statement.

While standards exist for the exchange of metadata between different servers, every database server uses a different mechanism to publish metadata, such as:

* A set of views, such as Oracle Database’s user\_tables and all\_constraints views
* A set of system-stored procedures, such as SQL Server’s sp\_tables procedure or Oracle Database’s dbms\_metadata package
* A special database, such as MySQL’s information\_schema database

Along with SQL Server’s system-stored procedures, which are a vestige of its Sybase lineage, SQL Server also includes a special schema called information\_schema that is provided automatically within each database. Both MySQL and SQL Server provide this interface to conform with the ANSI SQL:2003 standard. The remainder of this chapter discusses the information\_schema objects that are available in MySQL and SQL Server.

# information\_schema

All of the objects available within the information\_schema database (or schema, in the case of SQL Server) are views. Unlike the describe utility, which I used in several chapters of this book as a way to show the structure of various tables and views, the views within information\_schema can be queried and, thus, used programmatically (more on this later in the chapter). Here’s an example that demonstrates how to retrieve the names of all of the tables in the Sakila database:

mysql> SELECT table\_name, table\_type  
    -> FROM information\_schema.tables  
    -> WHERE table\_schema = 'sakila'  
    -> ORDER BY 1;  
+----------------------------+------------+  
| TABLE\_NAME                 | TABLE\_TYPE |  
+----------------------------+------------+  
| actor                      | BASE TABLE |  
| actor\_info                 | VIEW       |  
| address                    | BASE TABLE |  
| category                   | BASE TABLE |  
| city                       | BASE TABLE |  
| country                    | BASE TABLE |  
| customer                   | BASE TABLE |  
| customer\_list              | VIEW       |  
| film                       | BASE TABLE |  
| film\_actor                 | BASE TABLE |  
| film\_category              | BASE TABLE |  
| film\_list                  | VIEW       |  
| film\_text                  | BASE TABLE |  
| inventory                  | BASE TABLE |  
| language                   | BASE TABLE |  
| nicer\_but\_slower\_film\_list | VIEW       |  
| payment                    | BASE TABLE |  
| rental                     | BASE TABLE |  
| sales\_by\_film\_category     | VIEW       |  
| sales\_by\_store             | VIEW       |  
| staff                      | BASE TABLE |  
| staff\_list                 | VIEW       |  
| store                      | BASE TABLE |  
+----------------------------+------------+  
23 rows in set (0.00 sec)

As you can see, the information\_schema.tables view includes both tables and views; if you want to exclude the views, simply add another condition to the where clause:

mysql> SELECT table\_name, table\_type  
    -> FROM information\_schema.tables  
    -> WHERE table\_schema = 'sakila'  
    ->     
AND table\_type = 'BASE TABLE'  
  
    -> ORDER BY 1;  
+---------------+------------+  
| TABLE\_NAME    | TABLE\_TYPE |  
+---------------+------------+  
| actor         | BASE TABLE |  
| address       | BASE TABLE |  
| category      | BASE TABLE |  
| city          | BASE TABLE |  
| country       | BASE TABLE |  
| customer      | BASE TABLE |  
| film          | BASE TABLE |  
| film\_actor    | BASE TABLE |  
| film\_category | BASE TABLE |  
| film\_text     | BASE TABLE |  
| inventory     | BASE TABLE |  
| language      | BASE TABLE |  
| payment       | BASE TABLE |  
| rental        | BASE TABLE |  
| staff         | BASE TABLE |  
| store         | BASE TABLE |  
+---------------+------------+  
16 rows in set (0.00 sec)

If you are only interested in information about views, you can query information\_schema.views. Along with the view names, you can retrieve additional information, such as a flag that shows whether a view is updatable:

mysql> SELECT table\_name, is\_updatable  
    -> FROM information\_schema.views  
    -> WHERE table\_schema = 'sakila'  
    -> ORDER BY 1;  
+----------------------------+--------------+  
| TABLE\_NAME                 | IS\_UPDATABLE |  
+----------------------------+--------------+  
| actor\_info                 | NO           |  
| customer\_list              | YES          |  
| film\_list                  | NO           |  
| nicer\_but\_slower\_film\_list | NO           |  
| sales\_by\_film\_category     | NO           |  
| sales\_by\_store             | NO           |  
| staff\_list                 | YES          |  
+----------------------------+--------------+  
7 rows in set (0.00 sec)

Column information for both tables and views is available via the columns view. The following query shows column information for the film table:

mysql> SELECT column\_name, data\_type,   
  -> character\_maximum\_length char\_max\_len,  
    ->   numeric\_precision num\_prcsn, numeric\_scale num\_scale  
    -> FROM information\_schema.columns  
    -> WHERE table\_schema = 'sakila' AND table\_name = 'film'  
    -> ORDER BY ordinal\_position;  
+----------------------+-----------+--------------+-----------+-----------+  
| COLUMN\_NAME          | DATA\_TYPE | char\_max\_len | num\_prcsn | num\_scale |  
+----------------------+-----------+--------------+-----------+-----------+  
| film\_id              | smallint  |         NULL |         5 |         0 |  
| title                | varchar   |          255 |      NULL |      NULL |  
| description          | text      |        65535 |      NULL |      NULL |  
| release\_year         | year      |         NULL |      NULL |      NULL |  
| language\_id          | tinyint   |         NULL |         3 |         0 |  
| original\_language\_id | tinyint   |         NULL |         3 |         0 |  
| rental\_duration      | tinyint   |         NULL |         3 |         0 |  
| rental\_rate          | decimal   |         NULL |         4 |         2 |  
| length               | smallint  |         NULL |         5 |         0 |  
| replacement\_cost     | decimal   |         NULL |         5 |         2 |  
| rating               | enum      |            5 |      NULL |      NULL |  
| special\_features     | set       |           54 |      NULL |      NULL |  
| last\_update          | timestamp |         NULL |      NULL |      NULL |  
+----------------------+-----------+--------------+-----------+-----------+  
13 rows in set (0.00 sec)

The ordinal\_position column is included merely as a means to retrieve the columns in the order in which they were added to the table.

You can retrieve information about a table’s indexes via the information\_schema.statistics view as demonstrated by the following query, which retrieves information for the indexes built on the rental table:

mysql> SELECT index\_name, non\_unique, seq\_in\_index, column\_name  
    -> FROM information\_schema.statistics  
    -> WHERE table\_schema = 'sakila' AND table\_name = 'rental'  
    -> ORDER BY 1, 3;  
+---------------------+------------+--------------+--------------+  
| INDEX\_NAME          | NON\_UNIQUE | SEQ\_IN\_INDEX | COLUMN\_NAME  |  
+---------------------+------------+--------------+--------------+  
| idx\_fk\_customer\_id  |          1 |            1 | customer\_id  |  
| idx\_fk\_inventory\_id |          1 |            1 | inventory\_id |  
| idx\_fk\_staff\_id     |          1 |            1 | staff\_id     |  
| PRIMARY             |          0 |            1 | rental\_id    |  
| rental\_date         |          0 |            1 | rental\_date  |  
| rental\_date         |          0 |            2 | inventory\_id |  
| rental\_date         |          0 |            3 | customer\_id  |  
+---------------------+------------+--------------+--------------+  
7 rows in set (0.02 sec)

The rental table has a total of five indexes, one of which has three columns (rental\_date) and one of which is a unique index (PRIMARY) used for the primary key constraint.

You can retrieve the different types of constraints (foreign key, primary key, unique) that have been created via the information\_schema.table\_constraints view. Here’s a query that retrieves all of the constraints in the Sakila schema:

mysql> SELECT constraint\_name, table\_name, constraint\_type  
    -> FROM information\_schema.table\_constraints  
    -> WHERE table\_schema = 'sakila'  
    -> ORDER BY 3,1;  
+---------------------------+---------------+-----------------+  
| constraint\_name           | table\_name    | constraint\_type |  
+---------------------------+---------------+-----------------+  
| fk\_address\_city           | address       | FOREIGN KEY     |  
| fk\_city\_country           | city          | FOREIGN KEY     |  
| fk\_customer\_address       | customer      | FOREIGN KEY     |  
| fk\_customer\_store         | customer      | FOREIGN KEY     |  
| fk\_film\_actor\_actor       | film\_actor    | FOREIGN KEY     |  
| fk\_film\_actor\_film        | film\_actor    | FOREIGN KEY     |  
| fk\_film\_category\_category | film\_category | FOREIGN KEY     |  
| fk\_film\_category\_film     | film\_category | FOREIGN KEY     |  
| fk\_film\_language          | film          | FOREIGN KEY     |  
| fk\_film\_language\_original | film          | FOREIGN KEY     |  
| fk\_inventory\_film         | inventory     | FOREIGN KEY     |  
| fk\_inventory\_store        | inventory     | FOREIGN KEY     |  
| fk\_payment\_customer       | payment       | FOREIGN KEY     |  
| fk\_payment\_rental         | payment       | FOREIGN KEY     |  
| fk\_payment\_staff          | payment       | FOREIGN KEY     |  
| fk\_rental\_customer        | rental        | FOREIGN KEY     |  
| fk\_rental\_inventory       | rental        | FOREIGN KEY     |  
| fk\_rental\_staff           | rental        | FOREIGN KEY     |  
| fk\_staff\_address          | staff         | FOREIGN KEY     |  
| fk\_staff\_store            | staff         | FOREIGN KEY     |  
| fk\_store\_address          | store         | FOREIGN KEY     |  
| fk\_store\_staff            | store         | FOREIGN KEY     |  
| PRIMARY                   | film          | PRIMARY KEY     |  
| PRIMARY                   | film\_actor    | PRIMARY KEY     |  
| PRIMARY                   | staff         | PRIMARY KEY     |  
| PRIMARY                   | film\_category | PRIMARY KEY     |  
| PRIMARY                   | store         | PRIMARY KEY     |  
| PRIMARY                   | actor         | PRIMARY KEY     |  
| PRIMARY                   | film\_text     | PRIMARY KEY     |  
| PRIMARY                   | address       | PRIMARY KEY     |  
| PRIMARY                   | inventory     | PRIMARY KEY     |  
| PRIMARY                   | customer      | PRIMARY KEY     |  
| PRIMARY                   | category      | PRIMARY KEY     |  
| PRIMARY                   | language      | PRIMARY KEY     |  
| PRIMARY                   | city          | PRIMARY KEY     |  
| PRIMARY                   | payment       | PRIMARY KEY     |  
| PRIMARY                   | country       | PRIMARY KEY     |  
| PRIMARY                   | rental        | PRIMARY KEY     |  
| idx\_email                 | customer      | UNIQUE          |  
| idx\_unique\_manager        | store         | UNIQUE          |  
| rental\_date               | rental        | UNIQUE          |  
+---------------------------+---------------+-----------------+  
41 rows in set (0.02 sec)

[Table 15-1](#Table_15_1__information_schema_v) shows many of the information\_schema views that are available in MySQL version 8.0.

|  |  |
| --- | --- |
| Table 15-1. information\_schema views  View name | Provides information about... |

|  |  |
| --- | --- |
| schemata | Databases |

|  |  |
| --- | --- |
| tables | Tables and views |

|  |  |
| --- | --- |
| columns | Columns of tables and views |

|  |  |
| --- | --- |
| statistics | Indexes |

|  |  |
| --- | --- |
| user\_privileges | Who has privileges on which schema objects |

|  |  |
| --- | --- |
| schema\_privileges | Who has privileges on which databases |

|  |  |
| --- | --- |
| table\_privileges | Who has privileges on which tables |

|  |  |
| --- | --- |
| column\_privileges | Who has privileges on which columns of which tables |

|  |  |
| --- | --- |
| character\_sets | What character sets are available |

|  |  |
| --- | --- |
| collations | What collations are available for which character sets |

|  |  |
| --- | --- |
| collation\_character\_set\_applicability | Which character sets are available for which collation |

|  |  |
| --- | --- |
| table\_constraints | The unique, foreign key, and primary key constraints |

|  |  |
| --- | --- |
| key\_column\_usage | The constraints associated with each key column |

|  |  |
| --- | --- |
| routines | Stored routines (procedures and functions) |

|  |  |
| --- | --- |
| views | Views |

|  |  |
| --- | --- |
| triggers | Table triggers |

|  |  |
| --- | --- |
| plugins | Server plug-ins |

|  |  |
| --- | --- |
| engines | Available storage engines |

|  |  |
| --- | --- |
| partitions | Table partitions |

|  |  |
| --- | --- |
| events | Scheduled events |

|  |  |
| --- | --- |
| processlist | Running processes |

|  |  |
| --- | --- |
| referential\_constraints | Foreign keys |

|  |  |
| --- | --- |
| parameters | Stored procedure and function parameters |

|  |  |
| --- | --- |
| profiling | User profiling information |

While some of these views, such as engines, events, and plugins, are specific to MySQL, many of these views are available in SQL Server as well. If you are using Oracle Database, please consult the online [Oracle Database Reference Guide](https://oreil.ly/qV7sE) for information about the user\_, all\_, and dba\_ views, as well as the dbms\_metadata package.

# Working with Metadata

As I mentioned earlier, having the ability to retrieve information about your schema objects via SQL queries opens up some interesting possibilities. This section shows several ways in which you can make use of metadata in your applications.

## Schema Generation Scripts

While some project teams include a full-time database designer who oversees the design and implementation of the database, many projects take the “design-by-committee” approach, allowing multiple people to create database objects. After several weeks or months of development, you may need to generate a script that will create the various tables, indexes, views, and so on, that the team has deployed. Although a variety of tools and utilities will generate these types of scripts for you, you can also query the information\_schema views and generate the script yourself.

As an example, let’s build a script that will create the sakila.category table. Here’s the command used to build the table, which I extracted from the script used to build the example database:

CREATE TABLE category (  
  category\_id TINYINT UNSIGNED NOT NULL AUTO\_INCREMENT,  
  name VARCHAR(25) NOT NULL,  
  last\_update TIMESTAMP NOT NULL DEFAULT CURRENT\_TIMESTAMP   
  ON UPDATE CURRENT\_TIMESTAMP,  
  PRIMARY KEY  (category\_id)  
)ENGINE=InnoDB DEFAULT CHARSET=utf8;

Although it would certainly be easier to generate the script with the use of a procedural language (e.g., Transact-SQL or Java), since this is a book about SQL, I’m going to write a single query that will generate the create table statement. The first step is to query the information\_schema.columns table to retrieve information about the columns in the table:

mysql> SELECT 'CREATE TABLE category (' create\_table\_statement  
    -> UNION ALL  
    -> SELECT cols.txt  
    -> FROM  
    ->  (SELECT concat('  ',column\_name, ' ', column\_type,  
    ->    CASE  
    ->      WHEN is\_nullable = 'NO' THEN ' not null'  
    ->      ELSE ''  
    ->    END,  
    ->    CASE  
  ->     WHEN extra IS NOT NULL AND extra LIKE 'DEFAULT\_GENERATED%'  
    -> THEN concat(' DEFAULT ',column\_default,substr(extra,18))  
    ->      WHEN extra IS NOT NULL THEN concat(' ', extra)  
    ->      ELSE ''  
    ->    END,  
    ->    ',') txt  
    ->   FROM information\_schema.columns  
    ->   WHERE table\_schema = 'sakila' AND table\_name = 'category'  
    ->   ORDER BY ordinal\_position  
    ->  ) cols  
    -> UNION ALL  
    -> SELECT ')';  
+-----------------------------------------------------------------------+  
| create\_table\_statement                                                |  
+-----------------------------------------------------------------------+  
| CREATE TABLE category (                                               |  
|   category\_id tinyint(3) unsigned not null auto\_increment,            |  
|   name varchar(25) not null ,                                         |  
|   last\_update timestamp not null DEFAULT CURRENT\_TIMESTAMP |  
| on update CURRENT\_TIMESTAMP, |  
| )                                                                     |  
+-----------------------------------------------------------------------+  
5 rows in set (0.00 sec)

Well, that got us pretty close; we just need to add queries against the table\_constraints and key\_column\_usage views to retrieve information about the primary key constraint:

mysql> SELECT 'CREATE TABLE category (' create\_table\_statement  
    -> UNION ALL  
    -> SELECT cols.txt  
    -> FROM  
    ->  (SELECT concat('  ',column\_name, ' ', column\_type,  
    ->    CASE  
    ->      WHEN is\_nullable = 'NO' THEN ' not null'  
    ->      ELSE ''  
    ->    END,  
    ->    CASE  
    ->      WHEN extra IS NOT NULL AND extra LIKE 'DEFAULT\_GENERATED%'  
    ->        THEN concat(' DEFAULT ',column\_default,substr(extra,18))  
    ->      WHEN extra IS NOT NULL THEN concat(' ', extra)  
    ->      ELSE ''  
    ->    END,  
    ->    ',') txt  
    ->   FROM information\_schema.columns  
    ->   WHERE table\_schema = 'sakila' AND table\_name = 'category'  
    ->   ORDER BY ordinal\_position  
    ->  ) cols  
    -> UNION ALL  
    -> SELECT concat('  constraint primary key (')  
    -> FROM information\_schema.table\_constraints  
    -> WHERE table\_schema = 'sakila' AND table\_name = 'category'  
    ->   AND constraint\_type = 'PRIMARY KEY'  
    -> UNION ALL  
    -> SELECT cols.txt  
    -> FROM  
    ->  (SELECT concat(CASE WHEN ordinal\_position > 1 THEN '   ,'  
    ->     ELSE '    ' END, column\_name) txt  
    ->   FROM information\_schema.key\_column\_usage  
    ->   WHERE table\_schema = 'sakila' AND table\_name = 'category'  
    ->     AND constraint\_name = 'PRIMARY'  
    ->   ORDER BY ordinal\_position  
    ->  ) cols  
    -> UNION ALL  
    -> SELECT '  )'  
    -> UNION ALL  
    -> SELECT ')';  
+-----------------------------------------------------------------------+  
| create\_table\_statement                                                |  
+-----------------------------------------------------------------------+  
| CREATE TABLE category (                                               |  
|   category\_id tinyint(3) unsigned not null auto\_increment,            |  
|   name varchar(25) not null ,                                         |  
|   last\_update timestamp not null DEFAULT CURRENT\_TIMESTAMP |  
| on update CURRENT\_TIMESTAMP, |  
|   constraint primary key (                                      |  
|     category\_id                                                       |  
|   )                                                                   |  
| )                                                                     |  
+-----------------------------------------------------------------------+  
8 rows in set (0.02 sec)

To see whether the statement is properly formed, I’ll paste the query output into the mysql tool (I’ve changed the table name to category2 so that it won’t step on our existing table):

mysql> CREATE TABLE category2 (  
    ->   category\_id tinyint(3) unsigned not null auto\_increment,  
    ->   name varchar(25) not null ,  
    ->   last\_update timestamp not null DEFAULT CURRENT\_TIMESTAMP   
  -> on update CURRENT\_TIMESTAMP,  
    ->   constraint primary key (  
    ->     category\_id  
    ->   )  
    -> );  
Query OK, 0 rows affected (0.61 sec)

The statement executed without errors, and there is now a category2 table in the Sakila database. For the query to generate a well-formed create table statement for any table, more work is required (such as handling indexes and foreign key constraints), but I’ll leave that as an exercise.

##### Note

If you are using a graphical development tool such as Toad, Oracle SQL Developer, or MySQL Workbench, you will be able to easily generate these types of scripts without writing your own queries. But, just in case you are stuck on a deserted island with only the MySQL command-line client...

## Deployment Verification

Many organizations allow for database maintenance windows, wherein existing database objects may be administered (such as adding/dropping partitions) and new schema objects and code can be deployed. After the deployment scripts have been run, it’s a good idea to run a verification script to ensure that the new schema objects are in place with the appropriate columns, indexes, primary keys, and so forth. Here’s a query that returns the number of columns, number of indexes, and number of primary key constraints (0 or 1) for each table in the Sakila schema:

mysql> SELECT tbl.table\_name,  
    ->  (SELECT count(\*) FROM information\_schema.columns clm  
    ->   WHERE clm.table\_schema = tbl.table\_schema  
    ->     AND clm.table\_name = tbl.table\_name) num\_columns,  
    ->  (SELECT count(\*) FROM information\_schema.statistics sta  
    ->   WHERE sta.table\_schema = tbl.table\_schema  
    ->     AND sta.table\_name = tbl.table\_name) num\_indexes,  
    ->  (SELECT count(\*) FROM information\_schema.table\_constraints tc  
    ->   WHERE tc.table\_schema = tbl.table\_schema  
    ->     AND tc.table\_name = tbl.table\_name  
    ->     AND tc.constraint\_type = 'PRIMARY KEY') num\_primary\_keys  
    -> FROM information\_schema.tables tbl  
    -> WHERE tbl.table\_schema = 'sakila' AND tbl.table\_type = 'BASE TABLE'  
    -> ORDER BY 1;  
+---------------+-------------+-------------+------------------+  
| TABLE\_NAME    | num\_columns | num\_indexes | num\_primary\_keys |  
+---------------+-------------+-------------+------------------+  
| actor         |           4 |           2 |                1 |  
| address       |           9 |           3 |                1 |  
| category      |           3 |           1 |                1 |  
| city          |           4 |           2 |                1 |  
| country       |           3 |           1 |                1 |  
| customer      |           9 |           7 |                1 |  
| film          |          13 |           4 |                1 |  
| film\_actor    |           3 |           3 |                1 |  
| film\_category |           3 |           3 |                1 |  
| film\_text     |           3 |           3 |                1 |  
| inventory     |           4 |           4 |                1 |  
| language      |           3 |           1 |                1 |  
| payment       |           7 |           4 |                1 |  
| rental        |           7 |           7 |                1 |  
| staff         |          11 |           3 |                1 |  
| store         |           4 |           3 |                1 |  
+---------------+-------------+-------------+------------------+  
16 rows in set (0.01 sec)

You could execute this statement before and after the deployment and then verify any differences between the two sets of results before declaring the deployment a success.

## Dynamic SQL Generation

Some languages, such as Oracle’s PL/SQL and Microsoft’s Transact-SQL, are supersets of the SQL language, meaning that they include SQL statements in their grammar along with the usual procedural constructs, such as “if-then-else” and “while.” Other languages, such as Java, include the ability to interface with a relational database but do not include SQL statements in the grammar, meaning that all SQL statements must be contained within strings.

Therefore, most relational database servers, including SQL Server, Oracle Database, and MySQL, allow SQL statements to be submitted to the server as strings. Submitting strings to a database engine rather than utilizing its SQL interface is generally known as dynamic SQL execution. Oracle’s PL/SQL language, for example, includes an execute immediate command, which you can use to submit a string for execution, while SQL Server includes a system stored procedure called sp\_executesql for executing SQL statements dynamically.

MySQL provides the statements prepare, execute, and deallocate to allow for dynamic SQL execution. Here’s a simple example:

mysql> SET @qry = 'SELECT customer\_id, first\_name, last\_name FROM customer';  
Query OK, 0 rows affected (0.00 sec)  
  
mysql> PREPARE dynsql1 FROM @qry;  
Query OK, 0 rows affected (0.00 sec)  
Statement prepared  
  
mysql> EXECUTE dynsql1;  
+-------------+-------------+--------------+  
| customer\_id | first\_name  | last\_name    |  
+-------------+-------------+--------------+  
|         505 | RAFAEL      | ABNEY        |  
|         504 | NATHANIEL   | ADAM         |  
|          36 | KATHLEEN    | ADAMS        |  
|          96 | DIANA       | ALEXANDER    |  
...  
|          31 | BRENDA      | WRIGHT       |  
|         318 | BRIAN       | WYMAN        |  
|         402 | LUIS        | YANEZ        |  
|         413 | MARVIN      | YEE          |  
|          28 | CYNTHIA     | YOUNG        |  
+-------------+-------------+--------------+  
599 rows in set (0.02 sec)  
  
mysql> DEALLOCATE PREPARE dynsql1;  
Query OK, 0 rows affected (0.00 sec)

The set statement simply assigns a string to the qry variable, which is then submitted to the database engine (for parsing, security checking, and optimization) using the prepare statement. After executing the statement by calling execute, the statement must be closed using deallocate prepare, which frees any database resources (e.g., cursors) that have been utilized during execution.

The next example shows how you could execute a query that includes placeholders so that conditions can be specified at runtime:

mysql> SET @qry = 'SELECT customer\_id, first\_name, last\_name   
  FROM customer WHERE customer\_id =   
?  
';  
Query OK, 0 rows affected (0.00 sec)  
  
mysql> PREPARE dynsql2 FROM @qry;  
Query OK, 0 rows affected (0.00 sec)  
Statement prepared  
  
mysql> SET @custid = 9;  
Query OK, 0 rows affected (0.00 sec)  
  
mysql> EXECUTE dynsql2 USING @custid;  
+-------------+------------+-----------+  
| customer\_id | first\_name | last\_name |  
+-------------+------------+-----------+  
|           9 | MARGARET   | MOORE     |  
+-------------+------------+-----------+  
1 row in set (0.00 sec)  
  
mysql> SET @custid = 145;  
Query OK, 0 rows affected (0.00 sec)  
  
mysql> EXECUTE dynsql2 USING @custid;  
+-------------+------------+-----------+  
| customer\_id | first\_name | last\_name |  
+-------------+------------+-----------+  
|         145 | LUCILLE    | HOLMES    |  
+-------------+------------+-----------+  
1 row in set (0.00 sec)  
  
mysql> DEALLOCATE PREPARE dynsql2;  
Query OK, 0 rows affected (0.00 sec)

In this sequence, the query contains a placeholder (the ? at the end of the statement) so that the customer ID value can be submitted at runtime. The statement is prepared once and then executed twice, once for customer ID 9 and again for customer ID 145, after which the statement is closed.

What, you may wonder, does this have to do with metadata? Well, if you are going to use dynamic SQL to query a table, why not build the query string using metadata rather than hardcoding the table definition? The following example generates the same dynamic SQL string as the previous example, but it retrieves the column names from the information\_schema.columns view:

mysql> SELECT concat('SELECT ',  
    ->   concat\_ws(',', cols.col1, cols.col2, cols.col3, cols.col4,  
    ->     cols.col5, cols.col6, cols.col7, cols.col8, cols.col9),  
    ->   ' FROM customer WHERE customer\_id = ?')  
    ->   
INTO @qry  
  
    -> FROM  
    ->  (SELECT  
    ->     max(CASE WHEN ordinal\_position = 1 THEN column\_name  
    ->       ELSE NULL END) col1,  
    ->     max(CASE WHEN ordinal\_position = 2 THEN column\_name  
    ->       ELSE NULL END) col2,  
    ->     max(CASE WHEN ordinal\_position = 3 THEN column\_name  
    ->       ELSE NULL END) col3,  
    ->     max(CASE WHEN ordinal\_position = 4 THEN column\_name  
    ->       ELSE NULL END) col4,  
    ->     max(CASE WHEN ordinal\_position = 5 THEN column\_name  
    ->       ELSE NULL END) col5,  
    ->     max(CASE WHEN ordinal\_position = 6 THEN column\_name  
    ->       ELSE NULL END) col6,  
    ->     max(CASE WHEN ordinal\_position = 7 THEN column\_name  
    ->       ELSE NULL END) col7,  
    ->     max(CASE WHEN ordinal\_position = 8 THEN column\_name  
    ->       ELSE NULL END) col8,  
    ->     max(CASE WHEN ordinal\_position = 9 THEN column\_name  
    ->       ELSE NULL END) col9  
    ->   FROM information\_schema.columns  
    ->   WHERE table\_schema = 'sakila' AND table\_name = 'customer'  
    ->   GROUP BY table\_name  
    ->  ) cols;  
Query OK, 1 row affected (0.00 sec)  
mysql> SELECT @qry;  
+--------------------------------------------------------------------+  
| @qry                                                               |  
+--------------------------------------------------------------------+  
| SELECT customer\_id,store\_id,first\_name,last\_name,email,  
  address\_id,active,create\_date,last\_update   
  FROM customer WHERE customer\_id = ? |  
+--------------------------------------------------------------------+  
1 row in set (0.00 sec)  
  
mysql> PREPARE dynsql3 FROM @qry;  
Query OK, 0 rows affected (0.00 sec)  
Statement prepared  
  
mysql> SET @custid = 45;  
Query OK, 0 rows affected (0.00 sec)  
  
mysql> EXECUTE dynsql3 USING @custid;  
+-------------+----------+------------+-----------+  
| customer\_id | store\_id | first\_name | last\_name   
+-------------+----------+------------+-----------+  
|          45 |        1 | JANET      | PHILLIPS    
+-------------+----------+------------+-----------+  
  
 +-----------------------------------+------------+--------   
 | email                             | address\_id | active   
 +-----------------------------------+------------+--------   
 | JANET.PHILLIPS@sakilacustomer.org | 49 |     1   
 +-----------------------------------+------------+--------   
   
 +---------------------+---------------------+  
 | create\_date         | last\_update         |  
 +---------------------+---------------------+  
 | 2006-02-14 22:04:36 | 2006-02-15 04:57:20 |  
 +---------------------+---------------------+  
1 row in set (0.00 sec)  
  
mysql> DEALLOCATE PREPARE dynsql3;  
Query OK, 0 rows affected (0.00 sec)

The query pivots the first nine columns in the customer table, builds a query string using the concat and concat\_ws functions, and assigns the string to the qry variable. The query string is then executed as before.

##### Note

Generally, it would be better to generate the query using a procedural language that includes looping constructs, such as Java, PL/SQL, Transact-SQL, or MySQL’s Stored Procedure Language. However, I wanted to demonstrate a pure SQL example, so I had to limit the number of columns retrieved to some reasonable number, which in this example is nine.

# Test Your Knowledge

The following exercises are designed to test your understanding of metadata. When you’re finished, see [Appendix B](#Appendix_B__Solutions_to_Exercis_2) for the solutions.

## Exercise 15-1

Write a query that lists all of the indexes in the Sakila schema. Include the table names.

## Exercise 15-2

Write a query that generates output that can be used to create all of the indexes on the sakila.customer table. Output should be of the form:

"ALTER TABLE <table\_name> ADD INDEX <index\_name> (<column\_list>)"

# Chapter 16. Analytic Functions

Data volumes have been growing at a staggering pace, and organizations are having difficulty storing all of it, not to mention trying to make sense of it. While data analysis has traditionally occurred outside of the database server, using specialized tools or languages such as Excel, R, and Python, the SQL language includes a robust set of functions useful for analytical processing. If you need to generate rankings to identify the top 10 salespeople in your company or if you are generating a financial report for your customer and need to calculate three-month rolling averages, you can use SQL’s built-in analytic functions to perform these types of calculations.

# Analytic Function Concepts

After the database server has completed all of the steps necessary to evaluate a query, including joining, filtering, grouping, and sorting, the result set is complete and ready to be returned to the caller. Imagine if you could pause the query execution at this point and take a walk through the result set while it is still held in memory; what types of analysis might you want to do? If your result set contains sales data, perhaps you might want to generate rankings for salespeople or regions, or calculate percentage differences between one time period and another. If you are generating results for a financial report, perhaps you would like to calculate subtotals for each report section, and a grand total for the final section. Using analytic functions, you can do all of these things and more. Before diving into the details, the following subsections describe the mechanisms used by several of the most commonly used analytic functions.

## Data Windows

Let’s say you have written a query that generates monthly sales totals for a given time period. For example, the following query sums up the total monthly payments for film rentals for the period May through August 2005:

mysql> SELECT quarter(payment\_date) quarter,  
    ->   monthname(payment\_date) month\_nm,  
    ->   sum(amount) monthly\_sales  
    -> FROM payment  
    -> WHERE year(payment\_date) = 2005  
    -> GROUP BY quarter(payment\_date), monthname(payment\_date);  
+---------+----------+---------------+  
| quarter | month\_nm | monthly\_sales |  
+---------+----------+---------------+  
|       2 | May      |       4824.43 |  
|       2 | June     |       9631.88 |  
|       3 | July     |      28373.89 |  
|       3 | August   |      24072.13 |  
+---------+----------+---------------+  
4 rows in set (0.13 sec)

Looking at the results, you can see that July had the highest monthly total across all four months and that June had the highest monthly total for quarter 2. In order to determine the highest values programmatically, however, you will need to add additional columns to each row showing the maximum values per quarter and over the entire time period. Here’s the previous query but with two new columns to calculate these values:

mysql> SELECT quarter(payment\_date) quarter,  
    ->   monthname(payment\_date) month\_nm,  
    ->   sum(amount) monthly\_sales,  
    ->     
max(sum(amount))  
  
    ->       
over () max\_overall\_sales,  
  
    ->     
max(sum(amount))  
  
    ->       
over (partition by quarter(payment\_date)) max\_qrtr\_sales  
  
    -> FROM payment  
    -> WHERE year(payment\_date) = 2005  
    -> GROUP BY quarter(payment\_date), monthname(payment\_date);  
+---------+----------+---------------+-------------------+----------------+  
| quarter | month\_nm | monthly\_sales | max\_overall\_sales | max\_qrtr\_sales |  
+---------+----------+---------------+-------------------+----------------+  
|       2 | May      |       4824.43 |          28373.89 |        9631.88 |  
|       2 | June     |       9631.88 |          28373.89 |        9631.88 |  
|       3 | July     |      28373.89 |          28373.89 |       28373.89 |  
|       3 | August   |      24072.13 |          28373.89 |       28373.89 |  
+---------+----------+---------------+-------------------+----------------+  
4 rows in set (0.09 sec)

The analytic functions used to generate these additional columns group rows into two different sets: one set containing all rows in the same quarter and another set containing all of the rows. To accommodate this type of analysis, analytic functions include the ability to group rows into windows, which effectively partition the data for use by the analytic function without changing the overall result set. Windows are defined using the over clause combined with an optional partition by subclause. In the previous query, both analytic functions include an over clause, but the first one is empty, indicating that the window should include the entire result set, whereas the second one specifies that the window should include only rows within the same quarter. Data windows may contain anywhere from a single row to all of the rows in the result set, and different analytic functions can define different data windows.

## Localized Sorting

Along with partitioning your result set into data windows for your analytic functions, you may also specify a sort order. For example, if you want to define a ranking number for each month, where the value 1 is given to the month having the highest sales, you will need to specify which column (or columns) to use for the ranking:

mysql> SELECT quarter(payment\_date) quarter,  
    ->   monthname(payment\_date) month\_nm,  
    ->   sum(amount) monthly\_sales,  
    ->     
rank() over (order by sum(amount) desc)  
 sales\_rank  
    -> FROM payment  
    -> WHERE year(payment\_date) = 2005  
    -> GROUP BY quarter(payment\_date), monthname(payment\_date)  
    -> ORDER BY 1,2;  
+---------+----------+---------------+------------+  
| quarter | month\_nm | monthly\_sales | sales\_rank |  
+---------+----------+---------------+------------+  
|       2 | May      |       4824.43 |          4 |  
|       2 | June     |       9631.88 |          3 |  
|       3 | July     |      28373.89 |          1 |  
|       3 | August   |      24072.13 |          2 |  
+---------+----------+---------------+------------+  
4 rows in set (0.00 sec)

This query includes a call to the rank function, which will be covered in the next section, and specifies that the sum of the amount column be used to generate the rankings, with the values sorted in descending order. Thus, the month having the highest sales (July, in this case) will be given a ranking of 1.

Multiple order by Clauses

The previous example contains two order by clauses, one at the end of the query to determine how the result set should be sorted and another within the rank function to determine how the rankings should be allocated. While it is unfortunate that the same clause is used for different purposes, keep in mind that even if you are using analytic functions with one or more order by clauses, you will still need an order by clause at the end of your query if you want the result set to be sorted in a particular way.

In some cases, you will want to use both the partition by and order by subclauses in the same analytic function call. For example, the previous example can be modified to provide a different set of rankings per quarter, rather than a single ranking across the entire result set:

mysql> SELECT quarter(payment\_date) quarter,  
    ->   monthname(payment\_date) month\_nm,  
    ->   sum(amount) monthly\_sales,  
    ->     
rank() over (partition by quarter(payment\_date)  
  
    ->       
order by sum(amount) desc  
) qtr\_sales\_rank  
    -> FROM payment  
    -> WHERE year(payment\_date) = 2005  
    -> GROUP BY quarter(payment\_date), monthname(payment\_date)  
    -> ORDER BY 1, month(payment\_date);  
+---------+----------+---------------+----------------+  
| quarter | month\_nm | monthly\_sales | qtr\_sales\_rank |  
+---------+----------+---------------+----------------+  
|       2 | May      |       4824.43 |              2 |  
|       2 | June     |       9631.88 |              1 |  
|       3 | July     |      28373.89 |              1 |  
|       3 | August   |      24072.13 |              2 |  
+---------+----------+---------------+----------------+  
4 rows in set (0.00 sec)

While these examples were designed to illustrate the use of the over clause, the following sections will describe in detail the various analytic functions.

# Ranking

People love to rank things. If you visit your favorite news/sports/travel sites, you’ll see headlines similar to the following:

* Top 10 Vacation Values
* Best Mutual Fund Returns
* Preseason College Football Rankings
* Top 100 Songs of All Time

Companies also like to generate rankings, but for more practical purposes. Knowing which products are the best/worst sellers or which geographic regions generate the least/most revenue helps organizations make strategic decisions.

## Ranking Functions

There are multiple ranking functions available in the SQL standard, with each one taking a different approach to how ties are handled:

row\_number

Returns a unique number for each row, with rankings arbitrarily assigned in case of a tie

rank

Returns the same ranking in case of a tie, with gaps in the rankings

dense\_rank

Returns the same ranking in case of a tie, with no gaps in the rankings

Let’s look at an example to help illustrate the differences. Say that the marketing department wants to identify the top 10 customers so they can be offered a free film rental. The following query determines the number of film rentals for each customer and sorts the results in descending order:

mysql> SELECT customer\_id, count(\*) num\_rentals  
    -> FROM rental  
    -> GROUP BY customer\_id   
    -> ORDER BY 2 desc;  
+-------------+-------------+  
| customer\_id | num\_rentals |  
+-------------+-------------+  
|         148 |          46 |  
|         526 |          45 |  
|         236 |          42 |  
|         144 |          42 |  
  
|          75 |          41 |  
|         469 |          40 |  
|         197 |          40 |  
|         137 |          39 |  
|         468 |          39 |  
|         178 |          39 |  
|         459 |          38 |  
|         410 |          38 |  
|           5 |          38 |  
|         295 |          38 |  
|         257 |          37 |  
|         366 |          37 |  
|         176 |          37 |  
|         198 |          37 |  
|         267 |          36 |  
|         439 |          36 |  
|         354 |          36 |  
|         348 |          36 |  
|         380 |          36 |  
|          29 |          36 |  
|         371 |          35 |  
|         403 |          35 |  
|          21 |          35 |  
...  
|         136 |          15 |  
|         248 |          15 |  
|         110 |          14 |  
|         281 |          14 |  
|          61 |          14 |  
|         318 |          12 |  
+-------------+-------------+  
599 rows in set (0.16 sec)

Looking at the results, the third and fourth customers in the result set both rented 42 films; should they both receive the same ranking of 3? And if so, should the customer with 41 rentals be given the ranking 4, or should we skip one and assign ranking 5? To see how each function handles ties when assigning rankings, the next query adds three more columns, each one employing a different ranking function:

mysql> SELECT customer\_id, count(\*) num\_rentals,  
    ->     
row\_number()  
 over (order by count(\*) desc) row\_number\_rnk,  
    ->     
rank()  
 over (order by count(\*) desc) rank\_rnk,  
    ->     
dense\_rank  
() over (order by count(\*) desc) dense\_rank\_rnk  
    -> FROM rental  
    -> GROUP BY customer\_id  
    -> ORDER BY 2 desc;  
+-------------+-------------+----------------+----------+----------------+  
| customer\_id | num\_rentals | row\_number\_rnk | rank\_rnk | dense\_rank\_rnk |  
+-------------+-------------+----------------+----------+----------------+  
|         148 |          46 |              1 |        1 |              1 |  
|         526 |          45 |              2 |        2 |              2 |  
|         144 |          42 |              3 |        3 |              3 |  
|         236 |          42 |              4 |        3 |              3 |  
|          75 |          41 |              5 |        5 |              4 |  
  
|         197 |          40 |              6 |        6 |              5 |  
|         469 |          40 |              7 |        6 |              5 |  
|         468 |          39 |             10 |        8 |              6 |  
|         137 |          39 |              8 |        8 |              6 |  
|         178 |          39 |              9 |        8 |              6 |  
|           5 |          38 |             11 |       11 |              7 |  
|         295 |          38 |             12 |       11 |              7 |  
|         410 |          38 |             13 |       11 |              7 |  
|         459 |          38 |             14 |       11 |              7 |  
|         198 |          37 |             16 |       15 |              8 |  
|         257 |          37 |             17 |       15 |              8 |  
|         366 |          37 |             18 |       15 |              8 |  
|         176 |          37 |             15 |       15 |              8 |  
|         348 |          36 |             21 |       19 |              9 |  
|         354 |          36 |             22 |       19 |              9 |  
|         380 |          36 |             23 |       19 |              9 |  
|         439 |          36 |             24 |       19 |              9 |  
|          29 |          36 |             19 |       19 |              9 |  
|         267 |          36 |             20 |       19 |              9 |  
|          50 |          35 |             26 |       25 |             10 |  
|         506 |          35 |             37 |       25 |             10 |  
|         368 |          35 |             32 |       25 |             10 |  
|          91 |          35 |             27 |       25 |             10 |  
|         371 |          35 |             33 |       25 |             10 |  
|         196 |          35 |             28 |       25 |             10 |  
|         373 |          35 |             34 |       25 |             10 |  
|         204 |          35 |             29 |       25 |             10 |  
|         381 |          35 |             35 |       25 |             10 |  
|         273 |          35 |             30 |       25 |             10 |  
|          21 |          35 |             25 |       25 |             10 |  
|         403 |          35 |             36 |       25 |             10 |  
|         274 |          35 |             31 |       25 |             10 |  
|          66 |          34 |             42 |       38 |             11 |  
...  
|         136 |          15 |            594 |      594 |             30 |  
|         248 |          15 |            595 |      594 |             30 |  
|         110 |          14 |            597 |      596 |             31 |  
|         281 |          14 |            598 |      596 |             31 |  
|          61 |          14 |            596 |      596 |             31 |  
|         318 |          12 |            599 |      599 |             32 |  
+-------------+-------------+----------------+----------+----------------+  
599 rows in set (0.01 sec)

The third column uses the row\_number function to assign a unique ranking to each row, without regard to ties. Each of the 599 rows is assigned a number from 1 to 599, with the ranking value arbitrarily assigned for customers who have the same number of film rentals. The next two columns, however, assign the same ranking in case of a tie, but the difference lies in whether or not a gap is left in the ranking values after a tie. Looking at row 5 of the result set, you can see that the rank function skips the value 4 and assigns the value 5, whereas the dense\_rank function assigns the value 4.

To get back to the original request, how would you identify the top 10 customers? There are three possible solutions:

* Use the row\_number function to identify customers ranked from 1 to 10, which results in exactly 10 customers in this example, but in other cases might exclude customers having the same number of rentals as the 10th ranked customer.
* Use the rank function to identify customers ranked 10 or less, which also results in exactly 10 customers.
* Use the dense\_rank function to identify customers ranked 10 or less, which yields a list of 37 customers.

If there are no ties in your result set, then any of these functions will suffice, but for many situations the rank function may be the best option.

## Generating Multiple Rankings

The example in the previous section generates a single ranking across the entire set of customers, but what if you want to generate multiple sets of rankings within the same result set? To extend the prior example, let’s say the marketing department decides to offer free film rentals to the top five customers every month. To generate the data, the rental\_month column can be added to the previous query:

mysql> SELECT customer\_id,  
    ->     
monthname(rental\_date)  
   
rental\_month  
,  
    ->   count(\*) num\_rentals  
    -> FROM rental  
    -> GROUP BY customer\_id,   
monthname(rental\_date)  
  
    -> ORDER BY 2, 3 desc;  
+-------------+--------------+-------------+  
| customer\_id |   
rental\_month  
 | num\_rentals |  
+-------------+--------------+-------------+  
|         119 | August       |          18 |  
|          15 | August       |          18 |  
|         569 | August       |          18 |  
|         148 | August       |          18 |  
|         141 | August       |          17 |  
|          21 | August       |          17 |  
|         266 | August       |          17 |  
|         418 | August       |          17 |  
|         410 | August       |          17 |  
|         342 | August       |          17 |  
|         274 | August       |          16 |  
...  
|         281 | August       |           2 |  
|         318 | August       |           1 |  
|          75 | February     |           3 |  
|         155 | February     |           2 |  
|         175 | February     |           2 |  
|         516 | February     |           2 |  
|         361 | February     |           2 |  
|         269 | February     |           2 |  
|         208 | February     |           2 |  
|          53 | February     |           2 |  
...  
|          22 | February     |           1 |  
|         472 | February     |           1 |  
|         148 | July         |          22 |  
|         102 | July         |          21 |  
|         236 | July         |          20 |  
|          75 | July         |          20 |  
|          91 | July         |          19 |  
|          30 | July         |          19 |  
|          64 | July         |          19 |  
|         137 | July         |          19 |  
...  
|         339 | May          |           1 |  
|         485 | May          |           1 |  
|         116 | May          |           1 |  
|         497 | May          |           1 |  
|         180 | May          |           1 |  
+-------------+--------------+-------------+  
2466 rows in set (0.02 sec)

In order to create a new set of rankings for each month, you will need to add something to the rank function to describe how to divide the result set into different data windows (months, in this case). This is done using the partition by clause, which is added to the over clause:

mysql> SELECT customer\_id,  
    ->   monthname(rental\_date) rental\_month,  
    ->   count(\*) num\_rentals,  
    ->   rank()   
over (partition by monthname(rental\_date)  
  
    ->     order by count(\*) desc) rank\_rnk  
    -> FROM rental  
    -> GROUP BY customer\_id, monthname(rental\_date)  
    -> ORDER BY 2, 3 desc;  
+-------------+--------------+-------------+----------+  
| customer\_id | rental\_month | num\_rentals | rank\_rnk |  
+-------------+--------------+-------------+----------+  
|         569 |   
August         
|          18 |          
1  
 |  
|         119 | August       |          18 |        1 |  
|         148 | August       |          18 |        1 |  
|          15 | August       |          18 |        1 |  
|         141 | August       |          17 |        5 |  
|         410 | August       |          17 |        5 |  
|         418 | August       |          17 |        5 |  
|          21 | August       |          17 |        5 |  
|         266 | August       |          17 |        5 |  
|         342 | August       |          17 |        5 |  
|         144 | August       |          16 |       11 |  
|         274 | August       |          16 |       11 |  
...  
|         164 | August       |           2 |      596 |  
|         318 | August       |           1 |      599 |  
|          75 |   
February       
|           3 |          
1  
 |  
|         457 | February     |           2 |        2 |  
|          53 | February     |           2 |        2 |  
|         354 | February     |           2 |        2 |  
  
|         352 | February     |           1 |       24 |  
|         373 | February     |           1 |       24 |  
|         148 |   
July           
|          22 |          
1  
 |  
|         102 | July         |          21 |        2 |  
|         236 | July         |          20 |        3 |  
|          75 | July         |          20 |        3 |  
|          91 | July         |          19 |        5 |  
|         354 | July         |          19 |        5 |  
|          30 | July         |          19 |        5 |  
|          64 | July         |          19 |        5 |  
|         137 | July         |          19 |        5 |  
|         526 | July         |          19 |        5 |  
|         366 | July         |          19 |        5 |  
|         595 | July         |          19 |        5 |  
|         469 | July         |          18 |       13 |  
...  
|         457 | May          |           1 |      347 |  
|         356 | May          |           1 |      347 |  
|         481 | May          |           1 |      347 |  
|          10 | May          |           1 |      347 |  
+-------------+--------------+-------------+----------+  
2466 rows in set (0.03 sec)

Looking at the results, you can see that the rankings are reset to 1 for each month. In order to generate the desired results for the marketing department (top five customers from each month), you can simply wrap the previous query in a subquery and add a filter condition to exclude any rows with a ranking higher than five:

SELECT customer\_id, rental\_month, num\_rentals,  
  rank\_rnk ranking  
FROM  
 (SELECT customer\_id,  
  monthname(rental\_date) rental\_month,  
  count(\*) num\_rentals,  
  rank() over (partition by monthname(rental\_date)  
    order by count(\*) desc) rank\_rnk  
 FROM rental  
 GROUP BY customer\_id, monthname(rental\_date)  
 ) cust\_rankings  
WHERE rank\_rnk <= 5  
  
ORDER BY rental\_month, num\_rentals desc, rank\_rnk;

Since analytic functions can be used only in the SELECT clause, you will often need to nest queries if you need to do any filtering or grouping based on the results from the analytic function.

# Reporting Functions

Along with generating rankings, another common use for analytic functions is to find outliers (e.g., min or max values) or to generate sums or averages across an entire data set. For these types of uses, you will be using aggregate functions (min, max, avg, sum, count), but instead of using them with a group by clause, you will pair them with an over clause. Here’s an example that generates monthly and grand totals for all payments of $10 or higher:

mysql> SELECT monthname(payment\_date) payment\_month,  
    ->   amount,  
    ->     
sum(amount)  
   
  ->   
over (partition by monthname(payment\_date)) monthly\_total,  
  
    ->     
sum(amount) over () grand\_total  
  
    -> FROM payment  
    -> WHERE amount >= 10  
    -> ORDER BY 1;  
+---------------+--------+---------------+-------------+  
| payment\_month | amount | monthly\_total | grand\_total |  
+---------------+--------+---------------+-------------+  
| August        |  10.99 |        521.53 |     1262.86 |  
| August        |  11.99 |        521.53 |     1262.86 |  
| August        |  10.99 |        521.53 |     1262.86 |  
| August        |  10.99 |        521.53 |     1262.86 |  
...  
| August        |  10.99 |        521.53 |     1262.86 |  
| August        |  10.99 |        521.53 |     1262.86 |  
| August        |  10.99 |        521.53 |     1262.86 |  
| July          |  10.99 |        519.53 |     1262.86 |  
| July          |  10.99 |        519.53 |     1262.86 |  
| July          |  10.99 |        519.53 |     1262.86 |  
| July          |  10.99 |        519.53 |     1262.86 |  
...  
| July          |  10.99 |        519.53 |     1262.86 |  
| July          |  10.99 |        519.53 |     1262.86 |  
| July          |  10.99 |        519.53 |     1262.86 |  
| June          |  10.99 |        165.85 |     1262.86 |  
| June          |  10.99 |        165.85 |     1262.86 |  
| June          |  10.99 |        165.85 |     1262.86 |  
| June          |  10.99 |        165.85 |     1262.86 |  
| June          |  10.99 |        165.85 |     1262.86 |  
| June          |  10.99 |        165.85 |     1262.86 |  
| June          |  10.99 |        165.85 |     1262.86 |  
| June          |  10.99 |        165.85 |     1262.86 |  
| June          |  11.99 |        165.85 |     1262.86 |  
| June          |  10.99 |        165.85 |     1262.86 |  
| June          |  10.99 |        165.85 |     1262.86 |  
| June          |  10.99 |        165.85 |     1262.86 |  
| June          |  10.99 |        165.85 |     1262.86 |  
| June          |  10.99 |        165.85 |     1262.86 |  
| June          |  10.99 |        165.85 |     1262.86 |  
| May           |  10.99 |         55.95 |     1262.86 |  
| May           |  10.99 |         55.95 |     1262.86 |  
| May           |  10.99 |         55.95 |     1262.86 |  
| May           |  10.99 |         55.95 |     1262.86 |  
| May           |  11.99 |         55.95 |     1262.86 |  
+---------------+--------+---------------+-------------+  
114 rows in set (0.01 sec)

The grand\_total column contains the same value ($1,262.86) for every row because the over clause is empty, which specifies that the summation be done over the entire result set. The monthly\_total column, however, contains a different value for each month, since there is a partition by clause specifying that the result set be split into multiple data windows (one for each month).

While it may seem of little value to include a column such as grand\_total with the same value for every row, these types of columns can also be used for calculations, as shown in the following query:

mysql> SELECT monthname(payment\_date) payment\_month,  
    ->   sum(amount) month\_total,  
    ->     
round(sum(amount)  
   
/ sum(sum(amount)) over ()  
  
    ->       
\* 100, 2) pct\_of\_total  
  
    -> FROM payment  
    -> GROUP BY monthname(payment\_date);  
+---------------+-------------+--------------+  
| payment\_month | month\_total | pct\_of\_total |  
+---------------+-------------+--------------+  
| May           |     4824.43 |         7.16 |  
| June          |     9631.88 |        14.29 |  
| July          |    28373.89 |        42.09 |  
| August        |    24072.13 |        35.71 |  
| February      |      514.18 |         0.76 |  
+---------------+-------------+--------------+  
5 rows in set (0.04 sec)

This query calculates the total payments for each month by summing the amount column, and then calculates the percentage of the total payments for each month by summing the monthly sums to use as the denominator in the calculation.

Reporting functions may also be used for comparisons, such as the next query, which uses a case expression to determine whether a monthly total is the max, min, or somewhere in the middle:

mysql> SELECT monthname(payment\_date) payment\_month,  
    ->   sum(amount) month\_total,  
    ->     
CASE sum(amount)  
  
    ->       
WHEN max(sum(amount)) over () THEN 'Highest'  
  
    ->       
WHEN min(sum(amount)) over () THEN 'Lowest'  
  
    ->       
ELSE 'Middle'  
  
    ->     
END descriptor  
  
    -> FROM payment  
    -> GROUP BY monthname(payment\_date);  
+---------------+-------------+------------+  
| payment\_month | month\_total | descriptor |  
+---------------+-------------+------------+  
| May           |     4824.43 | Middle     |  
| June          |     9631.88 | Middle     |  
| July          |    28373.89 |   
Highest  
    |  
| August        |    24072.13 | Middle     |  
| February      |      514.18 |   
Lowest       
|  
+---------------+-------------+------------+  
5 rows in set (0.04 sec)

The descriptor column acts as a quasi-ranking function, in that it helps identify the top/bottom values across a set of rows.

## Window Frames

As described earlier in the chapter, data windows for analytic functions are defined using the partition by clause, which allows you to group rows by common values. But what if you need even finer control over which rows to include in a data window? For example, perhaps you want to generate a running total starting from the beginning of the year up to the current row. For these types of calculations, you can include a “frame” subclause to define exactly which rows to include in the data window. Here’s a query that sums payments for each week and includes a reporting function to calculate the rolling sum:

mysql> SELECT yearweek(payment\_date) payment\_week,  
    ->   sum(amount) week\_total,  
    ->   sum(sum(amount))  
    ->       
over (order by yearweek(payment\_date)  
  
    ->         
rows unbounded preceding  
) rolling\_sum  
    -> FROM payment  
    -> GROUP BY yearweek(payment\_date)  
    -> ORDER BY 1;  
+--------------+------------+-------------+  
| payment\_week | week\_total | rolling\_sum |  
+--------------+------------+-------------+  
|       200521 |    2847.18 |     2847.18 |  
|       200522 |    1977.25 |     4824.43 |  
|       200524 |    5605.42 |    10429.85 |  
|       200525 |    4026.46 |    14456.31 |  
|       200527 |    8490.83 |    22947.14 |  
|       200528 |    5983.63 |    28930.77 |  
|       200530 |   11031.22 |    39961.99 |  
|       200531 |    8412.07 |    48374.06 |  
|       200533 |   10619.11 |    58993.17 |  
|       200534 |    7909.16 |    66902.33 |  
|       200607 |     514.18 |    67416.51 |  
+--------------+------------+-------------+  
11 rows in set (0.04 sec)

The rolling\_sum column expression includes the rows unbounded preceding subclause to define a data window from the beginning of the result set up to and including the current row. The data window consists of a single row for the first row in the result set, two rows for the second row, etc. The value for the last row is the summation of the entire result set.

Along with rolling sums, you can calculate rolling averages. Here’s a query that calculates a three-week rolling average of total payments:

mysql> SELECT yearweek(payment\_date) payment\_week,  
    ->   sum(amount) week\_total,  
    ->     
avg(sum(amount))  
  
    ->     over (order by yearweek(payment\_date)  
    ->         
rows between 1 preceding and 1 following  
) rolling\_3wk\_avg  
    -> FROM payment  
    -> GROUP BY yearweek(payment\_date)  
    -> ORDER BY 1;  
+--------------+------------+-----------------+  
| payment\_week | week\_total | rolling\_3wk\_avg |  
+--------------+------------+-----------------+  
|       200521 |    2847.18 |     2412.215000 |  
|       200522 |    1977.25 |     3476.616667 |  
|       200524 |    5605.42 |     3869.710000 |  
|       200525 |    4026.46 |     6040.903333 |  
|       200527 |    8490.83 |     6166.973333 |  
|       200528 |    5983.63 |     8501.893333 |  
|       200530 |   11031.22 |     8475.640000 |  
|       200531 |    8412.07 |    10020.800000 |  
|       200533 |   10619.11 |     8980.113333 |  
|       200534 |    7909.16 |     6347.483333 |  
|       200607 |     514.18 |     4211.670000 |  
+--------------+------------+-----------------+  
11 rows in set (0.03 sec)

The rolling\_3wk\_avg column defines a data window consisting of the current row, the prior row, and the next row. The data window will therefore consist of three rows, except for the first and last rows, which will have a data window consisting of just two rows (since there is no prior row for the first row and no next row for the last row).

Specifying a number of rows for your data window works fine in many cases, but if there are gaps in your data, you might want to try a different approach. In the previous result set, for example, there is data for weeks 200521, 200522, and 200524, but no data for week 200523. If you want to specify a date interval rather than a number of rows, you can specify a range for your data window, as shown in the following query:

mysql> SELECT date(payment\_date), sum(amount),  
    ->   avg(sum(amount)) over (order by date(payment\_date)  
    ->       
range between interval 3 day preceding  
  
    ->         
and interval 3 day following  
) 7\_day\_avg  
    -> FROM payment  
    -> WHERE payment\_date BETWEEN '2005-07-01' AND '2005-09-01'  
    -> GROUP BY date(payment\_date)  
    -> ORDER BY 1;  
+--------------------+-------------+-------------+  
| date(payment\_date) | sum(amount) | 7\_day\_avg   |  
+--------------------+-------------+-------------+  
| 2005-07-05         |      128.73 | 1603.740000 |  
| 2005-07-06         |     2131.96 | 1698.166000 |  
| 2005-07-07         |     1943.39 | 1738.338333 |  
| 2005-07-08         |     2210.88 | 1766.917143 |  
| 2005-07-09         |     2075.87 | 2049.390000 |  
| 2005-07-10         |     1939.20 | 2035.628333 |  
| 2005-07-11         |     1938.39 | 2054.076000 |  
| 2005-07-12         |     2106.04 | 2014.875000 |  
| 2005-07-26         |      160.67 | 2046.642500 |  
| 2005-07-27         |     2726.51 | 2206.244000 |  
| 2005-07-28         |     2577.80 | 2316.571667 |  
| 2005-07-29         |     2721.59 | 2388.102857 |  
| 2005-07-30         |     2844.65 | 2754.660000 |  
| 2005-07-31         |     2868.21 | 2759.351667 |  
| 2005-08-01         |     2817.29 | 2795.662000 |  
| 2005-08-02         |     2726.57 | 2814.180000 |  
| 2005-08-16         |      111.77 | 1973.837500 |  
  
| 2005-08-17         |     2457.07 | 2123.822000 |  
| 2005-08-18         |     2710.79 | 2238.086667 |  
| 2005-08-19         |     2615.72 | 2286.465714 |  
| 2005-08-20         |     2723.76 | 2630.928571 |  
| 2005-08-21         |     2809.41 | 2659.905000 |  
| 2005-08-22         |     2576.74 | 2649.728000 |  
| 2005-08-23         |     2523.01 | 2658.230000 |  
+--------------------+-------------+-------------+  
24 rows in set (0.03 sec)

The 7\_day\_avg column specifies a range of +/-3 days and will include only those rows whose payment\_date values fall within that range. For the 2005-08-16 calculation, for example, only the values for 08-16, 08-17, 08-18, and 08-19 are included, since there are no rows for the three prior dates (08-13 through 08-15).

## Lag and Lead

Along with computing sums and averages over a data window, another common reporting task involves comparing values from one row to another. For example, if you are generating monthly sales totals, you may be asked to create a column showing the percentage difference from the prior month, which will require a way to retrieve the monthly sales total from the previous row. This can be accomplished using the lag function, which will retrieve a column value from a prior row in the result set, or the lead function, which will retrieve a column value from a following row. Here’s an example using both functions:

mysql> SELECT yearweek(payment\_date) payment\_week,  
    ->   sum(amount) week\_total,  
    ->     
lag(sum(amount), 1)  
  
    ->       
over (order by yearweek(payment\_date)) prev\_wk\_tot  
,  
    ->     
lead(sum(amount), 1)  
  
    ->       
over (order by yearweek(payment\_date)) next\_wk\_tot  
  
    -> FROM payment  
    -> GROUP BY yearweek(payment\_date)  
    -> ORDER BY 1;  
+--------------+------------+-------------+-------------+  
| payment\_week | week\_total | prev\_wk\_tot | next\_wk\_tot |  
+--------------+------------+-------------+-------------+  
|       200521 |    2847.18 |        NULL  
   
|     1977.25 |  
|       200522 |    1977.25 |     2847.18 |     5605.42 |  
|       200524 |    5605.42 |     1977.25 |     4026.46 |  
|       200525 |    4026.46 |     5605.42 |       
8490.83  
 |  
|       200527 |      
8490.83  
 |     4026.46 |     5983.63 |  
|       200528 |    5983.63 |       
8490.83  
 |    11031.22 |  
|       200530 |   11031.22 |     5983.63 |     8412.07 |  
|       200531 |    8412.07 |    11031.22 |    10619.11 |  
|       200533 |   10619.11 |     8412.07 |     7909.16 |  
|       200534 |    7909.16 |    10619.11 |      514.18 |  
|       200607 |     514.18 |     7909.16 |        NULL  
   
|  
+--------------+------------+-------------+-------------+  
11 rows in set (0.03 sec)

Looking at the results, the weekly total of 8,490.43 for week 200527 also appears in the next\_wk\_tot column for week 200525, as well as in the prev\_wk\_tot column for week 200528. Since there is no row prior to 200521 in the result set, the value generated by the lag function is null for the first row; likewise, the value generated by the lead function is null for the last row in the result set. Both lag and lead allow for an optional second parameter (which defaults to 1) to describe the number of rows prior/following from which to retrieve the column value.

Here’s how you could use the lag function to generate the percentage difference from the prior week:

mysql> SELECT yearweek(payment\_date) payment\_week,  
    ->   sum(amount) week\_total,  
    ->     
round((sum(amount) - lag(sum(amount), 1)  
  
    ->       
over (order by yearweek(payment\_date)))  
  
    ->       
/ lag(sum(amount), 1)  
  
    ->         
over (order by yearweek(payment\_date))  
  
    ->       
\* 100, 1) pct\_diff  
  
    -> FROM payment  
    -> GROUP BY yearweek(payment\_date)  
    -> ORDER BY 1;  
+--------------+------------+----------+  
| payment\_week | week\_total | pct\_diff |  
+--------------+------------+----------+  
|       200521 |    2847.18 |     NULL |  
|       200522 |    1977.25 |    -30.6 |  
|       200524 |    5605.42 |    183.5 |  
|       200525 |    4026.46 |    -28.2 |  
|       200527 |    8490.83 |    110.9 |  
|       200528 |    5983.63 |    -29.5 |  
|       200530 |   11031.22 |     84.4 |  
|       200531 |    8412.07 |    -23.7 |  
|       200533 |   10619.11 |     26.2 |  
|       200534 |    7909.16 |    -25.5 |  
|       200607 |     514.18 |    -93.5 |  
+--------------+------------+----------+  
11 rows in set (0.07 sec)

Comparing values from different rows in the same result set is a common practice in reporting systems, so you will likely find many uses for the lag and lead functions.

## Column Value Concatenation

Although not technically an analytic function, there is one more important function to demonstrate since it works with groups of rows within a data window. The group\_concat function is used to pivot a set of column values into a single delimited string, which is a handy way to denormalize your result set for generating XML or JSON documents. Here’s an example of how this function could be used to generate a comma-delimited list of actors for each film:

mysql> SELECT f.title,  
    ->     
group\_concat(a.last\_name order by a.last\_name  
   
  ->   
separator ', ')  
 actors  
    -> FROM actor a  
    ->   INNER JOIN film\_actor fa  
    ->   ON a.actor\_id = fa.actor\_id  
    ->   INNER JOIN film f  
    ->   ON fa.film\_id = f.film\_id  
    -> GROUP BY f.title  
    -> HAVING count(\*) = 3;  
+------------------------+--------------------------------+  
| title                  | actors                         |  
+------------------------+--------------------------------+  
| ANNIE IDENTITY         | GRANT, KEITEL, MCQUEEN         |  
| ANYTHING SAVANNAH      | MONROE, SWANK, WEST            |  
| ARK RIDGEMONT          | BAILEY, DEGENERES, GOLDBERG    |  
| ARSENIC INDEPENDENCE   | ALLEN, KILMER, REYNOLDS        |  
...  
| WHISPERER GIANT        | BAILEY, PECK, WALKEN           |  
| WIND PHANTOM           | BALL, DENCH, GUINESS           |  
| ZORRO ARK              | DEGENERES, MONROE, TANDY       |  
+------------------------+--------------------------------+  
119 rows in set (0.04 sec)

This query groups rows by film title and only includes films in which exactly three actors appear. The group\_concat function acts like a special type of aggregate function that pivots all of the last names of all actors appearing in each film into a single string. If you are using SQL Server, you can use the string\_agg function to generate this type of output, and Oracle users can use the listagg function.

# Test Your Knowledge

The following exercises are designed to test your understanding of analytic functions. When you’re finished, see [Appendix B](#Appendix_B__Solutions_to_Exercis_2) for the solutions.

For all exercises in this section, use the following data set from the Sales\_Fact table:

Sales\_Fact  
+---------+----------+-----------+  
| year\_no | month\_no | tot\_sales |  
+---------+----------+-----------+  
|    2019 |        1 |     19228 |  
|    2019 |        2 |     18554 |  
|    2019 |        3 |     17325 |  
|    2019 |        4 |     13221 |  
|    2019 |        5 |      9964 |  
|    2019 |        6 |     12658 |  
|    2019 |        7 |     14233 |  
|    2019 |        8 |     17342 |  
|    2019 |        9 |     16853 |  
|    2019 |       10 |     17121 |  
|    2019 |       11 |     19095 |  
|    2019 |       12 |     21436 |  
|    2020 |        1 |     20347 |  
|    2020 |        2 |     17434 |  
|    2020 |        3 |     16225 |  
|    2020 |        4 |     13853 |  
|    2020 |        5 |     14589 |  
|    2020 |        6 |     13248 |  
|    2020 |        7 |      8728 |  
|    2020 |        8 |      9378 |  
|    2020 |        9 |     11467 |  
|    2020 |       10 |     13842 |  
|    2020 |       11 |     15742 |  
|    2020 |       12 |     18636 |  
+---------+----------+-----------+  
24 rows in set (0.00 sec)

## Exercise 16-1

Write a query that retrieves every row from Sales\_Fact, and add a column to generate a ranking based on the tot\_sales column values. The highest value should receive a ranking of 1, and the lowest a ranking of 24.

## Exercise 16-2

Modify the query from the previous exercise to generate two sets of rankings from 1 to 12, one for 2019 data and one for 2020.

## Exercise 16-3

Write a query that retrieves all 2020 data, and include a column that will contain the tot\_sales value from the previous month.

# Chapter 17. Working with Large Databases

In the early days of relational databases, hard drive capacity was measured in megabytes, and databases were generally easy to administer simply because they couldn’t get very large. Today, however, hard drive capacity has ballooned to 15 TB, a modern disk array can store more than 4 PB of data, and storage in the cloud is essentially limitless. While relational databases face various challenges as data volumes continue to grow, there are strategies such as partitioning, clustering, and sharding that allow companies to continue to utilize relational databases by spreading data across multiple storage tiers and servers. Other companies have decided to move to big data platforms such as Hadoop in order to handle huge data volumes. This chapter looks at some of these strategies, with an emphasis on techniques for scaling relational databases.

# Partitioning

When exactly does a database table become “too big”? If you ask this question to 10 different data architects/administrators/developers, you will likely get 10 different answers. Most people, however, would agree that the following tasks become more difficult and/or time consuming as a table grows past a few million rows:

* Query execution requiring full table scans
* Index creation/rebuild
* Data archival/deletion
* Generation of table/index statistics
* Table relocation (e.g., move to a different tablespace)
* Database backups

These tasks can start as routine when a database is small, then become time consuming as more data accumulates, and then become problematic/impossible due to limited administrative time windows. The best way to prevent administrative issues from occurring in the future is to break large tables into pieces, or partitions, when the table is first created (although tables can be partitioned later, it is easier to do so initially). Administrative tasks can be performed on individual partitions, often in parallel, and some tasks can skip one or more partitions entirely.

## Partitioning Concepts

Table partitioning was introduced in the late 1990s by Oracle, but since then every major database server has added the ability to partition tables and indexes. When a table is partitioned, two or more table partitions are created, each having the exact same definition but with nonoverlapping subsets of data. For example, a table containing sales data could be partitioned by month using the column containing the sale date, or it could be partitioned by geographic region using the state/province code.

Once a table has been partitioned, the table itself becomes a virtual concept; the partitions hold the data, and any indexes are built on the data in the partitions. However, the database users can still interact with the table without knowing that the table had been partitioned. This is similar in concept to a view, in that the users interact with schema objects that are interfaces rather than actual tables. While every partition must have the same schema definition (columns, column types, etc.), there are several administrative features that can differ for each partition:

* Partitions may be stored on different tablespaces, which can be on different physical storage tiers.
* Partitions can be compressed using different compression schemes.
* Local indexes (more on this shortly) can be dropped for some partitions.
* Table statistics can be frozen on some partitions, while being periodically refreshed on others.
* Individual partitions can be pinned into memory or stored in the database’s flash storage tier.

Thus, table partitioning allows for flexibility with data storage and administration, while still presenting the simplicity of a single table to your user community.

## Table Partitioning

The partitioning scheme available in most relational databases is horizontal partitioning, which assigns entire rows to exactly one partition. Tables may also be partitioned vertically, which involves assigning sets of columns to different partitions, but this must be done manually. When partitioning a table horizontally, you must choose a partition key, which is the column whose values are used to assign a row to a particular partition. In most cases, a table’s partition key consists of a single column, and a partitioning function is applied to this column to determine in which partition each row should reside.

## Index Partitioning

If your partitioned table has indexes, you will get to choose whether a particular index should stay intact, known as a global index, or be broken into pieces such that each partition has its own index, which is called a local index. Global indexes span all partitions of the table and are useful for queries that do not specify a value for the partition key. For example, let’s say your table is partitioned on the sale\_date column, and a user executes the following query:

SELECT sum(amount) FROM sales WHERE geo\_region\_cd = 'US'

Since this query does not include a filter condition on the sale\_date column, the server will need to search every partition in order to find the total US sales. If a global index is built on the geo\_region\_cd column, however, then the server could use this index to quickly find all of the rows containing US sales.

## Partitioning Methods

While each database server has its own unique partitioning features, the next three sections describe the common partitioning methods available across most servers.

## Range partitioning

Range partitioning was the first partitioning method to be implemented, and it is still one of the most widely used. While range partitioning can be used for several different column types, the most common usage is to break up tables by date ranges. For example, a table named sales could be partitioned using the sale\_date column such that data for each week is stored in a different partition:

mysql> CREATE TABLE sales  
    ->  (sale\_id INT NOT NULL,  
    ->   cust\_id INT NOT NULL,  
    ->   store\_id INT NOT NULL,  
    ->   sale\_date DATE NOT NULL,  
    ->   amount DECIMAL(9,2)  
    ->  )  
    -> PARTITION BY RANGE (yearweek(sale\_date))  
    ->  (PARTITION s1 VALUES LESS THAN (202002),  
    ->   PARTITION s2 VALUES LESS THAN (202003),  
    ->   PARTITION s3 VALUES LESS THAN (202004),  
    ->   PARTITION s4 VALUES LESS THAN (202005),  
    ->   PARTITION s5 VALUES LESS THAN (202006),  
    ->   PARTITION s999 VALUES LESS THAN (MAXVALUE)  
    ->  );  
Query OK, 0 rows affected (1.78 sec)

This statement creates six different partitions, one for each of the first five weeks of 2020 and a sixth partition named s999 to hold any rows beyond week five of year 2020. For this table, the yearweek(sale\_date) expression is used as the partitioning function, and the sale\_date column serves as the partitioning key. To see the metadata about your partitioned tables, you can use the partitions table in the information\_schema database:

mysql> SELECT partition\_name, partition\_method, partition\_expression  
    ->   
FROM information\_schema.partitions  
  
    -> WHERE table\_name = 'sales'  
    -> ORDER BY partition\_ordinal\_position;  
+----------------+------------------+-------------------------+  
| PARTITION\_NAME | PARTITION\_METHOD | PARTITION\_EXPRESSION    |  
+----------------+------------------+-------------------------+  
| s1             | RANGE            | yearweek(`sale\_date`,0) |  
| s2             | RANGE            | yearweek(`sale\_date`,0) |  
| s3             | RANGE            | yearweek(`sale\_date`,0) |  
| s4             | RANGE            | yearweek(`sale\_date`,0) |  
| s5             | RANGE            | yearweek(`sale\_date`,0) |  
| s999           | RANGE            | yearweek(`sale\_date`,0) |  
+----------------+------------------+-------------------------+  
6 rows in set (0.00 sec)

One of the administrative tasks that will need to be performed on the sales table involves generating new partitions to hold future data (to keep data from being added to the maxvalue partition). Different databases handle this in different ways, but in MySQL you could use the reorganize partition clause of the alter table command to split the s999 partition into three pieces:

ALTER TABLE sales   
REORGANIZE PARTITION  
 s999 INTO  
 (PARTITION s6 VALUES LESS THAN (202007),  
  PARTITION s7 VALUES LESS THAN (202008),  
  PARTITION s999 VALUES LESS THAN (MAXVALUE)  
 );

If you execute the previous metadata query again, you will now see eight partitions:

mysql> SELECT partition\_name, partition\_method, partition\_expression  
    -> FROM information\_schema.partitions  
    -> WHERE table\_name = 'sales'  
    -> ORDER BY partition\_ordinal\_position;  
+----------------+------------------+-------------------------+  
| PARTITION\_NAME | PARTITION\_METHOD | PARTITION\_EXPRESSION    |  
+----------------+------------------+-------------------------+  
| s1             | RANGE            | yearweek(`sale\_date`,0) |  
| s2             | RANGE            | yearweek(`sale\_date`,0) |  
| s3             | RANGE            | yearweek(`sale\_date`,0) |  
| s4             | RANGE            | yearweek(`sale\_date`,0) |  
| s5             | RANGE            | yearweek(`sale\_date`,0) |  
| s6             | RANGE            | yearweek(`sale\_date`,0) |  
| s7             | RANGE            | yearweek(`sale\_date`,0) |  
  
| s999           | RANGE            | yearweek(`sale\_date`,0) |  
+----------------+------------------+-------------------------+  
8 rows in set (0.00 sec)

Next, let’s add a couple of rows to the table:

mysql> INSERT INTO sales  
    -> VALUES  
    ->  (1, 1, 1, '2020-01-18', 2765.15),  
    ->  (2, 3, 4, '2020-02-07', 5322.08);  
Query OK, 2 rows affected (0.18 sec)  
Records: 2  Duplicates: 0  Warnings: 0

The table now has two rows, but into which partitions were they inserted? To find out, let’s use the partition subclause of the from clause to count the number of rows in each partition:

mysql> SELECT concat('# of rows in S1 = ', count(\*)) partition\_rowcount  
    ->   
FROM sales PARTITION (s1)  
 UNION ALL  
    -> SELECT concat('# of rows in S2 = ', count(\*)) partition\_rowcount  
    ->   
FROM sales PARTITION (s2)  
 UNION ALL  
    -> SELECT concat('# of rows in S3 = ', count(\*)) partition\_rowcount  
    ->   
FROM sales PARTITION (s3)  
 UNION ALL  
    -> SELECT concat('# of rows in S4 = ', count(\*)) partition\_rowcount  
    ->   
FROM sales PARTITION (s4)  
 UNION ALL  
    -> SELECT concat('# of rows in S5 = ', count(\*)) partition\_rowcount  
    ->   
FROM sales PARTITION (s5)  
 UNION ALL  
    -> SELECT concat('# of rows in S6 = ', count(\*)) partition\_rowcount  
    ->   
FROM sales PARTITION (s6)  
 UNION ALL  
    -> SELECT concat('# of rows in S7 = ', count(\*)) partition\_rowcount  
    ->   
FROM sales PARTITION (s7)  
 UNION ALL  
    -> SELECT concat('# of rows in S999 = ', count(\*)) partition\_rowcount  
    ->   
FROM sales PARTITION (s999)  
;  
+-----------------------+  
| partition\_rowcount    |  
+-----------------------+  
| # of rows in S1 = 0   |  
| # of rows in   
S2  
 =   
1  
   |  
| # of rows in S3 = 0   |  
| # of rows in S4 = 0   |  
| # of rows in   
S5  
 =   
1  
   |  
| # of rows in S6 = 0   |  
| # of rows in S7 = 0   |  
| # of rows in S999 = 0 |  
+-----------------------+  
8 rows in set (0.00 sec)

The results show that one row was inserted into partition S2, and the other row was inserted into the S5 partition. The ability to query a specific partition involves knowing the partitioning scheme, so it is unlikely that your user community will be executing these types of queries, but they are commonly used for administrative types of activities.

## List partitioning

If the column chosen as the partitioning key contains state codes (e.g., CA, TX, VA, etc.), currencies (e.g., USD, EUR, JPY, etc.), or some other enumerated set of values, you may want to utilize list partitioning, which allows you to specify which values will be assigned to each partition. For example, let’s say that the sales table includes the column geo\_region\_cd, which contains the following values:

+---------------+--------------------------+  
| geo\_region\_cd | description              |  
+---------------+--------------------------+  
| US\_NE         | United States North East |  
| US\_SE         | United States South East |  
| US\_MW         | United States Mid West   |  
| US\_NW         | United States North West |  
| US\_SW         | United States South West |  
| CAN           | Canada                   |  
| MEX           | Mexico                   |  
| EUR\_E         | Eastern Europe           |  
| EUR\_W         | Western Europe           |  
| CHN           | China                    |  
| JPN           | Japan                    |  
| IND           | India                    |  
| KOR           | Korea                    |  
+---------------+--------------------------+  
13 rows in set (0.00 sec)

You could group these values into geographic regions and create a partition for each one, as in:

mysql> CREATE TABLE sales  
    ->  (sale\_id INT NOT NULL,  
    ->   cust\_id INT NOT NULL,  
    ->   store\_id INT NOT NULL,  
    ->   sale\_date DATE NOT NULL,  
    ->   geo\_region\_cd VARCHAR(6) NOT NULL,  
    ->   amount DECIMAL(9,2)  
    ->  )  
    -> PARTITION BY LIST COLUMNS (geo\_region\_cd)  
    ->  (PARTITION NORTHAMERICA VALUES IN ('US\_NE','US\_SE','US\_MW',  
    ->                                     'US\_NW','US\_SW','CAN','MEX'),  
    ->   PARTITION EUROPE VALUES IN ('EUR\_E','EUR\_W'),  
    ->   PARTITION ASIA VALUES IN ('CHN','JPN','IND')  
    ->  );  
Query OK, 0 rows affected (1.13 sec)

The table has three partitions, where each partition includes a set of two or more geo\_region\_cd values. Next, let’s add a few rows to the table:

mysql> INSERT INTO sales  
    -> VALUES  
    ->  (1, 1, 1, '2020-01-18', 'US\_NE', 2765.15),  
    ->  (2, 3, 4, '2020-02-07', 'CAN', 5322.08),  
    ->  (3, 6, 27, '2020-03-11',   
'KOR'  
, 4267.12);  
ERROR 1526 (HY000): Table has no partition for value from column\_list

It looks like there was a problem, and the error message indicates that one of the geographic region codes was not assigned to a partition. Looking at the create table statement, I see that I forgot to add Korea to the asia partition. This can be fixed using an alter table statement:

mysql> ALTER TABLE sales REORGANIZE PARTITION ASIA INTO  
    ->  (PARTITION ASIA VALUES IN ('CHN','JPN','IND',   
'KOR'  
));  
Query OK, 0 rows affected (1.28 sec)  
Records: 0  Duplicates: 0  Warnings: 0

That seemed to do the trick, but let’s check the metadata just to be sure:

mysql> SELECT partition\_name, partition\_expression,  
    ->   partition\_description  
    -> FROM information\_schema.partitions  
    -> WHERE table\_name = 'sales'  
    -> ORDER BY partition\_ordinal\_position;  
+----------------+----------------------+---------------------------------+  
| PARTITION\_NAME | PARTITION\_EXPRESSION | PARTITION\_DESCRIPTION           |  
+----------------+----------------------+---------------------------------+  
| NORTHAMERICA   | `geo\_region\_cd`      | 'US\_NE','US\_SE','US\_MW','US\_NW',|  
| | | 'US\_SW','CAN','MEX' |  
| EUROPE         | `geo\_region\_cd`      | 'EUR\_E','EUR\_W'                 |  
| ASIA           | `geo\_region\_cd`      | 'CHN','JPN','IND',  
'KOR'           
|  
+----------------+----------------------+---------------------------------+  
3 rows in set (0.00 sec)

Korea has indeed been added to the asia partition, and the data insertion will now proceed without any issues:

mysql> INSERT INTO sales  
    -> VALUES  
    ->  (1, 1, 1, '2020-01-18', 'US\_NE', 2765.15),  
    ->  (2, 3, 4, '2020-02-07', 'CAN', 5322.08),  
    ->  (3, 6, 27, '2020-03-11',   
'KOR'  
, 4267.12);  
Query OK, 3 rows affected (0.26 sec)  
Records: 3  Duplicates: 0  Warnings: 0

While range partitioning allows for a maxvalue partition to catch any rows that don’t map to any other partition, it’s important to keep in mind that list partitioning doesn’t provide for a spillover partition. Thus, any time you need to add another column value (e.g., the company starts selling products in Australia), you will need to modify the partitioning definition before rows with the new value can be added to the table.

## Hash partitioning

If your partition key column doesn’t lend itself to range or list partitioning, there is a third option that endeavors to distribute rows evenly across a set of partitions. The server does this by applying a hashing function to the column value, and this type of partitioning is (not surprisingly) called hash partitioning. Unlike list partitioning, where the column chosen as the partitioning key should contain only a small number of values, hash partitioning works best when the partitioning key column contains a large number of distinct values. Here’s another version of the sales table but with four hash partitions generated by hashing the values in the cust\_id column:

mysql> CREATE TABLE sales  
    ->  (sale\_id INT NOT NULL,  
    ->   cust\_id INT NOT NULL,  
    ->   store\_id INT NOT NULL,  
    ->   sale\_date DATE NOT NULL,  
    ->   amount DECIMAL(9,2)  
    ->  )  
    -> PARTITION BY HASH (cust\_id)  
    ->   PARTITIONS 4  
    ->    (PARTITION H1,  
    ->     PARTITION H2,  
    ->     PARTITION H3,  
    ->     PARTITION H4  
    ->    );  
Query OK, 0 rows affected (1.50 sec)

When rows are added to the sales table, they will be evenly distributed across the four partitions, which I named H1, H2, H3, and H4. In order to see how good a job it does, let’s add 16 rows, each with a different value for the cust\_id column:

mysql> INSERT INTO sales  
    -> VALUES  
    ->  (1, 1, 1, '2020-01-18', 1.1), (2, 3, 4, '2020-02-07', 1.2),  
    ->  (3, 17, 5, '2020-01-19', 1.3), (4, 23, 2, '2020-02-08', 1.4),  
    ->  (5, 56, 1, '2020-01-20', 1.6), (6, 77, 5, '2020-02-09', 1.7),  
    ->  (7, 122, 4, '2020-01-21', 1.8), (8, 153, 1, '2020-02-10', 1.9),  
    ->  (9, 179, 5, '2020-01-22', 2.0), (10, 244, 2, '2020-02-11', 2.1),  
    ->  (11, 263, 1, '2020-01-23', 2.2), (12, 312, 4, '2020-02-12', 2.3),  
    ->  (13, 346, 2, '2020-01-24', 2.4), (14, 389, 3, '2020-02-13', 2.5),  
    ->  (15, 472, 1, '2020-01-25', 2.6), (16, 502, 1, '2020-02-14', 2.7);  
Query OK, 16 rows affected (0.19 sec)  
Records: 16  Duplicates: 0  Warnings: 0

If the hashing function does a good job of distributing the rows evenly, we should ideally see four rows in each of the four partitions:

mysql> SELECT concat('# of rows in H1 = ', count(\*)) partition\_rowcount  
    -> FROM sales PARTITION (h1) UNION ALL  
    -> SELECT concat('# of rows in H2 = ', count(\*)) partition\_rowcount  
    -> FROM sales PARTITION (h2) UNION ALL  
    -> SELECT concat('# of rows in H3 = ', count(\*)) partition\_rowcount  
    -> FROM sales PARTITION (h3) UNION ALL  
    -> SELECT concat('# of rows in H4 = ', count(\*)) partition\_rowcount  
    -> FROM sales PARTITION (h4);  
+---------------------+  
| partition\_rowcount  |  
+---------------------+  
| # of rows in H1 = 4 |  
| # of rows in H2 = 5 |  
| # of rows in H3 = 3 |  
| # of rows in H4 = 4 |  
+---------------------+  
4 rows in set (0.00 sec)

Given that only 16 rows were inserted, this is a pretty good distribution, and as the number of rows increases, each partition should contain close to 25% of the rows as long as there are a reasonably large number of distinct values for the cust\_id column.

## Composite partitioning

If you need finer-grained control of how data is allocated to your partitions, you can employ composite partitioning, which allows you to use two different types of partitioning for the same table. With composite partitioning, the first partitioning method defines the partitions, and the second partitioning method defines the subpartitions. Here’s an example, again using the sales table, utilizing both range and hash partitioning:

mysql> CREATE TABLE sales  
    ->  (sale\_id INT NOT NULL,  
    ->   cust\_id INT NOT NULL,  
    ->   store\_id INT NOT NULL,  
    ->   sale\_date DATE NOT NULL,  
    ->   amount DECIMAL(9,2)  
    ->  )  
    -> PARTITION BY RANGE (yearweek(sale\_date))  
    -> SUBPARTITION BY HASH (cust\_id)  
    ->  (PARTITION s1 VALUES LESS THAN (202002)  
    ->     (SUBPARTITION s1\_h1,  
    ->      SUBPARTITION s1\_h2,  
    ->      SUBPARTITION s1\_h3,  
    ->      SUBPARTITION s1\_h4),  
    ->   PARTITION s2 VALUES LESS THAN (202003)  
    ->     (SUBPARTITION s2\_h1,  
    ->      SUBPARTITION s2\_h2,  
    ->      SUBPARTITION s2\_h3,  
    ->      SUBPARTITION s2\_h4),  
    ->   PARTITION s3 VALUES LESS THAN (202004)  
    ->     (SUBPARTITION s3\_h1,  
    ->      SUBPARTITION s3\_h2,  
    ->      SUBPARTITION s3\_h3,  
    ->      SUBPARTITION s3\_h4),  
    ->   PARTITION s4 VALUES LESS THAN (202005)  
    ->     (SUBPARTITION s4\_h1,  
    ->      SUBPARTITION s4\_h2,  
    ->      SUBPARTITION s4\_h3,  
    ->      SUBPARTITION s4\_h4),  
    ->   PARTITION s5 VALUES LESS THAN (202006)  
    ->     (SUBPARTITION s5\_h1,  
    ->      SUBPARTITION s5\_h2,  
    ->      SUBPARTITION s5\_h3,  
    ->      SUBPARTITION s5\_h4),  
    ->   PARTITION s999 VALUES LESS THAN (MAXVALUE)  
    ->     (SUBPARTITION s999\_h1,  
    ->      SUBPARTITION s999\_h2,  
    ->      SUBPARTITION s999\_h3,  
    ->      SUBPARTITION s999\_h4)  
    ->  );  
Query OK, 0 rows affected (9.72 sec)

There are 6 partitions, each having 4 subpartitions, for a total of 24 subpartitions. Next, let’s reinsert the 16 rows from the earlier example for hash partitioning:

mysql> INSERT INTO sales  
    -> VALUES  
    ->  (1, 1, 1, '2020-01-18', 1.1), (2, 3, 4, '2020-02-07', 1.2),  
    ->  (3, 17, 5, '2020-01-19', 1.3), (4, 23, 2, '2020-02-08', 1.4),  
    ->  (5, 56, 1, '2020-01-20', 1.6), (6, 77, 5, '2020-02-09', 1.7),  
    ->  (7, 122, 4, '2020-01-21', 1.8), (8, 153, 1, '2020-02-10', 1.9),  
    ->  (9, 179, 5, '2020-01-22', 2.0), (10, 244, 2, '2020-02-11', 2.1),  
    ->  (11, 263, 1, '2020-01-23', 2.2), (12, 312, 4, '2020-02-12', 2.3),  
    ->  (13, 346, 2, '2020-01-24', 2.4), (14, 389, 3, '2020-02-13', 2.5),  
    ->  (15, 472, 1, '2020-01-25', 2.6), (16, 502, 1, '2020-02-14', 2.7);  
Query OK, 16 rows affected (0.22 sec)  
Records: 16  Duplicates: 0  Warnings: 0

When you query the sales table, you can retrieve data from one of the partitions, in which case you retrieve data from the four subpartitions associated with the partition:

mysql> SELECT \*  
    -> FROM sales   
PARTITION (s3)  
;  
+---------+---------+----------+------------+--------+  
| sale\_id | cust\_id | store\_id | sale\_date  | amount |  
+---------+---------+----------+------------+--------+  
|       5 |      56 |        1 | 2020-01-20 |   1.60 |  
|      15 |     472 |        1 | 2020-01-25 |   2.60 |  
|       3 |      17 |        5 | 2020-01-19 |   1.30 |  
|       7 |     122 |        4 | 2020-01-21 |   1.80 |  
|      13 |     346 |        2 | 2020-01-24 |   2.40 |  
|       9 |     179 |        5 | 2020-01-22 |   2.00 |  
|      11 |     263 |        1 | 2020-01-23 |   2.20 |  
+---------+---------+----------+------------+--------+  
7 rows in set (0.00 sec)

Because the table is subpartitioned, you may also retrieve data from a single subpartition:

mysql> SELECT \*  
    -> FROM sales PARTITION (  
s3\_h3  
);  
+---------+---------+----------+------------+--------+  
| sale\_id | cust\_id | store\_id | sale\_date  | amount |  
+---------+---------+----------+------------+--------+  
|       7 |     122 |        4 | 2020-01-21 |   1.80 |  
|      13 |     346 |        2 | 2020-01-24 |   2.40 |  
+---------+---------+----------+------------+--------+  
2 rows in set (0.00 sec)

This query retrieves data only from the s3\_h3 subpartition of the s3 partition.

## Partitioning Benefits

One major advantage to partitioning is that you may only need to interact with as few as one partition, rather than the entire table. For example, if your table is range-partitioned on the sales\_date column and you execute a query that includes a filter condition such as WHERE sales\_date BETWEEN '2019-12-01' AND '2020-01-15', the server will check the table’s metadata to determine which partitions actually need to be included. This concept is called partition pruning, and it is one of the biggest advantages of table partitioning.

Similarly, if you execute a query that includes a join to a partitioned table and the query includes a condition on the partitioning column, the server can exclude any partitions that do not contain data pertinent to the query. This is known as partition-wise joins, and it is similar to partition pruning in that only those partitions that contain data needed by the query will be included.

From an administrative standpoint, one of the main benefits to partitioning is the ability to quickly delete data that is no longer needed. For example, financial data may need to be kept online for seven years; if a table has been partitioned based on transaction dates, any partitions holding data greater than seven years old can be dropped. Another administrative advantage to partitioned tables is the ability to perform updates on multiple partitions simultaneously, which can greatly reduce the time needed to touch every row in a table.

# Clustering

With enough storage combined with a reasonable partitioning strategy, you can store a great deal of data in a single relational database. But what happens if you need to handle thousands of concurrent users or generate tens of thousands of reports during a nightly cycle? Even if you have sufficient data storage, you may not have enough CPU, memory, or network bandwidth within a single server. One potential answer is clustering, which allows multiple servers to act as a single database.

Although there are several different clustering architectures, for the purposes of this discussion I am referring to shared-disk/shared-cache configurations, where every server in the cluster has access to all disks, and data cached in one server can be accessed by any other server in the cluster. With this type of architecture, an application server could attach to any one of the database servers in the cluster, with connections automatically failing over to another server in the cluster in case of failure. With an eight-server cluster, you should be able to handle a very large number of concurrent users and associated queries/reports/jobs.

Of the commercial database vendors, Oracle is the leader in this space, with many of the world’s biggest companies using the Oracle Exadata platform to host extremely large databases accessed by thousands of concurrent users. However, even this platform fails to meet the needs of the biggest companies, which led Google, Facebook, Amazon, and other companies to blaze new trails.

# Sharding

Let’s say you have been hired as the data architect for a new social media company. You are told to expect approximately one billion users, each of whom will generate 3.7 messages per day on average, and the data must be available indefinitely. After performing a few calculations, you determine that you would exhaust the biggest available relational database platform in less than a year. One possibility would be to partition not just individual tables but the entire database. Known as sharding, this approach partitions the data across multiple databases (called shards), so it is similar to table partitioning but on a larger scale and with far more complexity. If you were to employ this strategy for the social media company, you might decide to implement 100 separate databases, each one hosting the data for approximately 10 million users.

Sharding is a complex topic, and since this is an introductory book, I will refrain from going into detail, but here are a few of the issues that would need to be addressed:

* You will need to choose a sharding key, which is the value used to determine to which database to connect.
* While large tables will be divided into pieces, with individual rows assigned to a single shard, smaller reference tables may need to be replicated to all shards, and a strategy needs to be defined for how reference data can be modified and changes propagated to all shards.
* If individual shards become too large (e.g., the social media company now has two billion users), you will need a plan for adding more shards and redistributing data across the shards.
* When you need to make schema changes, you will need to have a strategy for deploying the changes across all of the shards so that all schemas stay in sync.
* If application logic needs to access data stored in two or more shards, you need to have a strategy for how to query across multiple databases and also how to implement transactions across multiple databases.

If this seems complicated, that’s because it is, and by the late 2000s many companies began looking for new approaches. The next section looks at other strategies for handling very large data sets completely outside the realm of relational databases.

# Big Data

After spending some time weighing the pros and cons of sharding, let’s say that you (the data architect of the social media company) decide to investigate other approaches. Rather than attempting to forge your own path, you might benefit from reviewing the work done by other companies that deal with massive amounts of data: companies like Amazon, Google, Facebook, and Twitter. Together, the set of technologies pioneered by these companies (and others) has been branded as big data, which has become an industry buzzword but has several possible definitions. One way to define the boundaries of big data is with the “3 Vs”:

Volume

In this context, volume generally means billions or trillions of data points.

Velocity

This is a measure of how quickly data arrives.

Variety

This means that data is not always structured (as in rows and columns in a relational database) but can also be unstructured (e.g., emails, videos, photos, audio files, etc.).

So, one way to characterize big data is any system designed to handle a huge amount of data of various formats arriving at a rapid pace. The following sections offer a quick description of some of the big data technologies that have evolved over the past 15 years or so.

## Hadoop

Hadoop is best described as an ecosystem, or a set of technologies and tools that work together. Some of the major components of Hadoop include:

Hadoop Distributed File System (HDFS)

Like the name implies, HDFS enables file management across a large number of servers.

MapReduce

This technology processes large amounts of structured and unstructured data by breaking a task into many small pieces that can be run in parallel across many servers.

YARN

This is a resource manager and job scheduler for HDFS.

Together, these technologies allow for the storage and processing of files across hundreds or even thousands of servers acting as a single logical system. While Hadoop is widely used, querying the data using MapReduce generally requires a programmer, which has led to the development of several SQL interfaces, including Hive, Impala, and Drill.

## NoSQL and Document Databases

In a relational database, data must generally conform to a predefined schema consisting of tables made up of columns holding numbers, strings, dates, etc. What happens, however, if the structure of the data isn’t known beforehand or if the structure is known but changes frequently? The answer for many companies is to combine both the data and schema definition into documents using a format such as XML or JSON and then store the documents in a database. By doing so, various types of data can be stored in the same database without the need to make schema modifications, which makes storage easier but puts the burden on query and analytic tools to make sense of the data stored in the documents.

Document databases are a subset of what are called NoSQL databases, which typically store data using a simple key-value mechanism. For example, using a document database such as MongoDB, you could utilize the customer ID as the key to store a JSON document containing all of the customer’s data, and other users can read the schema stored within the document to make sense of the data stored within.

## Cloud Computing

Prior to the advent of big data, most companies had to build their own data centers to house the database, web, and application servers used across the enterprise. With the advent of cloud computing, you can choose to essentially outsource your data center to platforms such as Amazon Web Services (AWS), Microsoft Azure, or Google Cloud. One of the biggest benefits to hosting your services in the cloud is instant scalability, which allows you to quickly dial up or down the amount of computing power needed to run your services. Startups love these platforms because they can start writing code without spending any money up front for servers, storage, networks, or software licenses.

As far as databases are concerned, a quick look at AWS’s database and analytics offerings yields the following options:

* Relational databases (MySQL, Aurora, PostgreSQL, MariaDB, Oracle, and SQL Server)
* In-memory database (ElastiCache)
* Data warehousing database (Redshift)
* NoSQL database (DynamoDB)
* Document database (DocumentDB)
* Graph database (Neptune)
* Time-series database (TimeStream)
* Hadoop (EMR)
* Data lakes (Lake Formation)

While relational databases dominated the landscape up until the mid-2000s, it’s pretty easy to see that companies are now mixing and matching various platforms and that relational databases may become less popular over time.

# Conclusion

Databases are getting larger, but at the same time storage, clustering, and partitioning technologies are becoming more robust. Working with huge amounts of data can be quite challenging, regardless of the technology stack. Whether you use relational databases, big data platforms, or a variety of database servers, SQL is evolving to facilitate data retrieval from various technologies. This will be the subject of the last chapter in this book, where I will demonstrate the use of a SQL engine to query data stored in multiple formats.

# Chapter 18. SQL and Big Data

While most of the content in this book covers the various features of the SQL language when using a relational database such as MySQL, the data landscape has changed quite a bit over the past decade, and SQL is changing to meet the needs of today’s rapidly evolving environments. Many organizations that had used relational databases exclusively just a few years ago are now also housing data in Hadoop clusters, data lakes, and NoSQL databases. At the same time, companies are struggling to find ways to gain insights from the ever-growing volumes of data, and the fact that this data is now spread across multiple data stores, perhaps both on-site and in the cloud, makes this a daunting task.

Because SQL is used by millions of people and has been integrated into thousands of applications, it makes sense to leverage SQL to harness this data and make it actionable. Over the past several years, a new breed of tools has emerged to enable SQL access to structured, semi-structured, and unstructured data: tools such as Presto, Apache Drill, and Toad Data Point. This chapter explores one of these tools, Apache Drill, to demonstrate how data in different formats and stored on different servers can be brought together for reporting and analysis.

# Introduction to Apache Drill

There have been numerous tools and interfaces developed to allow SQL access to data stored in Hadoop, NoSQL, Spark, and cloud-based distributed filesystems. Examples include Hive, which was one of the first attempts to allow users to query data stored in Hadoop, and Spark SQL, which is a library used to query data stored in various formats from within Spark. One relative newcomer is the open source Apache Drill, which first hit the scene in 2015 and has the following compelling features:

* Facilitates queries across multiple data formats, including delimited data, JSON, Parquet, and log files
* Connects to relational databases, Hadoop, NoSQL, HBase, and Kafka, as well as specialized data formats such as PCAP, BlockChain, and others
* Allows creation of custom plug-ins to connect to most any other data store
* Requires no up-front schema definitions
* Supports the SQL:2003 standard
* Works with popular business intelligence (BI) tools like Tableau and Apache Superset

Using Drill, you can connect to any number of data sources and begin querying, without the need to first set up a metadata repository. While it is beyond the scope of this book to discuss the installation and configuration options for Apache Drill, if you are interested in learning more, I highly recommend [Learning Apache Drill](https://learning.oreilly.com/library/view/learning-apache-drill/9781492032786/) by Charles Givre and Paul Rogers (O’Reilly).

# Querying Files Using Drill

Let’s start by using Drill to query data in a file. Drill understands how to read several different file formats, including packet capture (PCAP) files, which are in binary format and contain information about packets traveling over a network. All I have to do when I want to query a PCAP file is to configure Drill’s dfs (distributed filesystem) plug-in to include the path to the directory containing my files, and I’m ready to write queries.

The first thing I’d like to do is find out what columns are available in the file I will be querying. Drill includes partial support for information\_schema (covered in [Chapter 15](#Chapter_15__Metadata__Along_with_2)), so you can find out high-level information about the data files in your workspace:

apache drill> SELECT file\_name, is\_directory, is\_file, permission  
. . . . . . > FROM   
information\_schema.`files`  
  
. . . . . . > WHERE schema\_name = 'dfs.data';  
+-------------------+--------------+---------+------------+  
|     file\_name     | is\_directory | is\_file | permission |  
+-------------------+--------------+---------+------------+  
|   
attack-trace.pcap  
 | false        | true    | rwxrwx---  |  
+-------------------+--------------+---------+------------+  
1 row selected (0.238 seconds)

The results show that I have a single file named attack-trace.pcap in my data workspace, which is useful information, but I can’t query information\_schema.columns to find out what columns are available in the file. However, executing a query that returns no rows against the file will show the set of available columns:[1](#1_These_results_show_the_columns)

apache drill> SELECT \* FROM dfs.data.`attack-trace.pcap`  
. . . . . . >   
WHERE 1=2  
;  
+------+---------+-----------+-----------------+--------+--------+  
| type | network | timestamp | timestamp\_micro | src\_ip | dst\_ip |   
+------+---------+-----------+-----------------+--------+--------+  
 ​----------+----------+-----------------+-----------------+-------------+  
 ​ src\_port | dst\_port | src\_mac\_address | dst\_mac\_address | tcp\_session |  
​ ----------+----------+-----------------+-----------------+-------------+  
 ​---------+-----------+--------------+---------------+----------------+  
​ tcp\_ack | tcp\_flags | tcp\_flags\_ns | tcp\_flags\_cwr | tcp\_flags\_ece  |  
 ---------+-----------+--------------+---------------+----------------+  
 ---------------------------+--------------------------------------+  
​ tcp\_flags\_ece\_ecn\_capable | tcp\_flags\_ece\_congestion\_experienced |  
 ---------------------------+--------------------------------------+  
​ ---------------+---------------+---------------+---------------+  
​ tcp\_flags\_urg | tcp\_flags\_ack | tcp\_flags\_psh | tcp\_flags\_rst |   
​ ---------------+---------------+---------------+---------------+  
​ ---------------+---------------+------------------+---------------+  
 tcp\_flags\_syn | tcp\_flags\_fin | tcp\_parsed\_flags | packet\_length |  
​ ---------------+---------------+------------------+---------------+  
 ​------------+------+  
  is\_corrupt | data |  
​ ------------+------+  
  
No rows selected (0.285 seconds)

Now that I know the names of the columns in a PCAP file, I’m ready to write queries. Here’s a query that counts the number of packets sent from each IP address to each destination port:

apache drill> SELECT src\_ip, dst\_port,  
. . . . . . >   count(\*) AS packet\_count  
. . . . . . > FROM dfs.data.`attack-trace.pcap`  
. . . . . . > GROUP BY src\_ip, dst\_port;  
+----------------+----------+--------------+  
|     src\_ip     | dst\_port | packet\_count |  
+----------------+----------+--------------+  
| 98.114.205.102 | 445      | 18           |  
| 192.150.11.111 | 1821     | 3            |  
| 192.150.11.111 | 1828     | 17           |  
| 98.114.205.102 | 1957     | 6            |  
| 192.150.11.111 | 1924     | 6            |  
| 192.150.11.111 | 8884     | 15           |  
| 98.114.205.102 | 36296    | 12           |  
| 98.114.205.102 | 1080     | 159          |  
| 192.150.11.111 | 2152     | 112          |  
+----------------+----------+--------------+  
9 rows selected (0.254 seconds)

Here’s another query that aggregates packet information for each second:

apache drill> SELECT trunc(extract(second from `timestamp`)) as packet\_time,  
. . . . . . >   count(\*) AS num\_packets,  
. . . . . . >   sum(packet\_length) AS tot\_volume  
. . . . . . > FROM dfs.data.`attack-trace.pcap`  
. . . . . . > GROUP BY trunc(extract(second from `timestamp`));  
+-------------+-------------+------------+  
| packet\_time | num\_packets | tot\_volume |  
+-------------+-------------+------------+  
| 28.0        | 15          | 1260       |  
| 29.0        | 12          | 1809       |  
| 30.0        | 13          | 4292       |  
| 31.0        | 3           | 286        |  
| 32.0        | 2           | 118        |  
| 33.0        | 15          | 1054       |  
| 34.0        | 35          | 14446      |  
| 35.0        | 29          | 16926      |  
| 36.0        | 25          | 16710      |  
| 37.0        | 25          | 16710      |  
| 38.0        | 26          | 17788      |  
| 39.0        | 23          | 15578      |  
| 40.0        | 25          | 16710      |  
| 41.0        | 23          | 15578      |  
| 42.0        | 30          | 20052      |  
| 43.0        | 25          | 16710      |  
| 44.0        | 22          | 7484       |  
+-------------+-------------+------------+  
17 rows selected (0.422 seconds)

In this query, I needed to put backticks (`) around timestamp because it is a reserved word.

You can query files stored locally, on your network, in a distributed filesystem, or in the cloud. Drill has built-in support for many file types, but you can also build your own plug-in to allow Drill to query any type of file. The next two sections will explore querying data stored in a database.

# Querying MySQL Using Drill

Drill can connect to any relational database via a JDBC driver, so the next logical step is to show how Drill can query the Sakila sample database used for the examples in this book. All you need to do to get started is to load the JDBC driver for MySQL and configure Drill to connect to the MySQL database.

##### Note

At this point, you may be wondering, “Why would I use Drill to query MySQL?” One reason is that (as you will see at the end of this chapter) you can write queries using Drill that combine data from different sources, so you might write a query that joins data from MySQL, Hadoop, and comma-delimited files, for example.

The first step is to choose a database:

apache drill (information\_schema)>   
use mysql.sakila  
;  
+------+------------------------------------------+  
|  ok  |                 summary                  |  
+------+------------------------------------------+  
| true | Default schema changed to [mysql.sakila] |  
+------+------------------------------------------+  
1 row selected (0.062 seconds)

After choosing the database, you can issue the show tables command to see all of the tables available in the chosen schema:

apache drill (mysql.sakila)>   
show tables;  
  
+--------------+----------------------------+  
| TABLE\_SCHEMA |         TABLE\_NAME         |  
+--------------+----------------------------+  
| mysql.sakila | actor                      |  
| mysql.sakila | address                    |  
| mysql.sakila | category                   |  
| mysql.sakila | city                       |  
| mysql.sakila | country                    |  
| mysql.sakila | customer                   |  
| mysql.sakila | film                       |  
| mysql.sakila | film\_actor                 |  
| mysql.sakila | film\_category              |  
| mysql.sakila | film\_text                  |  
| mysql.sakila | inventory                  |  
| mysql.sakila | language                   |  
| mysql.sakila | payment                    |  
| mysql.sakila | rental                     |  
| mysql.sakila | sales                      |  
| mysql.sakila | staff                      |  
| mysql.sakila | store                      |  
| mysql.sakila | actor\_info                 |  
| mysql.sakila | customer\_list              |  
| mysql.sakila | film\_list                  |  
| mysql.sakila | nicer\_but\_slower\_film\_list |  
| mysql.sakila | sales\_by\_film\_category     |  
| mysql.sakila | sales\_by\_store             |  
| mysql.sakila | staff\_list                 |  
+--------------+----------------------------+  
24 rows selected (0.147 seconds)

I will start by executing a few queries demonstrated in earlier chapters. Here’s a simple two-table join from [Chapter 5](#Chapter_5__Querying_Multiple_Tab_2):

apache drill (mysql.sakila)> SELECT a.address\_id, a.address, ct.city  
. . . . . . . . . . . . . )> FROM address a  
. . . . . . . . . . . . . )>   INNER JOIN city ct  
. . . . . . . . . . . . . )>   ON a.city\_id = ct.city\_id  
. . . . . . . . . . . . . )> WHERE a.district = 'California';  
+------------+------------------------+----------------+  
| address\_id |        address         |      city      |  
+------------+------------------------+----------------+  
| 6          | 1121 Loja Avenue       | San Bernardino |  
| 18         | 770 Bydgoszcz Avenue   | Citrus Heights |  
| 55         | 1135 Izumisano Parkway | Fontana        |  
| 116        | 793 Cam Ranh Avenue    | Lancaster      |  
| 186        | 533 al-Ayn Boulevard   | Compton        |  
| 218        | 226 Brest Manor        | Sunnyvale      |  
| 274        | 920 Kumbakonam Loop    | Salinas        |  
| 425        | 1866 al-Qatif Avenue   | El Monte       |  
| 599        | 1895 Zhezqazghan Drive | Garden Grove   |  
+------------+------------------------+----------------+  
9 rows selected (3.523 seconds)

The next query comes from [Chapter 8](#Chapter_8__Grouping_and_Aggregat_2) and includes both a group by clause and a having clause:

apache drill (mysql.sakila)> SELECT fa.actor\_id, f.rating,   
. . . . . . . . . . . . . )> count(\*) num\_films  
. . . . . . . . . . . . . )> FROM film\_actor fa  
. . . . . . . . . . . . . )>   INNER JOIN film f  
. . . . . . . . . . . . . )>   ON fa.film\_id = f.film\_id  
. . . . . . . . . . . . . )> WHERE f.rating IN ('G','PG')  
. . . . . . . . . . . . . )>   
GROUP BY fa.actor\_id, f.rating  
  
. . . . . . . . . . . . . )>   
HAVING count(\*) > 9;  
  
+----------+--------+-----------+  
| actor\_id | rating | num\_films |  
+----------+--------+-----------+  
| 137      | PG     | 10        |  
| 37       | PG     | 12        |  
| 180      | PG     | 12        |  
| 7        | G      | 10        |  
| 83       | G      | 14        |  
| 129      | G      | 12        |  
| 111      | PG     | 15        |  
| 44       | PG     | 12        |  
| 26       | PG     | 11        |  
| 92       | PG     | 12        |  
| 17       | G      | 12        |  
| 158      | PG     | 10        |  
| 147      | PG     | 10        |  
| 14       | G      | 10        |  
| 102      | PG     | 11        |  
| 133      | PG     | 10        |  
+----------+--------+-----------+  
16 rows selected (0.277 seconds)

Finally, here is a query from [Chapter 16](#Chapter_16__Analytic_Functions_2) that includes three different ranking functions:

apache drill (mysql.sakila)> SELECT customer\_id, count(\*) num\_rentals,  
. . . . . . . . . . . . . )>     
row\_number()  
   
. . . . . . . . . . . . . )>  over (order by count(\*) desc)   
. . . . . . . . . . . . . )>     row\_number\_rnk,  
. . . . . . . . . . . . . )>     
rank()  
   
. . . . . . . . . . . . . )>  over (order by count(\*) desc) rank\_rnk,  
. . . . . . . . . . . . . )>     
dense\_rank()  
   
. . . . . . . . . . . . . )>  over (order by count(\*) desc)  
. . . . . . . . . . . . . )>       dense\_rank\_rnk  
. . . . . . . . . . . . . )> FROM rental  
. . . . . . . . . . . . . )> GROUP BY customer\_id  
. . . . . . . . . . . . . )> ORDER BY 2 desc;  
+-------------+-------------+----------------+----------+----------------+  
| customer\_id | num\_rentals | row\_number\_rnk | rank\_rnk | dense\_rank\_rnk |  
+-------------+-------------+----------------+----------+----------------+  
| 148         | 46          | 1              | 1        | 1              |  
| 526         | 45          | 2              | 2        | 2              |  
| 144         | 42          | 3              | 3        | 3              |  
| 236         | 42          | 4              | 3        | 3              |  
| 75          | 41          | 5              | 5        | 4              |  
| 197         | 40          | 6              | 6        | 5              |  
...  
| 248         | 15          | 595            | 594      | 30             |  
| 61          | 14          | 596            | 596      | 31             |  
| 110         | 14          | 597            | 596      | 31             |  
| 281         | 14          | 598            | 596      | 31             |  
| 318         | 12          | 599            | 599      | 32             |  
+-------------+-------------+----------------+----------+----------------+  
599 rows selected (1.827 seconds)

These few examples demonstrate Drill’s ability to execute reasonably complex queries against MySQL, but you will need to keep in mind that Drill works with many relational databases, not just MySQL, so some features of the language may differ (e.g., data conversion functions). For more information, read [Drill’s documentation about their SQL implementation](https://oreil.ly/d2JSe).

# Querying MongoDB Using Drill

After using Drill to query the sample Sakila data in MySQL, the next logical step is to convert the Sakila data to another commonly used format, store it in a nonrelational database, and use Drill to query the data. I decided to convert the data to JSON and store it in MongoDB, which is one of the more popular NoSQL platforms for document storage. Drill includes a plug-in for MongoDB and also understands how to read JSON documents, so it was relatively easy to load the JSON files into Mongo and begin writing queries.

Before diving into the queries, let’s take a look at the structure of the JSON files, since they aren’t in normalized form. The first of the two JSON files is films.json:

{"\_id":1,  
 "Actors":[  
   {"First name":"PENELOPE","Last name":"GUINESS","actorId":1},  
   {"First name":"CHRISTIAN","Last name":"GABLE","actorId":10},  
   {"First name":"LUCILLE","Last name":"TRACY","actorId":20},  
   {"First name":"SANDRA","Last name":"PECK","actorId":30},  
   {"First name":"JOHNNY","Last name":"CAGE","actorId":40},  
   {"First name":"MENA","Last name":"TEMPLE","actorId":53},  
   {"First name":"WARREN","Last name":"NOLTE","actorId":108},  
   {"First name":"OPRAH","Last name":"KILMER","actorId":162},  
   {"First name":"ROCK","Last name":"DUKAKIS","actorId":188},  
   {"First name":"MARY","Last name":"KEITEL","actorId":198}],  
 "Category":"Documentary",  
 "Description":"A Epic Drama of a Feminist And a Mad Scientist  
    who must Battle a Teacher in The Canadian Rockies",  
 "Length":"86",  
 "Rating":"PG",  
 "Rental Duration":"6",  
 "Replacement Cost":"20.99",  
 "Special Features":"Deleted Scenes,Behind the Scenes",  
 "Title":"ACADEMY DINOSAUR"},  
{"\_id":2,  
 "Actors":[  
   {"First name":"BOB","Last name":"FAWCETT","actorId":19},  
   {"First name":"MINNIE","Last name":"ZELLWEGER","actorId":85},  
   {"First name":"SEAN","Last name":"GUINESS","actorId":90},  
   {"First name":"CHRIS","Last name":"DEPP","actorId":160}],  
 "Category":"Horror",  
 "Description":"A Astounding Epistle of a Database Administrator  
    And a Explorer who must Find a Car in Ancient China",  
 "Length":"48",  
 "Rating":"G",  
 "Rental Duration":"3",  
 "Replacement Cost":"12.99",  
 "Special Features":"Trailers,Deleted Scenes",  
 "Title":"ACE GOLDFINGER"},  
...  
{"\_id":999,  
 "Actors":[  
   {"First name":"CARMEN","Last name":"HUNT","actorId":52},  
   {"First name":"MARY","Last name":"TANDY","actorId":66},  
   {"First name":"PENELOPE","Last name":"CRONYN","actorId":104},  
   {"First name":"WHOOPI","Last name":"HURT","actorId":140},  
   {"First name":"JADA","Last name":"RYDER","actorId":142}],  
 "Category":"Children",  
 "Description":"A Fateful Reflection of a Waitress And a Boat  
    who must Discover a Sumo Wrestler in Ancient China",  
 "Length":"101",  
 "Rating":"R",  
 "Rental Duration":"5",  
 "Replacement Cost":"28.99",  
 "Special Features":"Trailers,Deleted Scenes",  
 "Title":"ZOOLANDER FICTION"}  
{"\_id":1000,  
 "Actors":[  
   {"First name":"IAN","Last name":"TANDY","actorId":155},  
   {"First name":"NICK","Last name":"DEGENERES","actorId":166},  
   {"First name":"LISA","Last name":"MONROE","actorId":178}],  
 "Category":"Comedy",  
 "Description":"A Intrepid Panorama of a Mad Scientist And a Boy  
    who must Redeem a Boy in A Monastery",  
 "Length":"50",  
 "Rating":"NC-17",  
 "Rental Duration":"3",  
 "Replacement Cost":"18.99",  
 "Special Features":  
 "Trailers,Commentaries,Behind the Scenes",  
 "Title":"ZORRO ARK"}

There are 1,000 documents in this collection, and each document contains a number of scalar attributes (Title, Rating, \_id) but also includes a list called Actors, which contains 1 to N elements consisting of the actor ID, first name, and last name attributes for every actor appearing in the film. Therefore, this file contains all of the data found in the actor, film, and film\_actor tables within the MySQL Sakila database.

The second file is customer.json, which combines data from the customer, address, city, country, rental, and payment tables from the MySQL Sakila database:

{"\_id":1,  
 "Address":"1913 Hanoi Way",  
 "City":"Sasebo",  
 "Country":"Japan",  
 "District":"Nagasaki",  
 "First Name":"MARY",  
 "Last Name":"SMITH",  
 "Phone":"28303384290",  
 "Rentals":[  
   {"rentalId":1185,  
    "filmId":611,  
    "staffId":2,  
    "Film Title":"MUSKETEERS WAIT",  
    "Payments":[  
      {"Payment Id":3,"Amount":5.99,"Payment Date":"2005-06-15 00:54:12"}],  
    "Rental Date":"2005-06-15 00:54:12.0",  
    "Return Date":"2005-06-23 02:42:12.0"},  
   {"rentalId":1476,  
    "filmId":308,  
    "staffId":1,  
    "Film Title":"FERRIS MOTHER",  
    "Payments":[  
      {"Payment Id":5,"Amount":9.99,"Payment Date":"2005-06-15 21:08:46"}],  
    "Rental Date":"2005-06-15 21:08:46.0",  
    "Return Date":"2005-06-25 02:26:46.0"},  
...  
   {"rentalId":14825,  
    "filmId":317,  
    "staffId":2,  
    "Film Title":"FIREBALL PHILADELPHIA",  
    "Payments":[  
      {"Payment Id":30,"Amount":1.99,"Payment Date":"2005-08-22 01:27:57"}],  
    "Rental Date":"2005-08-22 01:27:57.0",  
    "Return Date":"2005-08-27 07:01:57.0"}  
  ]  
}

This file contains 599 entries (only one was shown here), which are loaded into Mongo as 599 documents in the customers collection. Each document contains the information about a single customer, along with all of the rentals and associated payments made by that customer. Furthermore, the documents contain nested lists, since each rental in the Rentals list also contains a list of Payments.

After the JSON files have been loaded, the Mongo database contains two collections (films and customers), and the data in these collections spans nine different tables from the MySQL Sakila database. This is a fairly typical scenario, since application programmers typically work with collections and generally prefer not to deconstruct their data for storage into normalized relational tables. The challenge from an SQL perspective is to determine how to flatten this data so that it behaves as if it were stored in multiple tables.

To illustrate, let’s construct the following query against the films collection: find all actors who have appeared in 10 or more films rated either G or PG. Here’s what the raw data looks like:

apache drill (mongo.sakila)> SELECT Rating, Actors  
. . . . . . . . . . . . . )> FROM films  
. . . . . . . . . . . . . )> WHERE Rating IN ('G','PG');  
+--------+----------------------------------------------------------------+  
| Rating |                                      Actors                    |  
+--------+----------------------------------------------------------------+  
| PG     |[{"First name":"PENELOPE","Last name":"GUINESS","actorId":"1"},  
  {"First name":"FRANCES","Last name":"DAY-LEWIS","actorId":"48"},  
  {"First name":"ANNE","Last name":"CRONYN","actorId":"49"},  
  {"First name":"RAY","Last name":"JOHANSSON","actorId":"64"},  
  {"First name":"PENELOPE","Last name":"CRONYN","actorId":"104"},  
  {"First name":"HARRISON","Last name":"BALE","actorId":"115"},  
  {"First name":"JEFF","Last name":"SILVERSTONE","actorId":"180"},  
  {"First name":"ROCK","Last name":"DUKAKIS","actorId":"188"}] |  
| PG     |[{"First name":"UMA","Last name":"WOOD","actorId":"13"},  
  {"First name":"HELEN","Last name":"VOIGHT","actorId":"17"},  
  {"First name":"CAMERON","Last name":"STREEP","actorId":"24"},  
  {"First name":"CARMEN","Last name":"HUNT","actorId":"52"},  
  {"First name":"JANE","Last name":"JACKMAN","actorId":"131"},  
           {"First name":"BELA","Last name":"WALKEN","actorId":"196"}] |  
...  
| G      |[{"First name":"ED","Last name":"CHASE","actorId":"3"},  
  {"First name":"JULIA","Last name":"MCQUEEN","actorId":"27"},  
  {"First name":"JAMES","Last name":"PITT","actorId":"84"},  
  {"First name":"CHRISTOPHER","Last name":"WEST","actorId":"163"},  
  {"First name":"MENA","Last name":"HOPPER","actorId":"170"}] |  
+--------+----------------------------------------------------------------+  
372 rows selected (0.432 seconds)

The Actors field is a list of one or more actor documents. In order to interact with this data as if it were a table, the flatten command can be used to turn the list into a nested table containing three fields:

apache drill (mongo.sakila)> SELECT f.Rating,   
flatten(Actors)  
 actor\_list  
. . . . . . . . . . . . . )>   FROM films f  
. . . . . . . . . . . . . )>   WHERE f.Rating IN ('G','PG');  
+--------+----------------------------------------------------------------+  
| Rating |                             actor\_list                         |  
+--------+----------------------------------------------------------------+  
| PG     | {"First name":"PENELOPE","Last name":"GUINESS","actorId":"1"}  |  
| PG     | {"First name":"FRANCES","Last name":"DAY-LEWIS","actorId":"48"}|  
| PG     | {"First name":"ANNE","Last name":"CRONYN","actorId":"49"}      |  
| PG     | {"First name":"RAY","Last name":"JOHANSSON","actorId":"64"}    |  
| PG     | {"First name":"PENELOPE","Last name":"CRONYN","actorId":"104"} |  
| PG     | {"First name":"HARRISON","Last name":"BALE","actorId":"115"}   |  
| PG     | {"First name":"JEFF","Last name":"SILVERSTONE","actorId":"180"}|  
| PG     | {"First name":"ROCK","Last name":"DUKAKIS","actorId":"188"}    |  
| PG     | {"First name":"UMA","Last name":"WOOD","actorId":"13"}         |  
| PG     | {"First name":"HELEN","Last name":"VOIGHT","actorId":"17"}     |  
| PG     | {"First name":"CAMERON","Last name":"STREEP","actorId":"24"}   |  
| PG     | {"First name":"CARMEN","Last name":"HUNT","actorId":"52"}      |  
| PG     | {"First name":"JANE","Last name":"JACKMAN","actorId":"131"}    |  
| PG     | {"First name":"BELA","Last name":"WALKEN","actorId":"196"}     |  
...  
| G      | {"First name":"ED","Last name":"CHASE","actorId":"3"}          |  
| G      | {"First name":"JULIA","Last name":"MCQUEEN","actorId":"27"}    |  
| G      | {"First name":"JAMES","Last name":"PITT","actorId":"84"}       |  
| G      | {"First name":"CHRISTOPHER","Last name":"WEST","actorId":"163"}|  
| G      | {"First name":"MENA","Last name":"HOPPER","actorId":"170"}     |  
+--------+----------------------------------------------------------------+  
2,119 rows selected (0.718 seconds)      |

This query returns 2,119 rows, rather than the 372 rows returned by the previous query, which indicates that on average 5.7 actors appear in each G or PG film. This query can then be wrapped in a subquery and used to group the data by rating and actor, as in:

apache drill (mongo.sakila)> SELECT g\_pg\_films.Rating,  
. . . . . . . . . . . . . )>   g\_pg\_films.actor\_list.`First name` first\_name,  
. . . . . . . . . . . . . )>   g\_pg\_films.actor\_list.`Last name` last\_name,  
. . . . . . . . . . . . . )>   count(\*) num\_films  
. . . . . . . . . . . . . )> FROM  
. . . . . . . . . . . . . )>  (SELECT f.Rating, flatten(Actors) actor\_list  
. . . . . . . . . . . . . )>   FROM films f  
. . . . . . . . . . . . . )>   WHERE f.Rating IN ('G','PG')  
. . . . . . . . . . . . . )>  ) g\_pg\_films  
. . . . . . . . . . . . . )> GROUP BY g\_pg\_films.Rating,  
. . . . . . . . . . . . . )>   g\_pg\_films.actor\_list.`First name`,  
. . . . . . . . . . . . . )>   g\_pg\_films.actor\_list.`Last name`  
. . . . . . . . . . . . . )> HAVING count(\*) > 9;  
+--------+------------+-------------+-----------+  
| Rating | first\_name |  last\_name  | num\_films |  
+--------+------------+-------------+-----------+  
| PG     | JEFF       | SILVERSTONE | 12        |  
| G      | GRACE      | MOSTEL      | 10        |  
| PG     | WALTER     | TORN        | 11        |  
| PG     | SUSAN      | DAVIS       | 10        |  
| PG     | CAMERON    | ZELLWEGER   | 15        |  
| PG     | RIP        | CRAWFORD    | 11        |  
| PG     | RICHARD    | PENN        | 10        |  
| G      | SUSAN      | DAVIS       | 13        |  
| PG     | VAL        | BOLGER      | 12        |  
| PG     | KIRSTEN    | AKROYD      | 12        |  
| G      | VIVIEN     | BERGEN      | 10        |  
| G      | BEN        | WILLIS      | 14        |  
| G      | HELEN      | VOIGHT      | 12        |  
| PG     | VIVIEN     | BASINGER    | 10        |  
| PG     | NICK       | STALLONE    | 12        |  
| G      | DARYL      | CRAWFORD    | 12        |  
| PG     | MORGAN     | WILLIAMS    | 10        |  
| PG     | FAY        | WINSLET     | 10        |  
+--------+------------+-------------+-----------+  
18 rows selected (0.466 seconds)

The inner query uses the flatten command to create one row for every actor who has appeared in a G or PG movie, and the outer query simply performs a grouping on this data set.

Next, let’s write a query against the customers collection in Mongo. This is a bit more challenging since each document contains a list of film rentals, each of which contains a list of payments. To make it a little more interesting, let’s also join to the films collection in order to see how Drill handles joins. The query should return all customers who have spent more than $80 to rent films rated either G or PG. Here’s what it looks like:

apache drill (mongo.sakila)> SELECT first\_name, last\_name,  
. . . . . . . . . . . . . )>   sum(cast(cust\_payments.payment\_data.Amount  
. . . . . . . . . . . . . )>         as decimal(4,2))) tot\_payments  
. . . . . . . . . . . . . )> FROM  
. . . . . . . . . . . . . )>  (SELECT cust\_data.first\_name,  
. . . . . . . . . . . . . )>     cust\_data.last\_name,  
. . . . . . . . . . . . . )>     f.Rating,  
. . . . . . . . . . . . . )>     flatten(cust\_data.rental\_data.Payments)  
. . . . . . . . . . . . . )>       payment\_data  
. . . . . . . . . . . . . )>   FROM films f  
. . . . . . . . . . . . . )>     INNER JOIN  
. . . . . . . . . . . . . )>    (SELECT c.`First Name` first\_name,  
. . . . . . . . . . . . . )>       c.`Last Name` last\_name,  
. . . . . . . . . . . . . )>       flatten(c.Rentals) rental\_data  
. . . . . . . . . . . . . )>     FROM customers c  
. . . . . . . . . . . . . )>    ) cust\_data  
. . . . . . . . . . . . . )>     ON f.\_id = cust\_data.rental\_data.filmID  
. . . . . . . . . . . . . )>   WHERE f.Rating IN ('G','PG')  
. . . . . . . . . . . . . )>  ) cust\_payments  
. . . . . . . . . . . . . )> GROUP BY first\_name, last\_name  
. . . . . . . . . . . . . )> HAVING  
. . . . . . . . . . . . . )>   sum(cast(cust\_payments.payment\_data.Amount  
. . . . . . . . . . . . . )>         as decimal(4,2))) > 80;  
+------------+-----------+--------------+  
| first\_name | last\_name | tot\_payments |  
+------------+-----------+--------------+  
| ELEANOR    | HUNT      | 85.80        |  
| GORDON     | ALLARD    | 85.86        |  
| CLARA      | SHAW      | 86.83        |  
| JACQUELINE | LONG      | 86.82        |  
| KARL       | SEAL      | 89.83        |  
| PRISCILLA  | LOWE      | 95.80        |  
| MONICA     | HICKS     | 85.82        |  
| LOUIS      | LEONE     | 95.82        |  
| JUNE       | CARROLL   | 88.83        |  
| ALICE      | STEWART   | 81.82        |  
+------------+-----------+--------------+  
10 rows selected (1.658 seconds)

The innermost query, which I named cust\_data, flattens the Rentals list so that the cust\_payments query can join to the films collection and also flatten the Payments list. The outermost query groups the data by customer name and applies a having clause to filter out customers who spent $80 or less on films rated G or PG.

# Drill with Multiple Data Sources

So far, I have used Drill to join multiple tables stored in the same database, but what if the data is stored in different databases? For example, let’s say the customer/rental/payment data is stored in MongoDB but the catalog of film/actor data is stored in MySQL. As long as Drill is configured to connect to both databases, you just need to describe where to find the data. Here’s the query from the previous section, but instead of joining to the films collection stored in MongoDB, the join specifies the film table stored in MySQL:

apache drill (mongo.sakila)> SELECT first\_name, last\_name,  
. . . . . . . . . . . . . )>   sum(cast(cust\_payments.payment\_data.Amount  
. . . . . . . . . . . . . )>         as decimal(4,2))) tot\_payments  
. . . . . . . . . . . . . )> FROM  
. . . . . . . . . . . . . )>  (SELECT cust\_data.first\_name,  
. . . . . . . . . . . . . )>     cust\_data.last\_name,  
. . . . . . . . . . . . . )>     f.Rating,  
. . . . . . . . . . . . . )>     flatten(cust\_data.rental\_data.Payments)  
. . . . . . . . . . . . . )>       payment\_data  
. . . . . . . . . . . . . )>   FROM   
mysql.sakila.film  
 f  
. . . . . . . . . . . . . )>     INNER JOIN  
. . . . . . . . . . . . . )>    (SELECT c.`First Name` first\_name,  
. . . . . . . . . . . . . )>       c.`Last Name` last\_name,  
. . . . . . . . . . . . . )>       flatten(c.Rentals) rental\_data  
. . . . . . . . . . . . . )>     FROM   
mongo.sakila.customers  
 c  
. . . . . . . . . . . . . )>    ) cust\_data  
. . . . . . . . . . . . . )>     ON f.film\_id =  
. . . . . . . . . . . . . )>       cast(cust\_data.rental\_data.filmID as integer)  
. . . . . . . . . . . . . )>   WHERE f.rating IN ('G','PG')  
. . . . . . . . . . . . . )>  ) cust\_payments  
. . . . . . . . . . . . . )> GROUP BY first\_name, last\_name  
. . . . . . . . . . . . . )> HAVING  
. . . . . . . . . . . . . )>   sum(cast(cust\_payments.payment\_data.Amount  
. . . . . . . . . . . . . )>         as decimal(4,2))) > 80;  
+------------+-----------+--------------+  
| first\_name | last\_name | tot\_payments |  
+------------+-----------+--------------+  
| LOUIS      | LEONE     | 95.82        |  
| JACQUELINE | LONG      | 86.82        |  
| CLARA      | SHAW      | 86.83        |  
| ELEANOR    | HUNT      | 85.80        |  
| JUNE       | CARROLL   | 88.83        |  
| PRISCILLA  | LOWE      | 95.80        |  
| ALICE      | STEWART   | 81.82        |  
| MONICA     | HICKS     | 85.82        |  
| GORDON     | ALLARD    | 85.86        |  
| KARL       | SEAL      | 89.83        |  
+------------+-----------+--------------+  
10 rows selected (1.874 seconds)

Since I’m using multiple databases in the same query, I specified the full path to each table/collection to make it clear as to where the data is being sourced. This is where Drill really shines, since I can combine data from multiple sources in the same query without having to transform and load the data from one source to another.

# Future of SQL

The future of relational databases is somewhat unclear. It is possible that the big data technologies of the past decade will continue to mature and gain market share. It’s also possible that a new set of technologies will emerge, overtaking Hadoop and NoSQL, and taking additional market share from relational databases. However, most companies still run their core business functions using relational databases, and it should take a long time for this to change.

The future of SQL seems a bit clearer, however. While the SQL language started out as a mechanism for interacting with data in relational databases, tools like Apache Drill act more like an abstraction layer, facilitating the analysis of data across various database platforms. In this author’s opinion, this trend will continue, and SQL will remain a critical tool for data analysis and reporting for many years.

[1](#1_2) These results show the columns in the file based on Drill’s understanding of the PCAP file structure. If you query a file whose format is not known to Drill, the result set will contain an array of strings with a single column named columns.

# Appendix A. ER Diagram for Example Database

[Figure A-1](#Figure_A_1__ER_diagram) is an entity-relationship (ER) diagram for the example database used in this book. As the name suggests, the diagram depicts the entities, or tables, in the database along with the foreign-key relationships between the tables. Here are a few tips to help you understand the notation:

* Each rectangle represents a table, with the table name above the upper-left corner of the rectangle. The primary-key column(s) are listed first, followed by nonkey columns.
* Lines between tables represent foreign key relationships. The markings at either end of the lines represent the allowable quantity, which can be zero (0), one (1), or many (<). For example, if you look at the relationship between the customer and rental tables, you would say that a rental is associated with exactly one customer, but a customer may have zero, one, or many rentals.

For more information on entity-relationship modeling, please see [the Wikipedia entry on this topic](https://oreil.ly/hLEeq).

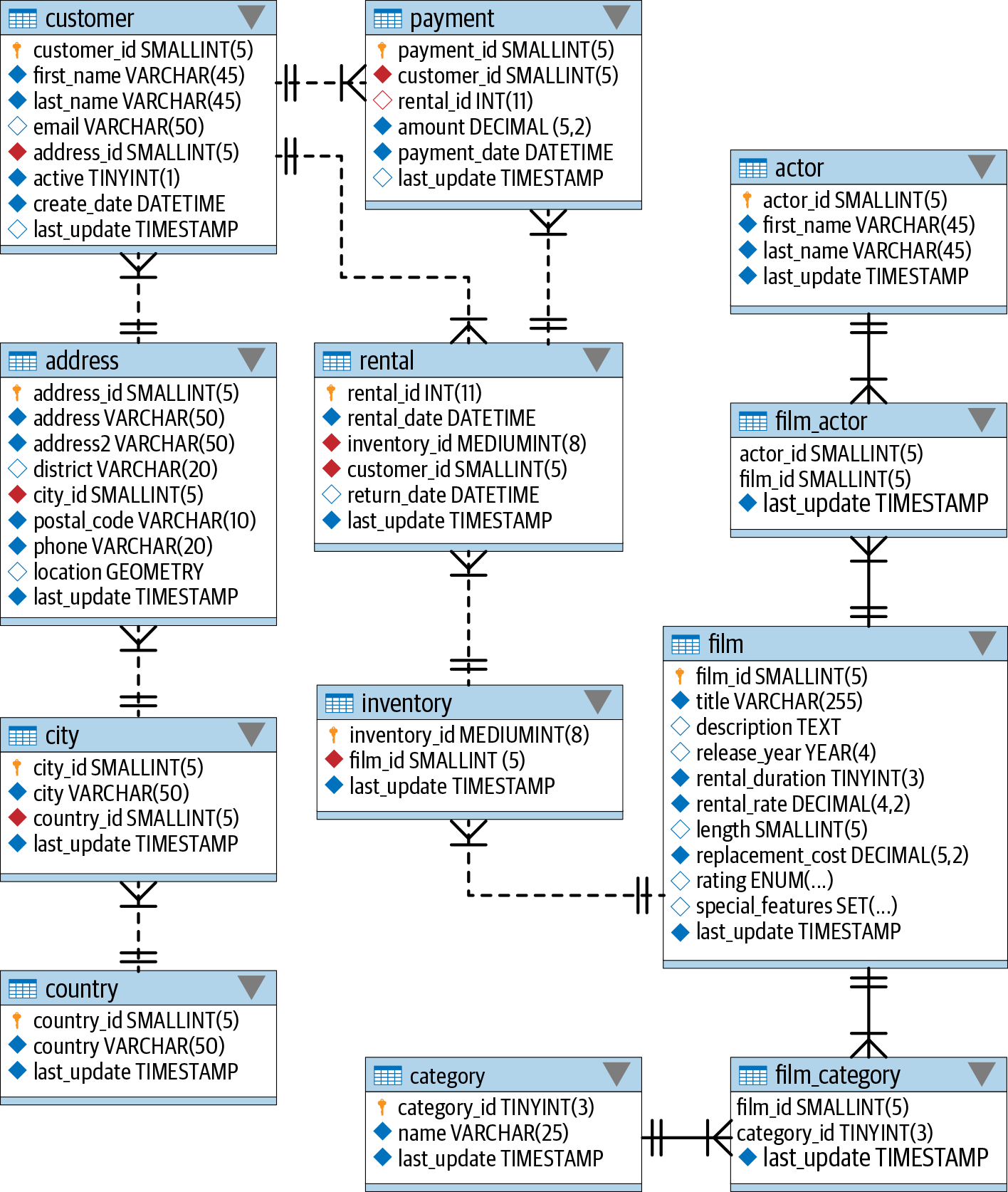


Figure A-1. ER diagram

# Appendix B. Solutions to Exercises

# Chapter 3

## Exercise 3-1

Retrieve the actor ID, first name, and last name for all actors. Sort by last name and then by first name.

mysql> SELECT actor\_id, first\_name, last\_name  
    -> FROM actor  
    -> ORDER BY 3,2;  
+----------+-------------+--------------+  
| actor\_id | first\_name  | last\_name    |  
+----------+-------------+--------------+  
|       58 | CHRISTIAN   | AKROYD       |  
|      182 | DEBBIE      | AKROYD       |  
|       92 | KIRSTEN     | AKROYD       |  
|      118 | CUBA        | ALLEN        |  
|      145 | KIM         | ALLEN        |  
|      194 | MERYL       | ALLEN        |  
...  
|       13 | UMA         | WOOD         |  
|       63 | CAMERON     | WRAY         |  
|      111 | CAMERON     | ZELLWEGER    |  
|      186 | JULIA       | ZELLWEGER    |  
|       85 | MINNIE      | ZELLWEGER    |  
+----------+-------------+--------------+  
200 rows in set (0.02 sec)

## Exercise 3-2

Retrieve the actor ID, first name, and last name for all actors whose last name equals 'WILLIAMS' or 'DAVIS'.

mysql> SELECT actor\_id, first\_name, last\_name  
    -> FROM actor  
    -> WHERE last\_name = 'WILLIAMS' OR last\_name = 'DAVIS';  
+----------+------------+-----------+  
| actor\_id | first\_name | last\_name |  
+----------+------------+-----------+  
|        4 | JENNIFER   | DAVIS     |  
|      101 | SUSAN      | DAVIS     |  
|      110 | SUSAN      | DAVIS     |  
|       72 | SEAN       | WILLIAMS  |  
|      137 | MORGAN     | WILLIAMS  |  
|      172 | GROUCHO    | WILLIAMS  |  
+----------+------------+-----------+  
6 rows in set (0.03 sec)

## Exercise 3-3

Write a query against the rental table that returns the IDs of the customers who rented a film on July 5, 2005 (use the rental.rental\_date column, and you can use the date() function to ignore the time component). Include a single row for each distinct customer ID.

mysql> SELECT DISTINCT customer\_id  
    -> FROM rental  
    -> WHERE date(rental\_date) = '2005-07-05';  
+-------------+  
| customer\_id |  
+-------------+  
|           8 |  
|          37 |  
|          60 |  
|         111 |  
|         114 |  
|         138 |  
|         142 |  
|         169 |  
|         242 |  
|         295 |  
|         296 |  
|         298 |  
|         322 |  
|         348 |  
|         349 |  
|         369 |  
|         382 |  
|         397 |  
|         421 |  
|         476 |  
|         490 |  
|         520 |  
|         536 |  
|         553 |  
|         565 |  
|         586 |  
|         594 |  
+-------------+  
27 rows in set (0.22 sec)

## Exercise 3-4

Fill in the blanks (denoted by <#>) for this multitable query to achieve the following results:

mysql> SELECT c.email, r.return\_date  
    -> FROM customer c  
    ->   INNER JOIN rental   
<1>  
  
    ->   ON c.customer\_id =   
<2>  
  
    -> WHERE date(r.rental\_date) = '2005-06-14'  
    -> ORDER BY   
<3> <4>  
;  
+---------------------------------------+---------------------+  
| email                                 | return\_date         |  
+---------------------------------------+---------------------+  
| DANIEL.CABRAL@sakilacustomer.org      | 2005-06-23 22:00:38 |  
| TERRANCE.ROUSH@sakilacustomer.org     | 2005-06-23 21:53:46 |  
| MIRIAM.MCKINNEY@sakilacustomer.org    | 2005-06-21 17:12:08 |  
| GWENDOLYN.MAY@sakilacustomer.org      | 2005-06-20 02:40:27 |  
| JEANETTE.GREENE@sakilacustomer.org    | 2005-06-19 23:26:46 |  
| HERMAN.DEVORE@sakilacustomer.org      | 2005-06-19 03:20:09 |  
| JEFFERY.PINSON@sakilacustomer.org     | 2005-06-18 21:37:33 |  
| MATTHEW.MAHAN@sakilacustomer.org      | 2005-06-18 05:18:58 |  
| MINNIE.ROMERO@sakilacustomer.org      | 2005-06-18 01:58:34 |  
| SONIA.GREGORY@sakilacustomer.org      | 2005-06-17 21:44:11 |  
| TERRENCE.GUNDERSON@sakilacustomer.org | 2005-06-17 05:28:35 |  
| ELMER.NOE@sakilacustomer.org          | 2005-06-17 02:11:13 |  
| JOYCE.EDWARDS@sakilacustomer.org      | 2005-06-16 21:00:26 |  
| AMBER.DIXON@sakilacustomer.org        | 2005-06-16 04:02:56 |  
| CHARLES.KOWALSKI@sakilacustomer.org   | 2005-06-16 02:26:34 |  
| CATHERINE.CAMPBELL@sakilacustomer.org | 2005-06-15 20:43:03 |  
+---------------------------------------+---------------------+  
16 rows in set (0.03 sec)

<1> is replaced by r.

<2> is replaced by r.customer\_id.

<3> is replaced by 2.

<4> is replaced by desc.

# Chapter 4

The following subset of rows from the payment table are used as an example for the first two exercises:

+------------+-------------+--------+--------------------+  
| payment\_id | customer\_id | amount | date(payment\_date) |  
+------------+-------------+--------+--------------------+  
|        101 |           4 |   8.99 | 2005-08-18         |  
|        102 |           4 |   1.99 | 2005-08-19         |  
|        103 |           4 |   2.99 | 2005-08-20         |  
|        104 |           4 |   6.99 | 2005-08-20         |  
|        105 |           4 |   4.99 | 2005-08-21         |  
|        106 |           4 |   2.99 | 2005-08-22         |  
|        107 |           4 |   1.99 | 2005-08-23         |  
|        108 |           5 |   0.99 | 2005-05-29         |  
|        109 |           5 |   6.99 | 2005-05-31         |  
|        110 |           5 |   1.99 | 2005-05-31         |  
|        111 |           5 |   3.99 | 2005-06-15         |  
|        112 |           5 |   2.99 | 2005-06-16         |  
|        113 |           5 |   4.99 | 2005-06-17         |  
|        114 |           5 |   2.99 | 2005-06-19         |  
|        115 |           5 |   4.99 | 2005-06-20         |  
|        116 |           5 |   4.99 | 2005-07-06         |  
|        117 |           5 |   2.99 | 2005-07-08         |  
|        118 |           5 |   4.99 | 2005-07-09         |  
|        119 |           5 |   5.99 | 2005-07-09         |  
|        120 |           5 |   1.99 | 2005-07-09         |  
+------------+-------------+--------+--------------------+

## Exercise 4-1

Which of the payment IDs would be returned by the following filter conditions?

customer\_id <> 5 AND (amount > 8 OR date(payment\_date) = '2005-08-23')

Payment IDs 101 and 107.

## Exercise 4-2

Which of the payment IDs would be returned by the following filter conditions?

customer\_id = 5 AND NOT (amount > 6 OR date(payment\_date) = '2005-06-19')

Payment IDs 108, 110, 111, 112, 113, 115, 116, 117, 118, 119, and 120.

## Exercise 4-3

Construct a query that retrieves all rows from the payment table where the amount is either 1.98, 7.98, or 9.98.

mysql> SELECT amount  
    -> FROM payment  
    -> WHERE amount IN (1.98, 7.98, 9.98);  
+--------+  
| amount |  
+--------+  
|   7.98 |  
|   9.98 |  
|   1.98 |  
|   7.98 |  
|   7.98 |  
|   7.98 |  
|   7.98 |  
+--------+  
7 rows in set (0.01 sec)

## Exercise 4-4

Construct a query that finds all customers whose last name contains an A in the second position and a W anywhere after the A.

mysql> SELECT first\_name, last\_name  
    -> FROM customer  
    -> WHERE last\_name LIKE '\_A%W%';  
+------------+------------+  
| first\_name | last\_name  |  
+------------+------------+  
| KAY        | CALDWELL   |  
| JOHN       | FARNSWORTH |  
| JILL       | HAWKINS    |  
| LEE        | HAWKS      |  
| LAURIE     | LAWRENCE   |  
| JEANNE     | LAWSON     |  
| LAWRENCE   | LAWTON     |  
| SAMUEL     | MARLOW     |  
| ERICA      | MATTHEWS   |  
+------------+------------+  
9 rows in set (0.02 sec)

# Chapter 5

## Exercise 5-1

Fill in the blanks (denoted by <#>) for the following query to obtain the results that follow:

mysql> SELECT c.first\_name, c.last\_name, a.address, ct.city  
    -> FROM customer c  
    ->   INNER JOIN address <1>  
    ->   ON c.address\_id = a.address\_id  
    ->   INNER JOIN city ct  
    ->   ON a.city\_id = <2>  
    -> WHERE a.district = 'California';  
+------------+-----------+------------------------+----------------+  
| first\_name | last\_name | address                | city           |  
+------------+-----------+------------------------+----------------+  
| PATRICIA   | JOHNSON   | 1121 Loja Avenue       | San Bernardino |  
| BETTY      | WHITE     | 770 Bydgoszcz Avenue   | Citrus Heights |  
| ALICE      | STEWART   | 1135 Izumisano Parkway | Fontana        |  
| ROSA       | REYNOLDS  | 793 Cam Ranh Avenue    | Lancaster      |  
| RENEE      | LANE      | 533 al-Ayn Boulevard   | Compton        |  
| KRISTIN    | JOHNSTON  | 226 Brest Manor        | Sunnyvale      |  
| CASSANDRA  | WALTERS   | 920 Kumbakonam Loop    | Salinas        |  
| JACOB      | LANCE     | 1866 al-Qatif Avenue   | El Monte       |  
| RENE       | MCALISTER | 1895 Zhezqazghan Drive | Garden Grove   |  
+------------+-----------+------------------------+----------------+  
9 rows in set (0.00 sec)

<1> is replaced by a.

<2> is replaced by ct.city\_id.

## Exercise 5-2

Write a query that returns the title of every film in which an actor with the first name JOHN appeared.

mysql> SELECT f.title  
    -> FROM film f  
    ->   INNER JOIN film\_actor fa  
    ->   ON f.film\_id = fa.film\_id  
    ->   INNER JOIN actor a  
    ->   ON fa.actor\_id = a.actor\_id  
    -> WHERE a.first\_name = 'JOHN';  
+---------------------------+  
| title                     |  
+---------------------------+  
| ALLEY EVOLUTION           |  
| BEVERLY OUTLAW            |  
| CANDLES GRAPES            |  
| CLEOPATRA DEVIL           |  
| COLOR PHILADELPHIA        |  
| CONQUERER NUTS            |  
| DAUGHTER MADIGAN          |  
| GLEAMING JAWBREAKER       |  
| GOLDMINE TYCOON           |  
| HOME PITY                 |  
| INTERVIEW LIAISONS        |  
| ISHTAR ROCKETEER          |  
| JAPANESE RUN              |  
| JERSEY SASSY              |  
| LUKE MUMMY                |  
| MILLION ACE               |  
| MONSTER SPARTACUS         |  
| NAME DETECTIVE            |  
| NECKLACE OUTBREAK         |  
| NEWSIES STORY             |  
| PET HAUNTING              |  
| PIANIST OUTFIELD          |  
| PINOCCHIO SIMON           |  
| PITTSBURGH HUNCHBACK      |  
| QUILLS BULL               |  
| RAGING AIRPLANE           |  
| ROXANNE REBEL             |  
| SATISFACTION CONFIDENTIAL |  
| SONG HEDWIG               |  
+---------------------------+  
29 rows in set (0.07 sec)

## Exercise 5-3

Construct a query that returns all addresses that are in the same city. You will need to join the address table to itself, and each row should include two different addresses.

mysql> SELECT a1.address addr1, a2.address addr2, a1.city\_id  
    -> FROM address a1  
    ->   INNER JOIN address a2  
    -> ON a1.city\_id = a2.city\_id  
    ->   AND a1.address < a2.address;  
+----------------------+--------------------+---------+  
| addr1                | addr2              | city\_id |  
+----------------------+--------------------+---------+  
| 23 Workhaven Lane | 47 MySakila Drive | 300 |  
| 1411 Lillydale Drive | 28 MySQL Boulevard | 576 |  
| 1497 Yuzhou Drive | 548 Uruapan Street | 312 |  
| 43 Vilnius Manor | 587 Benguela Manor | 42 |  
+----------------------+--------------------+---------+  
4 rows in set (0.01 sec)

# Chapter 6

## Exercise 6-1

If set A = {L M N O P} and set B = {P Q R S T}, what sets are generated by the following operations?

* A union B
* A union all B
* A intersect B
* A except B
  1. A union B = {L M N O P Q R S T}
  2. A union all B = {L M N O P P Q R S T}
  3. A intersect B = {P}
  4. A except B = {L M N O}

## Exercise 6-2

Write a compound query that finds the first and last names of all actors and customers whose last name starts with L.

mysql> SELECT first\_name, last\_name  
    -> FROM actor  
    -> WHERE last\_name LIKE 'L%'  
    -> UNION  
    -> SELECT first\_name, last\_name  
    -> FROM customer  
    -> WHERE last\_name LIKE 'L%';  
+------------+--------------+  
| first\_name | last\_name    |  
+------------+--------------+  
| MATTHEW    | LEIGH        |  
| JOHNNY     | LOLLOBRIGIDA |  
| MISTY      | LAMBERT      |  
| JACOB      | LANCE        |  
| RENEE      | LANE         |  
| HEIDI      | LARSON       |  
| DARYL      | LARUE        |  
| LAURIE     | LAWRENCE     |  
| JEANNE     | LAWSON       |  
| LAWRENCE   | LAWTON       |  
| KIMBERLY   | LEE          |  
| LOUIS      | LEONE        |  
| SARAH      | LEWIS        |  
| GEORGE     | LINTON       |  
| MAUREEN    | LITTLE       |  
| DWIGHT     | LOMBARDI     |  
| JACQUELINE | LONG         |  
| AMY        | LOPEZ        |  
| BARRY      | LOVELACE     |  
| PRISCILLA  | LOWE         |  
| VELMA      | LUCAS        |  
| WILLARD    | LUMPKIN      |  
| LEWIS      | LYMAN        |  
| JACKIE     | LYNCH        |  
+------------+--------------+  
24 rows in set (0.01 sec)

## Exercise 6-3

Sort the results from Exercise 6-2 by the last\_name column.

mysql> SELECT first\_name, last\_name  
    -> FROM actor  
    -> WHERE last\_name LIKE 'L%'  
    -> UNION  
    -> SELECT first\_name, last\_name  
    -> FROM customer  
    -> WHERE last\_name LIKE 'L%'  
    -> ORDER BY last\_name;  
+------------+--------------+  
| first\_name | last\_name    |  
+------------+--------------+  
| MISTY      | LAMBERT      |  
| JACOB      | LANCE        |  
| RENEE      | LANE         |  
| HEIDI      | LARSON       |  
| DARYL      | LARUE        |  
| LAURIE     | LAWRENCE     |  
| JEANNE     | LAWSON       |  
| LAWRENCE   | LAWTON       |  
| KIMBERLY   | LEE          |  
| MATTHEW    | LEIGH        |  
| LOUIS      | LEONE        |  
| SARAH      | LEWIS        |  
| GEORGE     | LINTON       |  
| MAUREEN    | LITTLE       |  
| JOHNNY     | LOLLOBRIGIDA |  
| DWIGHT     | LOMBARDI     |  
| JACQUELINE | LONG         |  
| AMY        | LOPEZ        |  
| BARRY      | LOVELACE     |  
| PRISCILLA  | LOWE         |  
| VELMA      | LUCAS        |  
| WILLARD    | LUMPKIN      |  
| LEWIS      | LYMAN        |  
| JACKIE     | LYNCH        |  
+------------+--------------+  
24 rows in set (0.00 sec)

# Chapter 7

## Exercise 7-1

Write a query that returns the 17th through 25th characters of the string 'Please find the substring in this string'.

mysql>   
SELECT SUBSTRING('Please find the substring in this string',17,9);  
  
+------------------------------------------------------------+  
| SUBSTRING('Please find the substring in this string',17,9) |  
+------------------------------------------------------------+  
| substring |  
+------------------------------------------------------------+  
1 row in set (0.00 sec)

## Exercise 7-2

Write a query that returns the absolute value and sign (−1, 0, or 1) of the number −25.76823. Also return the number rounded to the nearest hundredth.

mysql>   
SELECT ABS(-25.76823), SIGN(-25.76823), ROUND(-25.76823, 2);  
  
+----------------+-----------------+---------------------+  
| ABS(-25.76823) | SIGN(-25.76823) | ROUND(-25.76823, 2) |  
+----------------+-----------------+---------------------+  
| 25.76823 | −1 | −25.77 |  
+----------------+-----------------+---------------------+  
1 row in set (0.00 sec)

## Exercise 7-3

Write a query to return just the month portion of the current date.

mysql>   
SELECT EXTRACT(MONTH FROM CURRENT\_DATE());  
  
+----------------------------------+  
| EXTRACT(MONTH FROM CURRENT\_DATE) |  
+----------------------------------+  
| 12 |  
+----------------------------------+  
1 row in set (0.02 sec)

(Your result will most likely be different, unless it happens to be December when you try this exercise.)

# Chapter 8

## Exercise 8-1

Construct a query that counts the number of rows in the payment table.

mysql> SELECT count(\*) FROM payment;  
+----------+  
| count(\*) |  
+----------+  
|    16049 |  
+----------+  
1 row in set (0.02 sec)

## Exercise 8-2

Modify your query from Exercise 8-1 to count the number of payments made by each customer. Show the customer ID and the total amount paid for each customer.

mysql> SELECT customer\_id, count(\*), sum(amount)  
    -> FROM payment  
    -> GROUP BY customer\_id;  
+-------------+----------+-------------+  
| customer\_id | count(\*) | sum(amount) |  
+-------------+----------+-------------+  
|           1 |       32 |      118.68 |  
|           2 |       27 |      128.73 |  
|           3 |       26 |      135.74 |  
|           4 |       22 |       81.78 |  
|           5 |       38 |      144.62 |  
...  
|         595 |       30 |      117.70 |  
|         596 |       28 |       96.72 |  
|         597 |       25 |       99.75 |  
|         598 |       22 |       83.78 |  
|         599 |       19 |       83.81 |  
+-------------+----------+-------------+  
599 rows in set (0.03 sec)

## Exercise 8-3

Modify your query from Exercise 8-2 to include only those customers who have made at least 40 payments.

mysql> SELECT customer\_id, count(\*), sum(amount)  
    -> FROM payment  
    -> GROUP BY customer\_id  
    -> HAVING count(\*) >= 40;  
+-------------+----------+-------------+  
| customer\_id | count(\*) | sum(amount) |  
+-------------+----------+-------------+  
|          75 |       41 |      155.59 |  
|         144 |       42 |      195.58 |  
|         148 |       46 |      216.54 |  
|         197 |       40 |      154.60 |  
|         236 |       42 |      175.58 |  
|         469 |       40 |      177.60 |  
|         526 |       45 |      221.55 |  
+-------------+----------+-------------+  
7 rows in set (0.03 sec)

# Chapter 9

## Exercise 9-1

Construct a query against the film table that uses a filter condition with a noncorrelated subquery against the category table to find all action films (category.name = 'Action').

mysql> SELECT title  
    -> FROM film  
    -> WHERE film\_id IN  
    ->  (SELECT fc.film\_id  
    ->   FROM film\_category fc INNER JOIN category c  
    ->     ON fc.category\_id = c.category\_id  
    ->   WHERE c.name = 'Action');  
+-------------------------+  
| title                   |  
+-------------------------+  
| AMADEUS HOLY            |  
| AMERICAN CIRCUS         |  
| ANTITRUST TOMATOES      |  
| ARK RIDGEMONT           |  
| BAREFOOT MANCHURIAN     |  
| BERETS AGENT            |  
| BRIDE INTRIGUE          |  
| BULL SHAWSHANK          |  
| CADDYSHACK JEDI         |  
| CAMPUS REMEMBER         |  
| CASUALTIES ENCINO       |  
| CELEBRITY HORN          |  
| CLUELESS BUCKET         |  
| CROW GREASE             |  
| DANCES NONE             |  
| DARKO DORADO            |  
| DARN FORRESTER          |  
| DEVIL DESIRE            |  
| DRAGON SQUAD            |  
| DREAM PICKUP            |  
| DRIFTER COMMANDMENTS    |  
| EASY GLADIATOR          |  
| ENTRAPMENT SATISFACTION |  
| EXCITEMENT EVE          |  
| FANTASY TROOPERS        |  
| FIREHOUSE VIETNAM       |  
| FOOL MOCKINGBIRD        |  
| FORREST SONS            |  
| GLASS DYING             |  
| GOSFORD DONNIE          |  
| GRAIL FRANKENSTEIN      |  
| HANDICAP BOONDOCK       |  
| HILLS NEIGHBORS         |  
| KISSING DOLLS           |  
| LAWRENCE LOVE           |  
| LORD ARIZONA            |  
| LUST LOCK               |  
| MAGNOLIA FORRESTER      |  
| MIDNIGHT WESTWARD       |  
| MINDS TRUMAN            |  
| MOCKINGBIRD HOLLYWOOD   |  
| MONTEZUMA COMMAND       |  
| PARK CITIZEN            |  
| PATRIOT ROMAN           |  
| PRIMARY GLASS           |  
| QUEST MUSSOLINI         |  
| REAR TRADING            |  
| RINGS HEARTBREAKERS     |  
| RUGRATS SHAKESPEARE     |  
| SHRUNK DIVINE           |  
| SIDE ARK                |  
| SKY MIRACLE             |  
| SOUTH WAIT              |  
| SPEAKEASY DATE          |  
| STAGECOACH ARMAGEDDON   |  
| STORY SIDE              |  
| SUSPECTS QUILLS         |  
| TRIP NEWTON             |  
| TRUMAN CRAZY            |  
| UPRISING UPTOWN         |  
| WATERFRONT DELIVERANCE  |  
| WEREWOLF LOLA           |  
| WOMEN DORADO            |  
| WORST BANGER            |  
+-------------------------+  
64 rows in set (0.06 sec)

## Exercise 9-2

Rework the query from Exercise 9-1 using a correlated subquery against the category and film\_category tables to achieve the same results.

mysql> SELECT f.title  
    -> FROM film f  
    -> WHERE EXISTS  
    ->  (SELECT 1  
    ->   FROM film\_category fc INNER JOIN category c  
    ->     ON fc.category\_id = c.category\_id  
    ->   WHERE c.name = 'Action'  
    ->     AND fc.film\_id = f.film\_id);  
+-------------------------+  
| title                   |  
+-------------------------+  
| AMADEUS HOLY            |  
| AMERICAN CIRCUS         |  
| ANTITRUST TOMATOES      |  
| ARK RIDGEMONT           |  
| BAREFOOT MANCHURIAN     |  
| BERETS AGENT            |  
| BRIDE INTRIGUE          |  
| BULL SHAWSHANK          |  
| CADDYSHACK JEDI         |  
| CAMPUS REMEMBER         |  
| CASUALTIES ENCINO       |  
| CELEBRITY HORN          |  
| CLUELESS BUCKET         |  
| CROW GREASE             |  
| DANCES NONE             |  
| DARKO DORADO            |  
| DARN FORRESTER          |  
| DEVIL DESIRE            |  
| DRAGON SQUAD            |  
| DREAM PICKUP            |  
| DRIFTER COMMANDMENTS    |  
| EASY GLADIATOR          |  
| ENTRAPMENT SATISFACTION |  
| EXCITEMENT EVE          |  
| FANTASY TROOPERS        |  
| FIREHOUSE VIETNAM       |  
| FOOL MOCKINGBIRD        |  
| FORREST SONS            |  
| GLASS DYING             |  
| GOSFORD DONNIE          |  
| GRAIL FRANKENSTEIN      |  
| HANDICAP BOONDOCK       |  
| HILLS NEIGHBORS         |  
| KISSING DOLLS           |  
| LAWRENCE LOVE           |  
| LORD ARIZONA            |  
| LUST LOCK               |  
| MAGNOLIA FORRESTER      |  
| MIDNIGHT WESTWARD       |  
| MINDS TRUMAN            |  
| MOCKINGBIRD HOLLYWOOD   |  
| MONTEZUMA COMMAND       |  
| PARK CITIZEN            |  
| PATRIOT ROMAN           |  
| PRIMARY GLASS           |  
| QUEST MUSSOLINI         |  
| REAR TRADING            |  
| RINGS HEARTBREAKERS     |  
| RUGRATS SHAKESPEARE     |  
| SHRUNK DIVINE           |  
| SIDE ARK                |  
| SKY MIRACLE             |  
| SOUTH WAIT              |  
| SPEAKEASY DATE          |  
| STAGECOACH ARMAGEDDON   |  
| STORY SIDE              |  
| SUSPECTS QUILLS         |  
| TRIP NEWTON             |  
| TRUMAN CRAZY            |  
| UPRISING UPTOWN         |  
| WATERFRONT DELIVERANCE  |  
| WEREWOLF LOLA           |  
| WOMEN DORADO            |  
| WORST BANGER            |  
+-------------------------+  
64 rows in set (0.02 sec)

## Exercise 9-3

Join the following query to a subquery against the film\_actor table to show the level of each actor:

SELECT 'Hollywood Star' level, 30 min\_roles, 99999 max\_roles  
UNION ALL  
SELECT 'Prolific Actor' level, 20 min\_roles, 29 max\_roles  
UNION ALL  
SELECT 'Newcomer' level, 1 min\_roles, 19 max\_roles

The subquery against the film\_actor table should count the number of rows for each actor using group by actor\_id, and the count should be compared to the min\_roles/max\_roles columns to determine which level each actor belongs to.

mysql> SELECT actr.actor\_id, grps.level  
    -> FROM  
    ->  (SELECT actor\_id, count(\*) num\_roles  
    ->   FROM film\_actor  
    ->   GROUP BY actor\_id  
    ->  ) actr  
    ->   INNER JOIN  
    ->  (SELECT 'Hollywood Star' level, 30 min\_roles, 99999 max\_roles  
    ->   UNION ALL  
    ->   SELECT 'Prolific Actor' level, 20 min\_roles, 29 max\_roles  
    ->   UNION ALL  
    ->   SELECT 'Newcomer' level, 1 min\_roles, 19 max\_roles  
    ->  ) grps  
    ->   ON actr.num\_roles BETWEEN grps.min\_roles AND grps.max\_roles;  
+----------+----------------+  
| actor\_id | level          |  
+----------+----------------+  
|        1 | Newcomer       |  
|        2 | Prolific Actor |  
|        3 | Prolific Actor |  
|        4 | Prolific Actor |  
|        5 | Prolific Actor |  
|        6 | Prolific Actor |  
|        7 | Hollywood Star |  
...  
|      195 | Prolific Actor |  
|      196 | Hollywood Star |  
|      197 | Hollywood Star |  
|      198 | Hollywood Star |  
|      199 | Newcomer       |  
|      200 | Prolific Actor |  
+----------+----------------+  
200 rows in set (0.03 sec)

# Chapter 10

## Exercise 10-1

Using the following table definitions and data, write a query that returns each customer name along with their total payments:

Customer:  
Customer\_id Name  
----------- ---------------  
1 John Smith  
2 Kathy Jones  
3 Greg Oliver  
  
 Payment:  
Payment\_id Customer\_id Amount  
---------- ----------- --------  
101 1 8.99  
102 3 4.99  
103 1 7.99

Include all customers, even if no payment records exist for that customer.

mysql> SELECT c.name, sum(p.amount)  
    -> FROM customer c LEFT OUTER JOIN payment p  
    ->   ON c.customer\_id = p.customer\_id  
    -> GROUP BY c.name;  
+-------------+---------------+  
| name        | sum(p.amount) |  
+-------------+---------------+  
| John Smith  |         16.98 |  
| Kathy Jones |          NULL |  
| Greg Oliver |          4.99 |  
+-------------+---------------+  
3 rows in set (0.00 sec)

## Exercise 10-2

Reformulate your query from Exercise 10-1 to use the other outer join type (e.g., if you used a left outer join in Exercise 10-1, use a right outer join this time) such that the results are identical to Exercise 10-1.

MySQL> SELECT c.name, sum(p.amount)  
    -> FROM payment p RIGHT OUTER JOIN customer c  
    ->   ON c.customer\_id = p.customer\_id  
    -> GROUP BY c.name;  
+-------------+---------------+  
| name        | sum(p.amount) |  
+-------------+---------------+  
| John Smith  |         16.98 |  
| Kathy Jones |          NULL |  
| Greg Oliver |          4.99 |  
+-------------+---------------+  
3 rows in set (0.00 sec)

## Exercise 10-3 (Extra Credit)

Devise a query that will generate the set {1, 2, 3, ..., 99, 100}. (Hint: use a cross join with at least two from clause subqueries.)

SELECT ones.x + tens.x + 1  
FROM  
 (SELECT 0 x UNION ALL  
  SELECT 1 x UNION ALL  
  SELECT 2 x UNION ALL  
  SELECT 3 x UNION ALL  
  SELECT 4 x UNION ALL  
  SELECT 5 x UNION ALL  
  SELECT 6 x UNION ALL  
  SELECT 7 x UNION ALL  
  SELECT 8 x UNION ALL  
  SELECT 9 x  
 ) ones  
  CROSS JOIN  
 (SELECT 0 x UNION ALL  
  SELECT 10 x UNION ALL  
  SELECT 20 x UNION ALL  
  SELECT 30 x UNION ALL  
  SELECT 40 x UNION ALL  
  SELECT 50 x UNION ALL  
  SELECT 60 x UNION ALL  
  SELECT 70 x UNION ALL  
  SELECT 80 x UNION ALL  
  SELECT 90 x  
 ) tens;

# Chapter 11

## Exercise 11-1

Rewrite the following query, which uses a simple case expression, so that the same results are achieved using a searched case expression. Try to use as few when clauses as possible.

SELECT name,  
 CASE name  
 WHEN 'English' THEN 'latin1'  
 WHEN 'Italian' THEN 'latin1'  
 WHEN 'French' THEN 'latin1'  
 WHEN 'German' THEN 'latin1'  
 WHEN 'Japanese' THEN 'utf8'  
 WHEN 'Mandarin' THEN 'utf8'  
 ELSE 'Unknown'  
 END character\_set  
FROM language;

SELECT name,  
  CASE  
    WHEN name IN ('English','Italian','French','German')  
      THEN 'latin1'  
    WHEN name IN ('Japanese','Mandarin')  
      THEN 'utf8'  
    ELSE 'Unknown'  
  END character\_set  
FROM language;

## Exercise 11-2

Rewrite the following query so that the result set contains a single row with five columns (one for each rating). Name the five columns G, PG, PG\_13, R, and NC\_17.

mysql> SELECT rating, count(\*)  
    -> FROM film  
    -> GROUP BY rating;  
+--------+----------+  
| rating | count(\*) |  
+--------+----------+  
| PG     |      194 |  
| G      |      178 |  
| NC-17  |      210 |  
| PG-13  |      223 |  
| R      |      195 |  
+--------+----------+  
5 rows in set (0.00 sec)

mysql> SELECT  
    ->   sum(CASE WHEN rating = 'G' THEN 1 ELSE 0 END) g,  
    ->   sum(CASE WHEN rating = 'PG' THEN 1 ELSE 0 END) pg,  
    ->   sum(CASE WHEN rating = 'PG-13' THEN 1 ELSE 0 END) pg\_13,  
    ->   sum(CASE WHEN rating = 'R' THEN 1 ELSE 0 END) r,  
    ->   sum(CASE WHEN rating = 'NC-17' THEN 1 ELSE 0 END) nc\_17  
    -> FROM film;  
+------+------+-------+------+-------+  
| g    | pg   | pg\_13 | r    | nc\_17 |  
+------+------+-------+------+-------+  
|  178 |  194 |   223 |  195 |   210 |  
+------+------+-------+------+-------+  
1 row in set (0.00 sec)

# Chapter 12

## Exercise 12-1

Generate a unit of work to transfer $50 from account 123 to account 789. You will need to insert two rows into the transaction table and update two rows in the account table. Use the following table definitions/data:

Account:  
account\_id avail\_balance last\_activity\_date  
---------- ------------- ------------------  
123 500 2019-07-10 20:53:27  
789 75 2019-06-22 15:18:35  
  
 Transaction:  
txn\_id txn\_date account\_id txn\_type\_cd amount  
--------- ------------ ----------- ----------- --------  
1001 2019-05-15 123 C 500  
1002 2019-06-01 789 C 75

Use txn\_type\_cd = 'C' to indicate a credit (addition), and use txn\_type\_cd = 'D' to indicate a debit (subtraction).

START TRANSACTION;  
  
INSERT INTO transaction   
 (txn\_id, txn\_date, account\_id, txn\_type\_cd, amount)  
VALUES  
 (1003, now(), 123, 'D', 50);  
  
INSERT INTO transaction  
 (txn\_id, txn\_date, account\_id, txn\_type\_cd, amount)  
VALUES  
 (1004, now(), 789, 'C', 50);  
  
UPDATE account  
SET avail\_balance = available\_balance - 50,  
  last\_activity\_date = now()  
WHERE account\_id = 123;  
  
UPDATE account  
SET avail\_balance = available\_balance + 50,  
​  last\_activity\_date = now()  
WHERE account\_id = 789;  
  
COMMIT;

# Chapter 13

## Exercise 13-1

Generate an alter table statement for the rental table so that an error will be raised if a row having a value found in the rental.customer\_id column is deleted from the customer table.

ALTER TABLE rental  
ADD CONSTRAINT fk\_rental\_customer\_id FOREIGN KEY (customer\_id)  
REFERENCES customer (customer\_id) ON DELETE RESTRICT;

## Exercise 13-2

Generate a multicolumn index on the payment table that could be used by both of the following queries:

SELECT customer\_id, payment\_date, amount  
FROM payment  
WHERE payment\_date > cast('2019-12-31 23:59:59' as datetime);  
  
SELECT customer\_id, payment\_date, amount  
FROM payment  
​WHERE payment\_date > cast('2019-12-31 23:59:59' as datetime)  
 AND amount < 5;

CREATE INDEX idx\_payment01   
ON payment (payment\_date, amount);

# Chapter 14

## Exercise 14-1

Create a view definition that can be used by the following query to generate the given results:

SELECT title, category\_name, first\_name, last\_name  
FROM   
film\_ctgry\_actor  
  
WHERE last\_name = 'FAWCETT';   
  
+---------------------+---------------+------------+-----------+  
| title               | category\_name | first\_name | last\_name |  
+---------------------+---------------+------------+-----------+  
| ACE GOLDFINGER      | Horror        | BOB        | FAWCETT   |  
| ADAPTATION HOLES    | Documentary   | BOB        | FAWCETT   |  
| CHINATOWN GLADIATOR | New           | BOB        | FAWCETT   |  
| CIRCUS YOUTH        | Children      | BOB        | FAWCETT   |  
| CONTROL ANTHEM      | Comedy        | BOB        | FAWCETT   |  
| DARES PLUTO         | Animation     | BOB        | FAWCETT   |  
| DARN FORRESTER      | Action        | BOB        | FAWCETT   |  
| DAZED PUNK          | Games         | BOB        | FAWCETT   |  
| DYNAMITE TARZAN     | Classics      | BOB        | FAWCETT   |  
| HATE HANDICAP       | Comedy        | BOB        | FAWCETT   |  
| HOMICIDE PEACH      | Family        | BOB        | FAWCETT   |  
| JACKET FRISCO       | Drama         | BOB        | FAWCETT   |  
| JUMANJI BLADE       | New           | BOB        | FAWCETT   |  
| LAWLESS VISION      | Animation     | BOB        | FAWCETT   |  
| LEATHERNECKS DWARFS | Travel        | BOB        | FAWCETT   |  
| OSCAR GOLD          | Animation     | BOB        | FAWCETT   |  
| PELICAN COMFORTS    | Documentary   | BOB        | FAWCETT   |  
| PERSONAL LADYBUGS   | Music         | BOB        | FAWCETT   |  
| RAGING AIRPLANE     | Sci-Fi        | BOB        | FAWCETT   |  
| RUN PACIFIC         | New           | BOB        | FAWCETT   |  
| RUNNER MADIGAN      | Music         | BOB        | FAWCETT   |  
| SADDLE ANTITRUST    | Comedy        | BOB        | FAWCETT   |  
| SCORPION APOLLO     | Drama         | BOB        | FAWCETT   |  
| SHAWSHANK BUBBLE    | Travel        | BOB        | FAWCETT   |  
| TAXI KICK           | Music         | BOB        | FAWCETT   |  
| BERETS AGENT        | Action        | JULIA      | FAWCETT   |  
| BOILED DARES        | Travel        | JULIA      | FAWCETT   |  
| CHISUM BEHAVIOR     | Family        | JULIA      | FAWCETT   |  
| CLOSER BANG         | Comedy        | JULIA      | FAWCETT   |  
| DAY UNFAITHFUL      | New           | JULIA      | FAWCETT   |  
| HOPE TOOTSIE        | Classics      | JULIA      | FAWCETT   |  
| LUKE MUMMY          | Animation     | JULIA      | FAWCETT   |  
| MULAN MOON          | Comedy        | JULIA      | FAWCETT   |  
| OPUS ICE            | Foreign       | JULIA      | FAWCETT   |  
| POLLOCK DELIVERANCE | Foreign       | JULIA      | FAWCETT   |  
| RIDGEMONT SUBMARINE | New           | JULIA      | FAWCETT   |  
| SHANGHAI TYCOON     | Travel        | JULIA      | FAWCETT   |  
| SHAWSHANK BUBBLE    | Travel        | JULIA      | FAWCETT   |  
| THEORY MERMAID      | Animation     | JULIA      | FAWCETT   |  
| WAIT CIDER          | Animation     | JULIA      | FAWCETT   |  
+---------------------+---------------+------------+-----------+  
40 rows in set (0.00 sec)

CREATE VIEW film\_ctgry\_actor  
AS  
SELECT f.title,  
  c.name category\_name,  
  a.first\_name,  
  a.last\_name  
FROM film f  
  INNER JOIN film\_category fc  
  ON f.film\_id = fc.film\_id  
  INNER JOIN category c  
  ON fc.category\_id = c.category\_id  
  INNER JOIN film\_actor fa  
  ON fa.film\_id = f.film\_id  
  INNER JOIN actor a  
  ON fa.actor\_id = a.actor\_id;

## Exercise 14-2

The film rental company manager would like to have a report that includes the name of every country, along with the total payments for all customers who live in each country. Generate a view definition that queries the country table and uses a scalar subquery to calculate a value for a column named tot\_payments.

CREATE VIEW country\_payments  
AS  
SELECT c.country,  
 (SELECT sum(p.amount)  
  FROM city ct  
    INNER JOIN address a  
    ON ct.city\_id = a.city\_id  
    INNER JOIN customer cst  
    ON a.address\_id = cst.address\_id  
    INNER JOIN payment p  
    ON cst.customer\_id = p.customer\_id  
  WHERE ct.country\_id = c.country\_id  
 ) tot\_payments  
FROM country c

# Chapter 15

## Exercise 15-1

Write a query that lists all of the indexes in the Sakila schema. Include the table names.

mysql> SELECT DISTINCT table\_name, index\_name  
    -> FROM information\_schema.statistics  
    -> WHERE table\_schema = 'sakila';  
+---------------+-----------------------------+  
| TABLE\_NAME    | INDEX\_NAME                  |  
+---------------+-----------------------------+  
| actor         | PRIMARY                     |  
| actor         | idx\_actor\_last\_name         |  
| address       | PRIMARY                     |  
| address       | idx\_fk\_city\_id              |  
| address       | idx\_location                |  
| category      | PRIMARY                     |  
| city          | PRIMARY                     |  
| city          | idx\_fk\_country\_id           |  
| country       | PRIMARY                     |  
| film          | PRIMARY                     |  
| film          | idx\_title                   |  
| film          | idx\_fk\_language\_id          |  
| film          | idx\_fk\_original\_language\_id |  
| film\_actor    | PRIMARY                     |  
| film\_actor    | idx\_fk\_film\_id              |  
| film\_category | PRIMARY                     |  
| film\_category | fk\_film\_category\_category   |  
| film\_text     | PRIMARY                     |  
| film\_text     | idx\_title\_description       |  
| inventory     | PRIMARY                     |  
| inventory     | idx\_fk\_film\_id              |  
| inventory     | idx\_store\_id\_film\_id        |  
| language      | PRIMARY                     |  
| staff         | PRIMARY                     |  
| staff         | idx\_fk\_store\_id             |  
| staff         | idx\_fk\_address\_id           |  
| store         | PRIMARY                     |  
| store         | idx\_unique\_manager          |  
| store         | idx\_fk\_address\_id           |  
| customer      | PRIMARY                     |  
| customer      | idx\_email                   |  
| customer      | idx\_fk\_store\_id             |  
| customer      | idx\_fk\_address\_id           |  
| customer      | idx\_last\_name               |  
| customer      | idx\_full\_name               |  
| rental        | PRIMARY                     |  
| rental        | rental\_date                 |  
| rental        | idx\_fk\_inventory\_id         |  
| rental        | idx\_fk\_customer\_id          |  
| rental        | idx\_fk\_staff\_id             |  
| payment       | PRIMARY                     |  
| payment       | idx\_fk\_staff\_id             |  
| payment       | idx\_fk\_customer\_id          |  
| payment       | fk\_payment\_rental           |  
| payment       | idx\_payment01               |  
+---------------+-----------------------------+  
45 rows in set (0.00 sec)

## Exercise 15-2

Write a query that generates output that can be used to create all of the indexes on the sakila.customer table. Output should be of the form:

"ALTER TABLE <table\_name> ADD INDEX <index\_name> (<column\_list>)"

Here’s one solution utilizing a with clause:

mysql> WITH idx\_info AS  
    ->  (SELECT s1.table\_name, s1.index\_name,   
  -> s1.column\_name, s1.seq\_in\_index,  
    ->    (SELECT max(s2.seq\_in\_index)   
  -> FROM information\_schema.statistics s2  
    ->     WHERE s2.table\_schema = s1.table\_schema  
    ->       AND s2.table\_name = s1.table\_name  
    ->       AND s2.index\_name = s1.index\_name) num\_columns  
    ->   FROM information\_schema.statistics s1  
    ->   WHERE s1.table\_schema = 'sakila'  
    ->     AND s1.table\_name = 'customer'  
    ->  )  
    -> SELECT concat(  
    ->   CASE  
    ->     WHEN seq\_in\_index = 1 THEN  
    ->       concat('ALTER TABLE ', table\_name, ' ADD INDEX ',   
  -> index\_name, ' (', column\_name)  
    ->     ELSE concat('  , ', column\_name)  
    ->   END,  
    ->   CASE  
    ->     WHEN seq\_in\_index = num\_columns THEN ');'  
    ->     ELSE ''  
    ->   END  
    ->  ) index\_creation\_statement  
    -> FROM idx\_info  
    -> ORDER BY index\_name, seq\_in\_index;  
+----------------------------------------------------------------+  
| index\_creation\_statement                                       |  
+----------------------------------------------------------------+  
| ALTER TABLE customer ADD INDEX idx\_email (email);              |  
| ALTER TABLE customer ADD INDEX idx\_fk\_address\_id (address\_id); |  
| ALTER TABLE customer ADD INDEX idx\_fk\_store\_id (store\_id);     |  
| ALTER TABLE customer ADD INDEX idx\_full\_name (last\_name        |  
|   , first\_name);                                               |  
| ALTER TABLE customer ADD INDEX idx\_last\_name (last\_name);      |  
| ALTER TABLE customer ADD INDEX PRIMARY (customer\_id);          |  
+----------------------------------------------------------------+  
7 rows in set (0.00 sec)

After reading Chapter 16, however, you could use the following:

mysql> SELECT concat('ALTER TABLE ', table\_name, ' ADD INDEX ',   
  -> index\_name, ' (',  
    ->   group\_concat(column\_name order by seq\_in\_index separator ', '),  
    ->   ');'  
    ->  ) index\_creation\_statement  
    -> FROM information\_schema.statistics  
    -> WHERE table\_schema = 'sakila'  
    ->   AND table\_name = 'customer'  
    -> GROUP BY table\_name, index\_name;  
+-----------------------------------------------------------------------+  
| index\_creation\_statement                                              |  
+-----------------------------------------------------------------------+  
| ALTER TABLE customer ADD INDEX idx\_email (email);                     |  
| ALTER TABLE customer ADD INDEX idx\_fk\_address\_id (address\_id);        |  
| ALTER TABLE customer ADD INDEX idx\_fk\_store\_id (store\_id);            |  
| ALTER TABLE customer ADD INDEX idx\_full\_name (last\_name, first\_name); |  
| ALTER TABLE customer ADD INDEX idx\_last\_name (last\_name);             |  
| ALTER TABLE customer ADD INDEX PRIMARY (customer\_id);                 |  
+-----------------------------------------------------------------------+  
6 rows in set (0.00 sec)

# Chapter 16

For all exercises in this section, use the following data set from the Sales\_Fact table:

Sales\_Fact  
+---------+----------+-----------+  
| year\_no | month\_no | tot\_sales |  
+---------+----------+-----------+  
|    2019 |        1 |     19228 |  
|    2019 |        2 |     18554 |  
|    2019 |        3 |     17325 |  
|    2019 |        4 |     13221 |  
|    2019 |        5 |      9964 |  
|    2019 |        6 |     12658 |  
|    2019 |        7 |     14233 |  
|    2019 |        8 |     17342 |  
|    2019 |        9 |     16853 |  
|    2019 |       10 |     17121 |  
|    2019 |       11 |     19095 |  
|    2019 |       12 |     21436 |  
|    2020 |        1 |     20347 |  
|    2020 |        2 |     17434 |  
|    2020 |        3 |     16225 |  
|    2020 |        4 |     13853 |  
|    2020 |        5 |     14589 |  
|    2020 |        6 |     13248 |  
|    2020 |        7 |      8728 |  
|    2020 |        8 |      9378 |  
|    2020 |        9 |     11467 |  
|    2020 |       10 |     13842 |  
|    2020 |       11 |     15742 |  
|    2020 |       12 |     18636 |  
+---------+----------+-----------+  
24 rows in set (0.00 sec)

## Exercise 16-1

Write a query that retrieves every row from Sales\_Fact, and add a column to generate a ranking based on the tot\_sales column values. The highest value should receive a ranking of 1, and the lowest a ranking of 24.

mysql> SELECT year\_no, month\_no, tot\_sales,  
    ->   rank() over (order by tot\_sales desc) sales\_rank  
    -> FROM sales\_fact;  
+---------+----------+-----------+------------+  
| year\_no | month\_no | tot\_sales | sales\_rank |  
+---------+----------+-----------+------------+  
|    2019 |       12 |     21436 |          1 |  
|    2020 |        1 |     20347 |          2 |  
|    2019 |        1 |     19228 |          3 |  
|    2019 |       11 |     19095 |          4 |  
|    2020 |       12 |     18636 |          5 |  
|    2019 |        2 |     18554 |          6 |  
|    2020 |        2 |     17434 |          7 |  
|    2019 |        8 |     17342 |          8 |  
|    2019 |        3 |     17325 |          9 |  
|    2019 |       10 |     17121 |         10 |  
|    2019 |        9 |     16853 |         11 |  
|    2020 |        3 |     16225 |         12 |  
|    2020 |       11 |     15742 |         13 |  
|    2020 |        5 |     14589 |         14 |  
|    2019 |        7 |     14233 |         15 |  
|    2020 |        4 |     13853 |         16 |  
|    2020 |       10 |     13842 |         17 |  
|    2020 |        6 |     13248 |         18 |  
|    2019 |        4 |     13221 |         19 |  
|    2019 |        6 |     12658 |         20 |  
|    2020 |        9 |     11467 |         21 |  
|    2019 |        5 |      9964 |         22 |  
|    2020 |        8 |      9378 |         23 |  
|    2020 |        7 |      8728 |         24 |  
+---------+----------+-----------+------------+  
24 rows in set (0.02 sec)

## Exercise 16-2

Modify the query from the previous exercise to generate two sets of rankings from 1 to 12, one for 2019 data and one for 2020.

mysql> SELECT year\_no, month\_no, tot\_sales,  
    ->   rank() over (partition by year\_no  
    ->                order by tot\_sales desc) sales\_rank  
    -> FROM sales\_fact;  
+---------+----------+-----------+------------+  
| year\_no | month\_no | tot\_sales | sales\_rank |  
+---------+----------+-----------+------------+  
|    2019 |       12 |     21436 |          1 |  
|    2019 |        1 |     19228 |          2 |  
|    2019 |       11 |     19095 |          3 |  
|    2019 |        2 |     18554 |          4 |  
|    2019 |        8 |     17342 |          5 |  
|    2019 |        3 |     17325 |          6 |  
|    2019 |       10 |     17121 |          7 |  
|    2019 |        9 |     16853 |          8 |  
|    2019 |        7 |     14233 |          9 |  
|    2019 |        4 |     13221 |         10 |  
|    2019 |        6 |     12658 |         11 |  
|    2019 |        5 |      9964 |         12 |  
|    2020 |        1 |     20347 |          1 |  
|    2020 |       12 |     18636 |          2 |  
|    2020 |        2 |     17434 |          3 |  
|    2020 |        3 |     16225 |          4 |  
|    2020 |       11 |     15742 |          5 |  
|    2020 |        5 |     14589 |          6 |  
|    2020 |        4 |     13853 |          7 |  
|    2020 |       10 |     13842 |          8 |  
|    2020 |        6 |     13248 |          9 |  
|    2020 |        9 |     11467 |         10 |  
|    2020 |        8 |      9378 |         11 |  
|    2020 |        7 |      8728 |         12 |  
+---------+----------+-----------+------------+  
24 rows in set (0.00 sec)

## Exercise 16-3

Write a query that retrieves all 2020 data, and include a column that will contain the tot\_sales value from the previous month.

mysql> SELECT year\_no, month\_no, tot\_sales,  
    ->   lag(tot\_sales) over (order by month\_no) prev\_month\_sales  
    -> FROM sales\_fact  
    -> WHERE year\_no = 2020;  
+---------+----------+-----------+------------------+  
| year\_no | month\_no | tot\_sales | prev\_month\_sales |  
+---------+----------+-----------+------------------+  
|    2020 |        1 |     20347 |             NULL |  
|    2020 |        2 |     17434 |            20347 |  
|    2020 |        3 |     16225 |            17434 |  
|    2020 |        4 |     13853 |            16225 |  
|    2020 |        5 |     14589 |            13853 |  
|    2020 |        6 |     13248 |            14589 |  
|    2020 |        7 |      8728 |            13248 |  
|    2020 |        8 |      9378 |             8728 |  
|    2020 |        9 |     11467 |             9378 |  
|    2020 |       10 |     13842 |            11467 |  
|    2020 |       11 |     15742 |            13842 |  
|    2020 |       12 |     18636 |            15742 |  
+---------+----------+-----------+------------------+  
12 rows in set (0.00 sec)

Index

### Symbols

* \* (asterisk)
  + - in aggregate functions, [Grouping Concepts](#idm45831693755200), [How Nulls Are Handled](#idm45831693628448)
    - in select clause, [The select Clause](#idm45831695904480)
* \ (backslash), as escape character, [Including single quotes](#idm45831694601712)
* ( ) (parentheses)
  + - enclosing subqueries, [Derived (subquery-generated) tables](#idm45831695803728)
    - grouping arithmetic operations, [Working with Numeric Data](#idm45831694337264)
    - grouping compound queries, [Set Operation Precedence](#idm45831694732896)
    - grouping filter conditions, [The where Clause](#idm45831695953792), [Using Parentheses](#idm45831695529088)
* % (percent sign), modulo operator, [Performing Arithmetic Functions](#idm45831694263824)
* + (plus sign), concatenation operator, SQL Server, [Including special characters](#idm45831694547104)
  + - (see also arithmetic operators)
* ' ' (quotes, single)
  + - enclosing strings, [String Generation](#idm45831694659440)
    - escape sequence for, [Including single quotes](#ch7esc3)-[Including single quotes](#idm45831694585936)
* || (vertical bar, double), concatenation operator, Oracle, [Including special characters](#idm45831694555744)

### A

* abs() function, [Handling Signed Data](#idm45831694191616)
* acos() function, [Performing Arithmetic Functions](#idm45831694281072)
* add constraint keywords, [Constraint Creation](#idm45831692215360)
* add index keywords, [Index Creation](#idm45831692448880)
* add unique keywords, [Unique indexes](#idm45831692514608)
* add\_months() function, [Temporal functions that return dates](#idm45831693868400)
* ADO.NET, [SQL: A Nonprocedural Language](#idm45831696977232)
* aggregate functions, [Grouping Concepts](#ch8agg)-[How Nulls Are Handled](#idm45831693619712), [Reporting Functions](#ch16ag)-[Window Frames](#idm45831691496384)
  + - expressions in, [Using Expressions](#idm45831693661376)
    - filtering based on, [Grouping Concepts](#ch8fil2)-[Grouping Concepts](#idm45831693727376)
    - list of, [Aggregate Functions](#ch8lst)-[Aggregate Functions](#idm45831693706000)
    - null values with, [How Nulls Are Handled](#ch8null)-[How Nulls Are Handled](#idm45831693617056)
* aggregated data, views for, [Data Aggregation](#idm45831692090832)
* aliases
  + - for columns, [Column Aliases](#idm45831695865392)
    - for tables, [Using the Same Table Twice](#idm45831694989728), [Self-Joins](#idm45831694961104)
* all keyword, [Removing Duplicates](#idm45831695838208)
* all operator, [The all operator](#ch9all)-[The all operator](#idm45831693385584)
* alter table statement, [Generating numeric key data](#idm45831696209856)
  + - adding constraints in, [Constraint Creation](#idm45831692219440)
    - adding indexes in, [Index Creation](#idm45831692447728), [Unique indexes](#idm45831692397248)
    - removing constraints in, [Constraint Creation](#idm45831692175520)
    - removing indexes in, [Index Creation](#idm45831692414608)
    - specifying storage engine, [Transaction Savepoints](#idm45831692511616)
* Amazon Web Services (AWS), [Cloud Computing](#idm45831691185648)
* analytic functions, [Analytic Function Concepts](#ch16an)-[Localized Sorting](#idm45831691649200)
  + - column value concatenation with, [Column Value Concatenation](#idm45831691462976)
    - data windows used by, [Data Windows](#ch16win)-[Data Windows](#idm45831691701024), [Generating Multiple Rankings](#idm45831691587664), [Reporting Functions](#idm45831691541520), [Window Frames](#idm45831691519344)
    - localized sorting using, [Localized Sorting](#ch16ob)-[Localized Sorting](#idm45831691648432)
    - ranking functions, [Ranking](#ch16rn2)-[Generating Multiple Rankings](#idm45831691782144)
    - reporting functions, [Reporting Functions](#ch16rep2)-[Column Value Concatenation](#idm45831691455088)
* and operator, [The where Clause](#idm45831695683152), [Condition Evaluation](#idm45831695563872)
* ANSI mode, [String Generation](#idm45831695252352)
* ANSI SQL92 join syntax, [The ANSI Join Syntax](#ch5an2)-[The ANSI Join Syntax](#idm45831695050752)
* any operator, [The any operator](#ch9any)-[The any operator](#idm45831693402720)
* Apache Drill, [SQL Unplugged](#idm45831696864000), [SQL and Big Data](#ch18ad2)-[Introduction to Apache Drill](#idm45831691130384)
  + - df (distributed filesystem) plug-in, [Querying Files Using Drill](#idm45831695262096)
    - querying files, [Querying Files Using Drill](#ch18qf)-[Querying Files Using Drill](#idm45831691106496)
    - querying MongoDB, [Querying MongoDB Using Drill](#ch18mon)-[Querying MongoDB Using Drill](#idm45831691410992)
    - querying multiple databases, [Drill with Multiple Data Sources](#ch18mul)-[Drill with Multiple Data Sources](#idm45831696984912)
    - querying MySQL, [Querying MySQL Using Drill](#ch18qm)-[Querying MySQL Using Drill](#idm45831691091168)
* Archive storage engine, [Transaction Savepoints](#idm45831692517936)
* arithmetic functions, [Performing Arithmetic Functions](#ch7fun2)-[Performing Arithmetic Functions](#idm45831694247856)
* arithmetic operators, [Building a Condition](#idm45831695440256), [Working with Numeric Data](#idm45831694343728)
* as keyword, [Column Aliases](#idm45831695977616), [Defining Table Aliases](#idm45831695971312)
* asc keyword, [Ascending Versus Descending Sort Order](#idm45831695626560)
* ascii() function, [Including special characters](#idm45831694544992)
* asin() function, [Performing Arithmetic Functions](#idm45831694279760)
* asterisk (\*)
  + - in aggregate functions, [Grouping Concepts](#idm45831693756736), [How Nulls Are Handled](#idm45831693630240)
    - in select clause, [The select Clause](#idm45831695956496)
* atan() function, [Performing Arithmetic Functions](#idm45831694278992)
* atomicity, [What Is a Transaction?](#idm45831694889328)
* autocommit mode, [Starting a Transaction](#idm45831692598080)
* auto\_increment keyword, [Generating numeric key data](#idm45831696215760)
* avg() function, [Aggregate Functions](#idm45831693720816), [Reporting Functions](#ch16ag4)-[Window Frames](#idm45831691608016)
* AWS (Amazon Web Services), [Cloud Computing](#idm45831691186752)

### B

* B-tree (balanced-tree) indexes, [B-tree indexes](#idm45831692378976)
* backslash (\), as escape character, [Including single quotes](#idm45831694603040)
* begin transaction command, [Starting a Transaction](#idm45831692637424)
* between operator, [The between operator](#ch4bet)-[The between operator](#idm45831695369056), [Correlated Subqueries](#idm45831693425968)
* big data, [Big Data](#ch17big)-[Cloud Computing](#idm45831691200400)
  + - Apache Drill for, [SQL and Big Data](#ch18ad)-[Introduction to Apache Drill](#idm45831691131648)
      * + (see also Apache Drill)
    - cloud computing, [Cloud Computing](#ch17cc)-[Cloud Computing](#idm45831691636752)
    - future of, [Future of SQL](#idm45831691005504)
    - Hadoop, [SQL Unplugged](#idm45831696873184), [Hadoop](#idm45831691236992), [Introduction to Apache Drill](#idm45831691146144)
    - NoSQL and document databases, [SQL Unplugged](#idm45831696866624), [NoSQL and Document Databases](#idm45831691776048), [Introduction to Apache Drill](#idm45831691144800)
* bigint type, [Numeric Data](#idm45831696613376)
* bitmap indexes, [Bitmap indexes](#idm45831692532368)
* books and publications
  + - Database in Depth (O’Reilly), [What’s in Store](#idm45831697478208)
    - The Database Relational Model (Addison-Wesley), [What’s in Store](#idm45831696845968)
    - High Performance MySQL (O’Reilly), [Query Mechanics](#idm45831695960144)
    - An Introduction to Database Systems (Addison-Wesley), [What’s in Store](#idm45831696850880)
    - Learning Apache Drill (O’Reilly), [Introduction to Apache Drill](#idm45831691133152)
    - Mastering Regular Expressions (O’Reilly), [Using regular expressions](#idm45831695255328)
    - “A Relational Model of Data for Large Shared Data Banks” (Codd), [The Relational Model](#idm45831697173440)
    - SQL in a Nutshell (O’Reilly), [String functions that return strings](#idm45831695257952)
    - Unicode Explained (O’Reilly), [Character sets](#idm45831696909872)
* branch nodes, [B-tree indexes](#idm45831692357008)

### C

* C#, SQL integration toolkit for, [SQL: A Nonprocedural Language](#idm45831696990304)
* Cartesian product, [Cartesian Product](#ch5cp)-[Cartesian Product](#idm45831695131984), [Cross Joins](#ch10cj3)-[Cross Joins](#idm45831692988880)
  + - (see also cross joins)
* case expressions, [What Is Conditional Logic?](#ch11ce2)-[The case Expression](#idm45831692887600)
  + - conditional updates using, [Conditional Updates](#ch11up)-[Conditional Updates](#idm45831692742064)
    - division-by-zero checks using, [Division-by-Zero Errors](#ch11ze)-[Division-by-Zero Errors](#idm45831692752528)
    - existence checks using, [Checking for Existence](#ch11ex)-[Checking for Existence](#idm45831692776496)
    - handling null values using, [Handling Null Values](#ch11null)-[Handling Null Values](#idm45831692728288)
    - result set transformations using, [Result Set Transformations](#ch11tr)-[Result Set Transformations](#idm45831692803200)
    - searched case expressions, [Searched case Expressions](#ch11se)-[Searched case Expressions](#idm45831692976448)
    - simple case expressions, [Simple case Expressions](#ch11sim)-[Simple case Expressions](#idm45831692835712)
    - subqueries in, [Searched case Expressions](#ch11sub)-[Searched case Expressions](#idm45831692849824), [Conditional Updates](#idm45831693319792)
* cast() function, [String-to-date conversions](#ch7sdc3)-[String-to-date conversions](#idm45831695021232), [Conversion Functions](#ch7conv2)-[Conversion Functions](#idm45831693788752)
* ceil() function, [Controlling Number Precision](#idm45831694236304)
* char type, [Character Data](#idm45831696740368), [Working with String Data](#idm45831694687008)
* char() function, [Including special characters](#idm45831694578512)
* character data (see strings; text types)
* character sets, [Character sets](#ch2cs2)-[Character sets](#idm45831696692912), [Including special characters](#idm45831694886528)
* charindx() function, [String functions that return numbers](#idm45831694482656)
* check constraints, [Step 3: Building SQL Schema Statements](#idm45831696307840), [Column Value Violations](#idm45831696081856), [Constraints](#idm45831692251904)
* chr() function, [Including special characters](#idm45831694577248)
* clob type, [Text data](#idm45831696655712), [Working with String Data](#idm45831694674800)
* cloud computing, [Cloud Computing](#ch17cc2)-[Cloud Computing](#idm45831691196960)
* clustering, [Clustering](#idm45831692273520)
* coalesce() function, [The case Expression](#idm45831692896160)
* Codd, E. F. (author), “A Relational Model of Data for Large Shared Data Banks”, [The Relational Model](#idm45831697171616)
* code examples (see examples)
* columns, [The Relational Model](#idm45831697166016), [What Is SQL?](#idm45831697086560)
  + - aliases for, in select clause, [Column Aliases](#idm45831695866896)
    - concatenating values of, [Column Value Concatenation](#idm45831691464512)
    - numeric placeholders for, [Sorting via Numeric Placeholders](#idm45831695616240)
    - viewing information about, [information\_schema](#idm45831691924912)
* commit command, [Ending a Transaction](#idm45831692580784)
* common table expressions (CTEs), [Common table expressions](#ch9cte)-[Common table expressions](#idm45831693174144)
* comparison operators, [Building a Condition](#idm45831695441792)
  + - (see also conditions)
* composite partitioning, [Composite partitioning](#ch17com2)-[Composite partitioning](#idm45831691286640)
* compound keys, [The Relational Model](#idm45831697236688)
* compound queries, [Set Theory in Practice](#idm45831694867408), [Set Operation Precedence](#idm45831694730112)
  + - (see also sets)
* concat() function, [Including special characters](#ch7cat)-[Including special characters](#idm45831694534336), [String functions that return strings](#ch7build)-[String functions that return strings](#idm45831694409872)
* concatenation operator
  + - || (for Oracle Database), [Including special characters](#idm45831694560672), [String functions that return strings](#idm45831694621184)
    - + (for SQL Server), [Including special characters](#idm45831694552144), [String functions that return strings](#idm45831694446096)
* conditional logic, [What Is Conditional Logic?](#ch11ce)-[What Is Conditional Logic?](#idm45831692907376)
  + - (see also case expressions)
* conditions, [Building a Condition](#idm45831695453824)
  + - (see also operators)
    - equality conditions, [Equality Conditions](#ch4eq)-[Data modification using equality conditions](#idm45831695400976)
    - evaluation of, [Condition Evaluation](#ch4ev)-[Using the not Operator](#idm45831695489808)
    - filter conditions, [The where Clause](#idm45831695690160), [Filtering](#idm45831695579984)
    - grouping with parentheses, [The where Clause](#idm45831695662288), [Using Parentheses](#idm45831695527504)
    - join conditions, [Table Links](#idm45831695743536), [Equality Conditions](#idm45831695416256), [The ANSI Join Syntax](#idm45831695068240)
    - matching conditions, [Matching Conditions](#ch4mat2)-[Using regular expressions](#idm45831695238224), [String functions that return numbers](#idm45831694452256)
    - membership conditions, [Membership Conditions](#ch4mem2)-[Using not in](#idm45831695323744), [The in and not in operators](#ch9in4)-[The any operator](#idm45831693367536)
    - with multicolumn subqueries, [Multicolumn Subqueries](#ch9mc3)-[Multicolumn Subqueries](#idm45831693343856)
    - multiple, [The where Clause](#idm45831695670032), [Condition Evaluation](#ch4mu)-[Using the not Operator](#idm45831695456688)
    - with null values, [Null: That Four-Letter Word](#ch4nu2)-[Null: That Four-Letter Word](#idm45831697129344)
    - range conditions, [Range Conditions](#ch4ra2)-[String ranges](#idm45831695356832), [Correlated Subqueries](#idm45831693324384)
    - regular expressions in, [Using regular expressions](#ch4reg2)-[Using regular expressions](#idm45831695235696)
    - with scalar subqueries, [Noncorrelated Subqueries](#ch9sca3)-[Noncorrelated Subqueries](#idm45831693454144)
* connection ID, [Query Mechanics](#idm45831695982448)
* consistency, [Constraints](#idm45831692243328)
* constraint clause, [Step 3: Building SQL Schema Statements](#idm45831696315232), [Step 3: Building SQL Schema Statements](#idm45831696258560)
* constraints, [Constraints](#idm45831692261808)
  + - check constraints, [Step 3: Building SQL Schema Statements](#idm45831696306528), [Column Value Violations](#idm45831696080592)
    - creating, [Constraint Creation](#ch13cc)-[Constraint Creation](#idm45831692172544)
    - foreign key constraints, [Step 3: Building SQL Schema Statements](#idm45831696259648), [Nonexistent Foreign Key](#idm45831696088304), [What Is a Join?](#idm45831695148688)
    - on subclauses for, [Constraint Creation](#ch13on3)-[Constraint Creation](#idm45831692179600)
    - primary key constraints, [Step 3: Building SQL Schema Statements](#idm45831696313968)
    - removing, [Constraint Creation](#idm45831692188608)
    - types of, [Constraints](#ch13con)-[Constraints](#idm45831692234752)
    - viewing information about, [information\_schema](#idm45831691901600)
* containing query or statement, [Derived (subquery-generated) tables](#idm45831695799008), [What Is a Subquery?](#idm45831693505424)
* conventions used in this book, [Conventions Used in This Book](#idm45831697343664)
* conversion functions, [Invalid Date Conversions](#idm45831696070256), [String-to-date conversions](#ch7sdc4)-[Functions for generating dates](#idm45831693936288), [Conversion Functions](#ch7conv3)-[Conversion Functions](#idm45831693787824)
* convert() function, [Functions for generating dates](#idm45831693942528)
* Coordinated Universal Time (UTC), [Dealing with Time Zones](#idm45831694161328)
* correlated subqueries, [Correlated Subqueries](#ch9corr2)-[Data Manipulation Using Correlated Subqueries](#idm45831693271104)
* cos() function, [Performing Arithmetic Functions](#idm45831694277952)
* cot() function, [Performing Arithmetic Functions](#idm45831694276688)
* count() function, [Grouping Concepts](#idm45831693758352), [Aggregate Functions](#idm45831693718288), [Counting Distinct Values](#ch8dt)-[Counting Distinct Values](#idm45831693929040), [Outer Joins](#idm45831693050832), [Reporting Functions](#idm45831691549488)
* create index statement, [Index Creation](#idm45831692436400)
* create table statement, [Step 3: Building SQL Schema Statements](#ch2sc2)-[Step 3: Building SQL Schema Statements](#idm45831696244384), [Constraint Creation](#idm45831692228368)
* create view statement, [Views](#idm45831695768048), [What Are Views?](#idm45831692236240)
* cross joins, [Cartesian Product](#idm45831695133136), [Cross Joins](#ch10cj2)-[Cross Joins](#idm45831692989808)
* CSV storage engine, [Transaction Savepoints](#idm45831692521408)
* CTEs (common table expressions), [Common table expressions](#ch9cte2)-[Common table expressions](#idm45831693167776)
* current\_date() function, [Functions for generating dates](#idm45831693929936)
* current\_time() function, [Functions for generating dates](#idm45831694043984)
* current\_timestamp() function, [Functions for generating dates](#idm45831693927440)

### D

* data dictionary, [SQL Statement Classes](#idm45831697028736), [Data About Data](#idm45831691951824)
  + - (see also metadata)
* data security (see security)
* data statements, [SQL Statement Classes](#idm45831697054832), [SQL Statement Classes](#idm45831697118368)
  + - (see also delete statement; insert statement; select statement; update statement)
* data types, [MySQL Data Types](#ch2dt2)-[Temporal Data](#idm45831696448048)
  + - numeric, [Numeric Data](#ch2num2)-[Numeric Data](#idm45831696592400)
    - strings, [Character Data](#idm45831696892272), [Working with String Data](#ch7dat2)-[Working with String Data](#idm45831694668240)
    - temporal, [Temporal Data](#ch2tem2)-[Temporal Data](#idm45831696444480), [String representations of temporal data](#idm45831694067552)
    - text, [Text data](#ch2tt2)-[Text data](#idm45831696640816)
* data windows, [Data Windows](#ch16win2)-[Data Windows](#idm45831691721232), [Generating Multiple Rankings](#idm45831691586128), [Reporting Functions](#idm45831691539984), [Window Frames](#idm45831691517808)
* database connection, [Query Mechanics](#idm45831695983712)
* Database in Depth (Date), [What’s in Store](#idm45831697012464)
* The Database Relational Model (Date), [What’s in Store](#idm45831696847488)
* database servers, [What Is MySQL?](#ch1com3)-[What Is MySQL?](#idm45831696884016)
  + - (see also DB2 Universal Database; MySQL; Oracle Database; SQL Server)
* database systems, [Introduction to Databases](#idm45831697240352)
* databases, [Introduction to Databases](#ch1db)-[The Relational Model](#idm45831697114448)
  + - big data, [Big Data](#ch17big2)-[Cloud Computing](#idm45831691637680), [SQL and Big Data](#ch18ad3)-[Introduction to Apache Drill](#idm45831691129120), [Future of SQL](#idm45831691003968)
    - clustering, [Clustering](#idm45831692272256)
    - consistency of, [Constraints](#idm45831692241872)
    - data types for, [MySQL Data Types](#ch2dt3)-[Temporal Data](#idm45831696447008)
    - hierarchical, [Nonrelational Database Systems](#ch1hier2)-[Nonrelational Database Systems](#idm45831697397568)
    - history of, [Introduction to Databases](#ch1hist)-[The Relational Model](#idm45831697168080)
    - listing in MySQL, [Using the mysql Command-Line Tool](#idm45831696795904)
    - metadata for (see metadata)
    - multiuser (see multiuser databases)
    - network, [Nonrelational Database Systems](#ch1net2)-[Nonrelational Database Systems](#idm45831697289008)
    - new technologies for, [SQL Unplugged](#idm45831696881536)
    - partitioning (see partitioning databases)
    - querying (see queries; SQL)
    - relational (see relational databases)
    - sharding, [Sharding](#ch17sh2)-[Sharding](#idm45831691600928)
    - specifying in MySQL, [Using the mysql Command-Line Tool](#idm45831696791056)
* date type, [Temporal Data](#idm45831696543472), [Generating Temporal Data](#idm45831694127712), [String representations of temporal data](#idm45831694074416)
* Date, C. J. (author)
  + - Database in Depth (O’Reilly), [What’s in Store](#idm45831696853568)
    - The Database Relational Model (Addison-Wesley), [What’s in Store](#idm45831696844176)
    - An Introduction to Database Systems (Addison-Wesley), [What’s in Store](#idm45831696849232)
* dateadd() function, [Temporal functions that return dates](#idm45831693875536)
* datediff() function, [Temporal functions that return numbers](#ch7diff2)-[Temporal functions that return numbers](#idm45831693813040), [Using Expressions](#idm45831694018000)
* datepart() function, [Temporal functions that return strings](#idm45831693834432)
* dates (see temporal data)
* datetime type, [Temporal Data](#idm45831696541504), [Generating Temporal Data](#idm45831694126384), [String representations of temporal data](#idm45831694072752)
* date\_add() function, [Temporal functions that return dates](#ch7ivl2)-[Temporal functions that return dates](#idm45831693876800)
* daylight saving time, [Dealing with Time Zones](#idm45831698327664)
* dayname() function, [Temporal functions that return strings](#idm45831693847008)
* DB2 Universal Database, [What Is MySQL?](#idm45831696900352)
  + - clob type, [Text data](#idm45831696657296)
    - except all implemented, [The except Operator](#idm45831694790640)
    - intersect all implemented, [The intersect Operator](#idm45831694811872)
* deadlock detection, [Ending a Transaction](#idm45831692632448)
* deallocate statement, [Dynamic SQL Generation](#idm45831691745568)
* decode() function, [The case Expression](#idm45831692898688)
* delete statement, [Deleting Data](#idm45831696122976), [Data Manipulation Using Correlated Subqueries](#idm45831693279744)
* dense\_rank() function, [Ranking Functions](#ch16fun3)-[Ranking Functions](#idm45831691605968)
* deployment verification, [Deployment Verification](#idm45831691779952)
* derived tables, [Derived (subquery-generated) tables](#idm45831695807312)
* desc keyword, [Ascending Versus Descending Sort Order](#idm45831695625312)
* describe command, [Step 3: Building SQL Schema Statements](#idm45831696286176), [The Sakila Database](#idm45831696005040), [What Are Views?](#idm45831692911792)
* distinct keyword, [Removing Duplicates](#idm45831695847824), [Counting Distinct Values](#idm45831693675344)
* division-by-zero error checking, [Division-by-Zero Errors](#ch11ze2)-[Division-by-Zero Errors](#idm45831692751472)
* document databases, [NoSQL and Document Databases](#idm45831691206224)
* double type, [Numeric Data](#idm45831696587040)
* drop constraint keywords, [Constraint Creation](#idm45831692176752)
* drop index keywords (MySQL), [Index Creation](#idm45831692415760)
* drop index statement (Oracle Database and SQL Server), [Index Creation](#idm45831692411280)
* drop table statement, [The Sakila Database](#idm45831696073904)
* DSL/Alpha language, [What Is SQL?](#idm45831697076224)
* dual table, [Using the mysql Command-Line Tool](#idm45831696775344)
* durability, [What Is a Transaction?](#idm45831693230320)
* dynamic SQL execution, [Dynamic SQL Generation](#idm45831692329856)
* dynamic SQL generation, [Dynamic SQL Generation](#ch15dg2)-[Dynamic SQL Generation](#idm45831691724256)

### E

* engine keyword, [Transaction Savepoints](#idm45831692510272)
  + - (see also storage engines)
* entities, [What Is SQL?](#idm45831697087872)
* enum type, [Step 3: Building SQL Schema Statements](#idm45831696305536)
* equality conditions, [Equality Conditions](#ch4eq2)-[Data modification using equality conditions](#idm45831695749472)
* ER (entity-relationship) diagram for Sakila database, [ER Diagram for Example Database](#idm45831691265264)
* errors
  + - column value, invalid, [Column Value Violations](#idm45831696083840)
    - date value, formatted incorrectly, [Invalid Date Conversions](#idm45831696072176)
    - division-by-zero, checking for, [Division-by-Zero Errors](#ch11ze3)-[Division-by-Zero Errors](#idm45831692750544)
    - foreign key, nonexistent, [Nonexistent Foreign Key](#idm45831696103296)
    - primary key, nonunique, [Nonunique Primary Key](#idm45831696113344)
* examples
  + - MySQL used for, [What Is MySQL?](#idm45831697067376)
    - Sakila database for, [Using the Examples in This Book](#idm45831697322176), [Creating a MySQL Database](#idm45831696826080), [Creating a MySQL Database](#idm45831697147728), [The Sakila Database](#ch2sak2)-[The Sakila Database](#idm45831696060416)
* except and except all operators, [Set Theory Primer](#idm45831694910880), [The except Operator](#ch6ex)-[The except Operator](#idm45831694773232)
* execute immediate command, [Dynamic SQL Generation](#idm45831691751936)
* execute statement, [Dynamic SQL Generation](#idm45831692326480)
* execution plan, [Query Mechanics](#idm45831695964224)
* exists operator, [The exists Operator](#ch9ist)-[The exists Operator](#idm45831693302208), [Checking for Existence](#ch11ex2)-[Checking for Existence](#idm45831692770512)
* exit command, [Using the mysql Command-Line Tool](#idm45831696763216)
* exp() function, [Performing Arithmetic Functions](#idm45831694275424)
* explain statement, [How Indexes Are Used](#idm45831694631968)
* explicit groups, [Implicit Versus Explicit Groups](#ch8gb2)-[Implicit Versus Explicit Groups](#idm45831693680800)
* exponentiation, [Performing Arithmetic Functions](#idm45831694258432)
* expressions
  + - arithmetic (see arithmetic functions; arithmetic operators)
    - in conditions, [Building a Condition](#idm45831695452288)
      * + (see also conditions)
* extract() function, [Temporal functions that return strings](#idm45831693843536)

### F

* files
  + - querying with Apache Drill, [Querying Files Using Drill](#ch18qf2)-[Querying Files Using Drill](#idm45831691137040)
    - text types for, [Text data](#ch2tt3)-[Text data](#idm45831696639552)
* filter conditions, [The where Clause](#idm45831695691664), [Filtering](#idm45831695582848)
  + - (see also conditions; having clause; where clause)
* fixed-length strings, [Character Data](#idm45831696742896)
* float type, [Numeric Data](#idm45831696589456)
* floating-point numbers, [Numeric Data](#idm45831696621056), [Controlling Number Precision](#ch7prec2)-[Controlling Number Precision](#idm45831694432064)
* floor() function, [Controlling Number Precision](#idm45831694235040)
* for xml clause, [The insert statement](#idm45831696143600)
* foreign key constraints, [Step 3: Building SQL Schema Statements](#idm45831696261152), [Nonexistent Foreign Key](#idm45831696093200), [What Is a Join?](#idm45831695160528), [Constraints](#idm45831692254000)
* foreign keys, [The Relational Model](#idm45831697322928), [What Is SQL?](#idm45831697080560)
  + - joins using, [What Is a Join?](#idm45831695364640)
    - nonexistant, error from, [Nonexistent Foreign Key](#idm45831696105216)
    - self-referencing, [Self-Joins](#idm45831694973680)
* Friedl, Jeffrey E. F. (author), Mastering Regular Expressions (O’Reilly), [Using regular expressions](#idm45831695248816)
* from clause, [The select Clause](#idm45831695911424), [The from Clause](#ch3fr)-[Defining Table Aliases](#idm45831695703904)
  + - older join syntax in, [The ANSI Join Syntax](#idm45831695071104)
    - omitting, [Using the mysql Command-Line Tool](#idm45831697320576), [The select Clause](#idm45831695874752)
    - subqueries in, [Subqueries as Data Sources](#ch9from2)-[Task-oriented subqueries](#idm45831693188528)
    - table aliases in, [Defining Table Aliases](#idm45831695726736)
    - table names in, [Tables](#ch3tt)-[Views](#idm45831695760256)
* full-text indexes, [Text indexes](#idm45831692309936)
* functions
  + - aggregate (see aggregate functions)
    - analytic (see analytic functions)
    - arithmetic, [Performing Arithmetic Functions](#ch7fun3)-[Performing Arithmetic Functions](#idm45831694246928)
    - conversion, [Invalid Date Conversions](#idm45831696068992), [String-to-date conversions](#ch7sdc5)-[Functions for generating dates](#idm45831693935184), [Conversion Functions](#ch7conv4)-[Conversion Functions](#idm45831693786672)
    - string, [String Manipulation](#ch7smf2)-[String functions that return strings](#idm45831694348736)

### G

* getutcdate() function, [Dealing with Time Zones](#idm45831694155216)
* Givre, Charles (author), Learning Apache Drill, [Introduction to Apache Drill](#idm45831691422640)
* global index, [Index Partitioning](#idm45831691394352)
* global.time\_zone value, [Dealing with Time Zones](#idm45831694149280)
* GMT (Greenwich Mean Time), [Dealing with Time Zones](#idm45831694180592)
* Go, SQL integration toolkit for, [SQL: A Nonprocedural Language](#idm45831696979664)
* group by clause, [The group by and having Clauses](#ch3gh)-[The group by and having Clauses](#idm45831695650880), [Grouping Concepts](#idm45831708826976), [Implicit Versus Explicit Groups](#ch8gb3)-[Implicit Versus Explicit Groups](#idm45831693680032)
* grouping, [Grouping Concepts](#ch8grp)-[Grouping Concepts](#idm45831693728912)
  + - (see also parentheses (( )))
    - aggregate functions with, [Grouping Concepts](#ch8agg2)-[How Nulls Are Handled](#idm45831693618320)
    - based on expressions, [Grouping via Expressions](#ch8exp)-[Grouping via Expressions](#idm45831693647968)
    - explicit groups, [Implicit Versus Explicit Groups](#ch8gb)-[Implicit Versus Explicit Groups](#idm45831693681568)
    - filtering results of, [Grouping Concepts](#ch8fil)-[Grouping Concepts](#idm45831693728144), [Group Filter Conditions](#ch8hv)-[Group Filter Conditions](#idm45831693523008)
    - implicit groups, [Implicit Versus Explicit Groups](#idm45831708813888)
    - multicolumn grouping, [Multicolumn Grouping](#idm45831693607744)
    - rollups with, [Generating Rollups](#ch8roll)-[Generating Rollups](#idm45831693545648)
    - single-column grouping, [Single-Column Grouping](#idm45831693612048)
    - sorting results of, [Grouping Concepts](#idm45831693752176)
* group\_concat() function, [Column Value Concatenation](#idm45831691465776)

### H

* Hadoop, [SQL Unplugged](#idm45831696878336), [Hadoop](#idm45831691220192), [Introduction to Apache Drill](#idm45831691150560)
* hash partitioning, [Hash partitioning](#ch17ha2)-[Hash partitioning](#idm45831691558992)
* hashing function, [Hash partitioning](#idm45831691319776)
* having clause, [The group by and having Clauses](#ch3gh2)-[The group by and having Clauses](#idm45831695649584), [Grouping Concepts](#idm45831693795248), [Group Filter Conditions](#ch8hv2)-[Group Filter Conditions](#idm45831693522256), [The all operator](#idm45831693391840)
  + - (see also conditions)
* HDFS (Hadoop Distributed File System), [Hadoop](#idm45831691216912)
* hierarchical database systems, [Nonrelational Database Systems](#ch1hier)-[Nonrelational Database Systems](#idm45831697398832)
* High Performance MySQL (Schwartz, et al.), [Query Mechanics](#idm45831695959024)
* Hive, [Introduction to Apache Drill](#idm45831694638624)
* horizontal partitioning, [Table Partitioning](#idm45831691406128)

### I

* IBM DB2 Universal Database (see DB2 Universal Database)
* ID, connection, [Query Mechanics](#idm45831695981184)
* if() function, [The case Expression](#idm45831692897424)
* implicit groups, [Implicit Versus Explicit Groups](#idm45831693701488)
* in operator, [Membership Conditions](#ch4ino)-[Using subqueries](#idm45831695333104), [The in and not in operators](#ch9in)-[The in and not in operators](#idm45831693419424)
* index partitioning, [Index Partitioning](#idm45831691395456)
* indexes, [Indexes](#ch13in)-[Indexes](#idm45831692693520)
  + - B-tree indexes, [B-tree indexes](#idm45831692358352)
    - bitmap indexes, [Bitmap indexes](#idm45831692531104)
    - creating, [Index Creation](#ch13cr)-[Multicolumn indexes](#idm45831692449872)
    - default type of, [B-tree indexes](#idm45831692359696)
    - disadvantages of, [The Downside of Indexes](#ch13dis)-[The Downside of Indexes](#idm45831692911248)
    - displaying, [Index Creation](#idm45831692430640)
    - ideal number of, [The Downside of Indexes](#idm45831692304048)
    - multicolumn indexes, [Multicolumn indexes](#idm45831692375104)
    - query optimizer using, [Index Creation](#idm45831692444064), [How Indexes Are Used](#ch13qu)-[How Indexes Are Used](#idm45831692369936)
    - removing, [Index Creation](#idm45831692418032)
    - text indexes, [Text indexes](#idm45831692311168)
    - unique indexes, [Unique indexes](#ch13un2)-[Unique indexes](#idm45831692617824)
    - viewing information about, [information\_schema](#idm45831691908336)
* information\_schema database, [Data About Data](#ch15sch)-[information\_schema](#idm45831691819264)
  + - (see also schema statements)
    - Apache Drill access to, [Querying Files Using Drill](#idm45831691126144)
    - querying, [information\_schema](#ch15qu)-[information\_schema](#idm45831691900640)
* inner join keywords, [Table Links](#ch3jo3)-[Table Links](#idm45831695728512), [Inner Joins](#idm45831695102784)
* inner joins, [Inner Joins](#ch5in)-[Inner Joins](#idm45831695091136)
* InnoDB storage engine, [Nonexistent Foreign Key](#idm45831696090880), [Transaction Savepoints](#idm45831692520464), [Constraints](#idm45831692851744)
* insert statement, [The insert statement](#ch2in2)-[The insert statement](#idm45831696777712), [Subqueries as Expression Generators](#idm45831693129232)
* insert() function, [String functions that return strings](#ch7ins)-[String functions that return strings](#idm45831694389856)
* instr() function, [String functions that return numbers](#idm45831694485456)
* int type, [Numeric Data](#idm45831696614640)
* integers, [Numeric Data](#idm45831696622208)
* intersect and intersect all operators, [Set Theory Primer](#idm45831694916416), [The intersect Operator](#ch6in)-[The intersect Operator](#idm45831694808464)
* An Introduction to Database Systems (Date), [What’s in Store](#idm45831696852224)
* is not null operator, [Null: That Four-Letter Word](#idm45831695317536)
* is null operator, [Null: That Four-Letter Word](#ch4inull)-[Null: That Four-Letter Word](#idm45831695186784)

### J

* Java, SQL integration toolkit for, [SQL: A Nonprocedural Language](#idm45831696991536)
* JDBC (Java Database Connectivity), [SQL: A Nonprocedural Language](#idm45831696978464)
* JDBC driver for MySQL, [Querying MySQL Using Drill](#idm45831691096400)
* join keyword, [Cartesian Product](#idm45831695197936), [Inner Joins](#idm45831695121344)
  + - (see also on subclause; using subclause)
* joins, [The Relational Model](#idm45831697127536), [Table Links](#ch3jo2)-[Table Links](#idm45831695729776), [Querying Multiple Tables](#ch5jo)-[The ANSI Join Syntax](#idm45831695053424)
  + - ANSI SQL92 syntax for, [The ANSI Join Syntax](#ch5an)-[The ANSI Join Syntax](#idm45831695057232)
    - conditions for, [Table Links](#idm45831695745424), [Equality Conditions](#idm45831695417664), [The ANSI Join Syntax](#idm45831695069776)
    - cross joins, [Cartesian Product](#idm45831696861152), [Cross Joins](#ch10cj)-[Cross Joins](#idm45831693236144)
    - default type of, [Inner Joins](#idm45831695097664)
    - inner joins, [Inner Joins](#ch5in2)-[Inner Joins](#idm45831695088688)
    - multiple, constructing, [Joining Three or More Tables](#ch5th)-[Using the Same Table Twice](#idm45831694986960)
    - multiple, order of, [Joining Three or More Tables](#idm45831695034192)
    - natural joins, [Natural Joins](#ch10nj2)-[Natural Joins](#idm45831695233680)
    - older syntax for, [The ANSI Join Syntax](#idm45831695085984)
    - outer joins, [Inner Joins](#idm45831696862080), [Outer Joins](#ch10out)-[Three-Way Outer Joins](#idm45831693002576)
    - partition-wise joins, [Partitioning Benefits](#idm45831691276688)
    - same table joined multiple times in, [Using the Same Table Twice](#ch5tw)-[Using the Same Table Twice](#idm45831694980336)
    - self-joins, [Self-Joins](#ch5se)-[Self-Joins](#idm45831694956832)
    - subqueries as tables in, [Using Subqueries as Tables](#ch5sub)-[Using Subqueries as Tables](#idm45831694999664)
    - views using, [What Are Views?](#idm45831692138240), [Joining Partitioned Data](#ch14vj2)-[Joining Partitioned Data](#idm45831692052480)
* JSON files
  + - document databases using, [NoSQL and Document Databases](#idm45831691205120)
    - loading into MongoDB, [Querying MongoDB Using Drill](#ch18load)-[Querying MongoDB Using Drill](#idm45831691047344)

### K

* keys (see foreign keys; primary keys)
* Korpela, Jukka (author), Unicode Explained (O’Reilly), [Character sets](#idm45831696695120)

### L

* lag() function, [Lag and Lead](#ch16ll)-[Lag and Lead](#idm45831691474720)
* last\_day() function, [Temporal functions that return dates](#idm45831693864160)
* lead() function, [Lag and Lead](#ch16ll2)-[Lag and Lead](#idm45831691468512)
* leaf nodes, [B-tree indexes](#idm45831692355904)
* Learning Apache Drill (O’Reilly), [Introduction to Apache Drill](#idm45831691423776)
* left outer joins, [Outer Joins](#ch10lo)-[Left Versus Right Outer Joins](#idm45831693033680)
* len() function, [String functions that return numbers](#idm45831694516832)
* length() function, [String functions that return numbers](#idm45831694518096)
* like operator, [Using wildcards](#idm45831695294064), [String functions that return numbers](#idm45831694454848)
* list partitioning, [List partitioning](#ch17li2)-[List partitioning](#idm45831691612144)
* ln() function, [Performing Arithmetic Functions](#idm45831694274160)
* local index, [Index Partitioning](#idm45831691393248)
* locate() function, [String functions that return numbers](#idm45831694493984)
* locking, [Locking](#ch12lck2)-[Lock Granularities](#idm45831693096496)
  + - granularities of, [Lock Granularities](#ch12gr)-[Lock Granularities](#idm45831693095344)
    - read lock, [Locking](#idm45831692680928)
    - storage engine determining, [Transaction Savepoints](#ch12eng3)-[Transaction Savepoints](#idm45831692505488)
    - versioning approach, [Locking](#idm45831694238720)
    - write lock, [Locking](#idm45831692760544)
* logical operators
  + - and operator, [The where Clause](#idm45831695681888), [Condition Evaluation](#idm45831695565408)
    - not operator, [Using the not Operator](#idm45831695492736)
    - or operator, [The where Clause](#idm45831695679088), [Condition Evaluation](#idm45831695555792)
* longtext type, [Text data](#idm45831696678448)
* low-cardinality data, [Bitmap indexes](#idm45831708732080)

### M

* MapReduce, [Hadoop](#idm45831691217680)
* Mastering Regular Expressions (O’Reilly), [Using regular expressions](#idm45831695783472)
* matching conditions, [Matching Conditions](#ch4mat)-[Using regular expressions](#idm45831695239312), [String functions that return numbers](#idm45831694453408)
* max() function, [Aggregate Functions](#idm45831693723696), [Reporting Functions](#ch16ag3)-[Reporting Functions](#idm45831691521936)
* mediumint type, [Numeric Data](#idm45831696615792)
* mediumtext type, [Text data](#idm45831696679712)
* membership conditions, [Membership Conditions](#ch4mem)-[Using not in](#idm45831695325040), [The in and not in operators](#ch9in5)-[The any operator](#idm45831693366432)
* MEMORY storage engine, [Transaction Savepoints](#idm45831692522176)
* Merge storage engine, [Transaction Savepoints](#idm45831692519200)
* metadata, [Data About Data](#ch15met)-[Data About Data](#idm45831692157856)
  + - about partitioned tables, [Range partitioning](#idm45831691375696)
    - Apache Drill access to, [Querying Files Using Drill](#idm45831691118944)
    - deployment verification using, [Deployment Verification](#idm45831691947568)
    - dynamic SQL generation using, [Dynamic SQL Generation](#ch15dg)-[Dynamic SQL Generation](#idm45831691725024)
    - in information\_schema database, [Data About Data](#ch15sch2)-[information\_schema](#idm45831691818000)
    - querying, [information\_schema](#ch15qu2)-[information\_schema](#idm45831691893488)
    - schema generation scripts from, [Schema Generation Scripts](#ch15scrip)-[Schema Generation Scripts](#idm45831691790672)
* Microsoft SQL Server (see SQL Server)
* min() function, [Aggregate Functions](#idm45831693761872), [Reporting Functions](#ch16ag2)-[Reporting Functions](#idm45831691522704)
* minus operator, [The except Operator](#idm45831694796096)
* mod() function, [Performing Arithmetic Functions](#idm45831694280784)
* MongoDB
  + - document databases using, [NoSQL and Document Databases](#idm45831693336304)
    - querying with Apache Drill, [Querying MongoDB Using Drill](#ch18mon2)-[Querying MongoDB Using Drill](#idm45831691027520)
* multi-parent hierarchy, [Nonrelational Database Systems](#idm45831697193760)
* multibyte character sets, [Character sets](#idm45831697258800)
* multicolumn grouping, [Multicolumn Grouping](#idm45831693598864)
* multicolumn indexes, [Multicolumn indexes](#idm45831692373568)
* multicolumn subqueries, [Multicolumn Subqueries](#ch9mc2)-[Multicolumn Subqueries](#idm45831693345120)
* multiple-row, single-column subqueries, [Multiple-Row, Single-Column Subqueries](#ch9mr2)-[The any operator](#idm45831693403984)
* multiuser databases, [Multiuser Databases](#idm45831692732304)
  + - locking for, [Locking](#ch12lck)-[Lock Granularities](#idm45831692646784), [Transaction Savepoints](#ch12eng4)-[Transaction Savepoints](#idm45831692504320)
    - transactions for, [What Is a Transaction?](#ch12tr)-[Transaction Savepoints](#idm45831692483440)
* MyISAM storage engine, [Transaction Savepoints](#idm45831692525680)
* MySQL, [What Is MySQL?](#idm45831697264832)
  + - auto\_increment keyword, [Generating numeric key data](#idm45831696217296)
    - data types, [MySQL Data Types](#ch2dt)-[Temporal Data](#idm45831696448912)
    - databases in, listing, [Using the mysql Command-Line Tool](#idm45831696794752)
    - databases in, specifying, [Using the mysql Command-Line Tool](#idm45831696789584)
    - date formats, [Invalid Date Conversions](#idm45831696058512)
    - date ranges allowed, [Temporal Data](#idm45831696499680)
    - default index type, [B-tree indexes](#idm45831692354672)
    - dual table in, [Using the mysql Command-Line Tool](#idm45831696772688)
    - except operator not implemented, [The except Operator](#idm45831694801232)
    - full-text indexes, [Text indexes](#idm45831692307664)
    - if() function, [The case Expression](#idm45831692901760)
    - installing, [Creating a MySQL Database](#idm45831697181072)
    - intersect operator not implemented, [The intersect Operator](#idm45831694822208)
    - JDBC driver for, [Querying MySQL Using Drill](#idm45831691095136)
    - locking granularities, [Lock Granularities](#idm45831694844240)
    - metadata access, [Data About Data](#idm45831691944976)
    - parentheses not allowed in compound queries, [Set Operation Precedence](#idm45831694731616)
    - query execution by, [Query Mechanics](#ch3ex2)-[Query Mechanics](#idm45831695942304)
    - querying with Apache Drill, [Querying MySQL Using Drill](#ch18qm2)-[Querying MySQL Using Drill](#idm45831691072528)
    - silent truncation of strings, [String Generation](#ch7sil)-[String Generation](#idm45831694623648)
    - storage engines, [Transaction Savepoints](#ch12eng)-[Transaction Savepoints](#idm45831692567440)
    - transaction approach, [Starting a Transaction](#idm45831692615216)
    - updatable view restrictions, [Updatable Views](#idm45831692585888)
    - utc\_timestamp() function, [Dealing with Time Zones](#idm45831694154448)
* mysql command, [SQL: A Nonprocedural Language](#idm45831696955680), [Using the mysql Command-Line Tool](#ch2mys)-[Using the mysql Command-Line Tool](#idm45831696760400)
  + - feedback from, [SQL Examples](#idm45831697235888)
    - query execution by, [Query Mechanics](#ch3ex3)-[Query Mechanics](#idm45831695941376)
    - --xml option, [The insert statement](#idm45831696149136)
* MySQL stored procedure language, [SQL: A Nonprocedural Language](#idm45831696996720)
* MySQL Workbench, [Schema Generation Scripts](#idm45831691784880)

### N

* natural joins, [Natural Joins](#ch10nj)-[Natural Joins](#idm45831692942544)
* natural keys, [The Relational Model](#idm45831697144848)
* network database systems, [Nonrelational Database Systems](#ch1net)-[Nonrelational Database Systems](#idm45831708886256)
* NewSQL, [SQL Unplugged](#idm45831696874448)
* noncorrelated subqueries, [Noncorrelated Subqueries](#ch9non2)-[Multicolumn Subqueries](#idm45831693490224)
* nonprocedural languages, [SQL: A Nonprocedural Language](#idm45831697011616)
* nonrelational databases, [Nonrelational Database Systems](#ch1non)-[Nonrelational Database Systems](#idm45831697287744)
* normalization, [The Relational Model](#idm45831697121488), [Step 2: Refinement](#ch2nor2)-[Step 2: Refinement](#idm45831696325216)
* NoSQL, [SQL Unplugged](#idm45831696875712), [NoSQL and Document Databases](#idm45831691207328), [Introduction to Apache Drill](#idm45831691148352)
* not in operator, [Using not in](#idm45831695331504), [The in and not in operators](#ch9in2)-[The in and not in operators](#idm45831693418656)
* not null keywords, [Step 3: Building SQL Schema Statements](#idm45831696274368)
* not operator, [Using the not Operator](#idm45831695491424)
* now() function, [Using the mysql Command-Line Tool](#idm45831697480512)
* null values, [Step 3: Building SQL Schema Statements](#idm45831697190384)
  + - aggregate functions handling, [How Nulls Are Handled](#ch8null2)-[How Nulls Are Handled](#idm45831693615792)
    - all operator handling, [The all operator](#idm45831693398800)
    - case expressions handling, [Handling Null Values](#ch11null2)-[Handling Null Values](#idm45831692723632)
    - comparisons with, [Null: That Four-Letter Word](#ch4nu)-[Null: That Four-Letter Word](#idm45831695191152)
    - disallowing for a table column, [Step 3: Building SQL Schema Statements](#idm45831696275808)
    - not in operator handling, [The all operator](#idm45831693400048)
    - outer joins resulting in, [Outer Joins](#idm45831693042384)
* numeric data
  + - arithmetic functions for, [Performing Arithmetic Functions](#ch7fun)-[Performing Arithmetic Functions](#idm45831694249488)
    - arithmetic operators for, [Building a Condition](#idm45831695438992), [Working with Numeric Data](#idm45831694345712)
    - precision of, controlling, [Controlling Number Precision](#ch7prec)-[Controlling Number Precision](#idm45831697227104)
    - signed, functions for, [Handling Signed Data](#ch7sign)-[Handling Signed Data](#idm45831694187344)
* numeric data types, [Numeric Data](#ch2num)-[Numeric Data](#idm45831706680416)

### O

* on delete clause, [Constraint Creation](#ch13on)-[Constraint Creation](#idm45831692181920)
* on subclause, [Table Links](#idm45831695742064), [Equality Conditions](#idm45831695414944), [Inner Joins](#idm45831695156192)
* on update clause, [Constraint Creation](#ch13on2)-[Constraint Creation](#idm45831692180864)
* online resources
  + - Apache Drill's SQL implementation, [Querying MySQL Using Drill](#idm45831691092672)
    - database management systems, [What’s in Store](#idm45831696842384)
    - for this book, [How to Contact Us](#idm45831697279984)
    - MySQL, [Creating a MySQL Database](#idm45831696824640)
    - Oracle Database Reference Guide, [information\_schema](#idm45831691820768)
    - Sakila database, [Using the Examples in This Book](#idm45831704198256), [Creating a MySQL Database](#idm45831696823104), [Creating a MySQL Database](#idm45831697146640)
* operators
  + - between conditions (see logical operators)
    - for null values, [Null: That Four-Letter Word](#ch4nu3)-[Null: That Four-Letter Word](#idm45831704872832)
    - for sets (see set operators)
    - within conditions (see arithmetic operators; comparison operators)
* optimizer, [SQL: A Nonprocedural Language](#idm45831697024448)
* optimizer hints, [SQL: A Nonprocedural Language](#idm45831697000848)
* or operator, [The where Clause](#idm45831695680352), [Condition Evaluation](#idm45831695554096)
* Oracle Database, [What Is MySQL?](#idm45831697035552)
  + - add\_months() function, [Temporal functions that return dates](#idm45831693870032)
    - bitmap indexes, [Bitmap indexes](#idm45831692703840)
    - char, varchar2 and clob sizes, [Text data](#idm45831696651936)
    - chr() function, [Including special characters](#idm45831694575984)
    - clob type, [Text data](#idm45831696663136), [Working with String Data](#idm45831694673504)
    - concatenation operator (||), [Including special characters](#idm45831694558480), [String functions that return strings](#idm45831694412528)
    - create index statement, [Index Creation](#idm45831692602016)
    - current date and time functions, [Functions for generating dates](#idm45831693925168)
    - date ranges allowed, [Temporal Data](#idm45831696502688)
    - decode() function, [The case Expression](#idm45831692903712)
    - default index type, [B-tree indexes](#idm45831692351600)
    - drop index statement, [Index Creation](#idm45831692408416)
    - execute immediate command, [Dynamic SQL Generation](#idm45831691789328)
    - from clause required in, [Using the mysql Command-Line Tool](#idm45831696774224)
    - instr() function, [String functions that return numbers](#idm45831694487120)
    - locking approach, [Locking](#idm45831696016240)
    - locking granularities, [Lock Granularities](#idm45831694845040)
    - metadata access, [Data About Data](#idm45831692045824), [information\_schema](#idm45831691822304)
    - minus operator, [The except Operator](#idm45831694804784)
    - pivot clause, [Result Set Transformations](#idm45831692797520)
    - plan\_table table, [How Indexes Are Used](#idm45831692287568)
    - replace() function, [String functions that return strings](#idm45831694388672)
    - rollups, generating, [Generating Rollups](#idm45831693692128)
    - sequence object, [Generating numeric key data](#idm45831696220224)
    - session time zone setting, [Dealing with Time Zones](#idm45831694134240)
    - substr() function, [String functions that return strings](#idm45831694369776)
    - subtracting dates, [Temporal functions that return numbers](#idm45831693859648)
    - temporary tables, duration of, [Temporary tables](#idm45831697217216)
    - to\_date() function, [Functions for generating dates](#idm45831693946544)
    - transaction approach, [Starting a Transaction](#idm45831694702720)
    - unique keyword, [Unique indexes](#idm45831692384368)
    - updatable view restrictions, [Updating Complex Views](#idm45831692812992)
    - varchar2 data type, [Character Data](#idm45831696726896)
    - VPD (Virtual Private Database), [Data Security](#idm45831692102944)
* Oracle Exadata platform, [Clustering](#idm45831691484096)
* Oracle SQL Developer, [Schema Generation Scripts](#idm45831691786144)
* Oracle Text, [Text indexes](#idm45831692308832)
* order by clause, [The order by Clause](#ch3sor)-[Sorting via Numeric Placeholders](#idm45831695624176)
  + - in compound queries, [Sorting Compound Query Results](#ch6sort3)-[Sorting Compound Query Results](#idm45831694753040)
    - with grouping, [Grouping Concepts](#idm45831693748688)
    - localized, [Localized Sorting](#ch16ob3)-[Localized Sorting](#idm45831691646672)
    - subqueries in, [Subqueries as Expression Generators](#idm45831693135456)
* outer joins, [Inner Joins](#idm45831695104064), [Outer Joins](#ch10out2)-[Three-Way Outer Joins](#idm45831693001280)
  + - left outer joins, [Outer Joins](#ch10lo2)-[Left Versus Right Outer Joins](#idm45831693073312)
    - right outer joins, [Left Versus Right Outer Joins](#ch10ro)-[Left Versus Right Outer Joins](#idm45831693071104)
    - three-way outer joins, [Three-Way Outer Joins](#ch10tw)-[Three-Way Outer Joins](#idm45831693000016)
* over clause, [Data Windows](#idm45831692117584), [Generating Multiple Rankings](#idm45831691671952), [Reporting Functions](#idm45831691562176)

### P

* Package database/sql, [SQL: A Nonprocedural Language](#idm45831696973440)
* packet capture (PCAP) files, [Querying Files Using Drill](#ch18qf4)-[Querying Files Using Drill](#idm45831691102672)
* page locks, [Lock Granularities](#idm45831692661600)
* parentheses (( ))
  + - enclosing subqueries, [Derived (subquery-generated) tables](#idm45831695805264)
    - grouping arithmetic operations, [Working with Numeric Data](#idm45831694338288)
    - grouping compound queries, [Set Operation Precedence](#idm45831694735200)
    - grouping filter conditions, [The where Clause](#idm45831695955184), [Using Parentheses](#idm45831695771824)
* partition by clause, [Data Windows](#idm45831692111856), [Localized Sorting](#idm45831691661376), [Generating Multiple Rankings](#idm45831691588928), [Reporting Functions](#idm45831691543200)
* partition by hash keywords, [Hash partitioning](#idm45831691494848)
* partition by list keywords, [List partitioning](#idm45831691341264)
* partition by range keywords, [Range partitioning](#idm45831694352448)
* partition function, [Table Partitioning](#idm45831691399296)
* partition key, [Table Partitioning](#idm45831691401328)
* partition pruning, [Partitioning Benefits](#idm45831691278368)
* partition-wise joins, [Partitioning Benefits](#idm45831691290288)
* partitioning databases, [Partitioning](#ch17pa)-[Partitioning Concepts](#idm45831691420384)
  + - benefits of, [Partitioning Benefits](#idm45831691283888)
    - composite partitioning, [Composite partitioning](#ch17com)-[Composite partitioning](#idm45831691287776)
    - hash partitioning, [Hash partitioning](#ch17ha)-[Hash partitioning](#idm45831691559888)
    - index partitioning, [Index Partitioning](#idm45831691397152)
    - list partitioning, [List partitioning](#ch17li)-[List partitioning](#idm45831691327520)
    - metadata regarding, [Range partitioning](#idm45831696699760)
    - range partitioning, [Range partitioning](#ch17ran)-[Range partitioning](#idm45831691355296)
    - reasons for, [Partitioning](#idm45831691435584)
    - reorganizing partitions, [Range partitioning](#idm45831691373104)
    - table partitioning, [Table Partitioning](#idm45831691408784)
* PCAP (packet capture) files, [Querying Files Using Drill](#ch18qf3)-[Querying Files Using Drill](#idm45831691135776)
* percent sign (%), modulo operator, [Performing Arithmetic Functions](#idm45831694264944)
* permissions, [Query Mechanics](#idm45831696043648), [Data Security](#idm45831692264624), [Querying Files Using Drill](#idm45831691115584)
* pivot clause, [Result Set Transformations](#idm45831692795984)
* PL/SQL language, [SQL: A Nonprocedural Language](#idm45831696997824)
* plan\_table table, [How Indexes Are Used](#idm45831692284800)
* plus sign (+), concatenation operator, SQL Server, [Including special characters](#idm45831694548736)
  + - (see also arithmetic operators)
* position() function, [String functions that return numbers](#idm45831694503472)
* PostgreSQL, [What Is MySQL?](#idm45831697267104)
* pow() function, [Performing Arithmetic Functions](#idm45831694259648)
* precision of floating-point types, [Numeric Data](#idm45831696572064)
* prepare statement, [Dynamic SQL Generation](#idm45831691746736)
* Presto, [SQL and Big Data](#idm45831691156608)
* primary key constraints, [Step 3: Building SQL Schema Statements](#idm45831696312432), [Constraints](#idm45831692300816)
* primary keys, [The Relational Model](#idm45831697165680), [What Is SQL?](#idm45831697081824), [Step 3: Building SQL Schema Statements](#idm45831696437920)
  + - generating values for, [Generating numeric key data](#idm45831696225184)
    - nonunique, error from, [Nonunique Primary Key](#idm45831696159664)
* private tables, [Data Security](#idm45831692265888)
* procedural languages, [SQL: A Nonprocedural Language](#idm45831697010416)
* programming languages, integrating SQL with, [SQL: A Nonprocedural Language](#idm45831696998928)
* Python DB, [SQL: A Nonprocedural Language](#idm45831696974704)
* Python, SQL integration toolkit for, [SQL: A Nonprocedural Language](#idm45831696987840)

### Q

* queries
  + - aggregate functions in (see aggregate functions)
    - analytic functions in (see analytic functions)
    - with Apache Drill (see Apache Drill)
    - case expressions in (see case expressions)
    - clauses in, [SQL Examples](#idm45831706191856), [Query Clauses](#idm45831695939312)
      * + (see also from clause; group by clause; having clause; order by clause; select statement; where clause)
    - compound, [Set Theory in Practice](#idm45831694865680), [Set Operation Precedence](#idm45831694728848)
      * + (see also sets)
    - execution of, by MySQL, [Query Mechanics](#ch3ex)-[Query Mechanics](#idm45831695943232)
    - on multiple databases, [Drill with Multiple Data Sources](#ch18mul2)-[Drill with Multiple Data Sources](#idm45831691771856)
    - on multiple tables (see joins)
    - permission to execute, [Query Mechanics](#idm45831695974400)
    - subqueries (see subqueries)
    - tuning, [How Indexes Are Used](#idm45831692371536)
    - XML output from, [The insert statement](#idm45831696152176)
* query optimizer, [Query Mechanics](#idm45831695965680), [Index Creation](#idm45831692445520), [How Indexes Are Used](#ch13qu2)-[How Indexes Are Used](#idm45831708823712)
* quit command, [Using the mysql Command-Line Tool](#idm45831696764336)
* quote() function, [Including single quotes](#idm45831694595424)
* quotes, single (' ')
  + - enclosing strings, [String Generation](#idm45831694662512)
    - escape sequence for, [Including single quotes](#ch7esc)-[Including single quotes](#idm45831694589360)

### R

* range between subclause, [Window Frames](#idm45831691503904)
* range conditions, [Range Conditions](#ch4ra)-[String ranges](#idm45831695400240), [Correlated Subqueries](#idm45831693325488)
* range partitioning, [Range partitioning](#ch17ran2)-[Range partitioning](#idm45831691352672)
* rank() function, [Ranking Functions](#ch16fun2)-[Generating Multiple Rankings](#idm45831691568960)
* ranking functions, [Ranking](#ch16rn)-[Generating Multiple Rankings](#idm45831691571184)
* read lock, [Locking](#idm45831692761808)
* references keyword, [Step 3: Building SQL Schema Statements](#idm45831696257296), [Constraint Creation](#idm45831692225216)
* regexp operator, [Using regular expressions](#idm45831695263952), [String functions that return numbers](#idm45831694444784)
* regular expressions, [Using regular expressions](#ch4reg)-[Using regular expressions](#idm45831695236960)
* relational databases, [The Relational Model](#ch1rel)-[The Relational Model](#idm45831697113008)
  + - future of, [Future of SQL](#idm45831691002432)
    - history of, [Preface](#idm45831697414352), [The Relational Model](#idm45831697176608)
    - querying (see queries; SQL)
    - relationship to SQL, [What Is SQL?](#idm45831697553216)
    - servers using, [What Is MySQL?](#ch1com)-[What Is MySQL?](#idm45831696889776)
      * + (see also specific servers)
* “A Relational Model of Data for Large Shared Data Banks” (Codd), [The Relational Model](#idm45831697170144)
* reorganize partition keywords, [Range partitioning](#idm45831691371152)
* replace() function, [String functions that return strings](#idm45831694387472)
* reporting functions, [Reporting Functions](#ch16rep)-[Column Value Concatenation](#idm45831691470336)
* resources (see books and publications; online resources)
* result sets, [What Is SQL?](#idm45831697083088), [What Is SQL?](#idm45831706191536), [Query Mechanics](#idm45831704872384)
  + - analytic functions for (see analytic functions)
    - duplicates in, including, [Removing Duplicates](#idm45831695835184), [The intersect Operator](#idm45831694816576), [The except Operator](#idm45831694815792)
    - duplicates in, removing, [Removing Duplicates](#idm45831695846672), [The union Operator](#idm45831694838480), [Counting Distinct Values](#idm45831693674080)
    - sorting, [The order by Clause](#ch3sor2)-[Sorting via Numeric Placeholders](#idm45831695611808)
      * + (see also order by clause)
    - sorting, for compound queries, [Sorting Compound Query Results](#ch6sort2)-[Sorting Compound Query Results](#idm45831694753904)
    - transforming, [Result Set Transformations](#ch11tr2)-[Result Set Transformations](#idm45831693010016)
* right outer joins, [Left Versus Right Outer Joins](#ch10ro2)-[Left Versus Right Outer Joins](#idm45831693017456)
* Rogers, Paul (author), Learning Apache Drill, [Introduction to Apache Drill](#idm45831691134384)
* rollback command, [Ending a Transaction](#idm45831692587776)
* rollback to savepoint command, [Transaction Savepoints](#idm45831692499280)
* rollback transaction command, [Transaction Savepoints](#idm45831692487360)
* rollups, generating, [Generating Rollups](#ch8roll2)-[Generating Rollups](#idm45831693544880)
* round() function, [Controlling Number Precision](#idm45831694227632)
* row locks, [Lock Granularities](#idm45831692660496)
* rows, [The Relational Model](#idm45831697164208), [What Is SQL?](#idm45831697085616)
* rows between subclause, [Window Frames](#idm45831691505680)
* rows unbounded preceding subclause, [Window Frames](#idm45831692705408)
* row\_number() function, [Ranking Functions](#ch16fun)-[Ranking Functions](#idm45831691604720)
* Ruby DBI, [SQL: A Nonprocedural Language](#idm45831696975968)
* Ruby, SQL integration toolkit for, [SQL: A Nonprocedural Language](#idm45831696989072)

### S

* Sakila database, [The Sakila Database](#ch2sak)-[The Sakila Database](#idm45831695999920)
  + - downloading, [Using the Examples in This Book](#idm45831706717584), [Creating a MySQL Database](#idm45831696827424), [Creating a MySQL Database](#idm45831696938000)
    - ER diagram for, [ER Diagram for Example Database](#idm45831691266800)
* save transaction command, [Transaction Savepoints](#idm45831692488224)
* savepoint command, [Transaction Savepoints](#idm45831692502176)
* savepoints, [Transaction Savepoints](#ch12sav2)-[Transaction Savepoints](#idm45831692480880)
* scalar subqueries, [Noncorrelated Subqueries](#ch9sca2)-[Noncorrelated Subqueries](#idm45831693489104)
  + - in order by clause, [Subqueries as Expression Generators](#idm45831693149872)
    - in select clause, [Subqueries as Expression Generators](#idm45831693158624)
    - in values clause of insert statement, [Subqueries as Expression Generators](#idm45831693126544)
* scale of floating-point types, [Numeric Data](#idm45831696570608)
* schema statements, [SQL Statement Classes](#idm45831697051472)
  + - (see also alter table statement; create table statement; drop table statement)
    - metadata from (see metadata)
    - scripts generating, [Schema Generation Scripts](#ch15scrip2)-[Schema Generation Scripts](#idm45831692071120)
    - transactions not used for, [Ending a Transaction](#idm45831692596144)
* Schwartz, Baron (author), High Performance MySQL (O’Reilly), [Query Mechanics](#idm45831695957856)
* search expressions, [Using wildcards](#idm45831695311136)
  + - (see also matching conditions)
* searched case expressions, [Searched case Expressions](#ch11se2)-[Searched case Expressions](#idm45831692850928)
* security
  + - permissions, [Query Mechanics](#idm45831695970464), [Data Security](#idm45831692110672), [Querying Files Using Drill](#idm45831691113392)
    - views for, [Data Security](#idm45831692124208)
    - VPD (Virtual Private Database), [Data Security](#idm45831692100704)
* select statement, [The select Clause](#ch3sel)-[Removing Duplicates](#idm45831696735488)
  + - (see also from clause; group by clause; having clause; order by clause; where clause)
    - all keyword in, [Removing Duplicates](#idm45831695836720)
    - column aliases in, [Column Aliases](#idm45831695868752)
    - column names in, [The select Clause](#idm45831695896512)
    - distinct keyword in, [Removing Duplicates](#idm45831695848912), [Counting Distinct Values](#idm45831693676880)
    - expressions in, [The select Clause](#idm45831695885840)
      * + (see also expressions)
    - function calls in, [The select Clause](#idm45831695884480)
      * + (see also functions)
    - literals in, [The select Clause](#idm45831695888368)
    - subqueries in, [Subqueries as Expression Generators](#idm45831693157088)
      * + (see also subqueries)
* self-joins, [Self-Joins](#ch5se2)-[Self-Joins](#idm45831694955408)
* self-referencing foreign key, [Self-Joins](#idm45831694974912)
* SEQUEL language, [What Is SQL?](#idm45831697073696)
* sequence object, [Generating numeric key data](#idm45831696218528)
* servers, [What Is MySQL?](#ch1com2)-[What Is MySQL?](#idm45831697120640)
  + - (see also DB2 Universal Database; MySQL; Oracle Database; SQL Server)
* session.time\_zone value, [Dealing with Time Zones](#idm45831694165888)
* set autocommit command, [Starting a Transaction](#idm45831692590624)
* set command, [String Generation](#idm45831694639584)
* set implicit\_transactions command, [Starting a Transaction](#idm45831692656000)
* set operators, [Set Theory in Practice](#ch6ops)-[The except Operator](#idm45831694774288)
  + - except and except all, [Set Theory Primer](#idm45831694918736), [The except Operator](#ch6ex2)-[The except Operator](#idm45831694772304)
    - intersect and intersect all, [Set Theory Primer](#idm45831694917760), [The intersect Operator](#ch6in2)-[The intersect Operator](#idm45831694807040)
    - precedence of, [Set Operation Precedence](#ch6pre)-[Set Operation Precedence](#idm45831694724240)
    - union and union all, [Set Theory Primer](#idm45831694929376), [The union Operator](#ch6un2)-[The union Operator](#idm45831694828640)
* set showplan\_text on statement, [How Indexes Are Used](#idm45831692286032)
* sets, [Set Theory Primer](#ch6set)-[Set Theory in Practice](#idm45831694861120)
  + - combining operations on, [Set Theory Primer](#idm45831694903888)
    - operation precedence for, [Set Operation Precedence](#ch6pre2)-[Set Operation Precedence](#idm45831694722688)
    - sorting results of, [Sorting Compound Query Results](#ch6sort)-[Sorting Compound Query Results](#idm45831694754672)
    - table requirements for operations, [Set Theory in Practice](#idm45831694879280)
* sharding, [Sharding](#ch17sh)-[Sharding](#idm45831691298000)
* shared-disk/shared-cache clustering configurations, [Clustering](#idm45831691485200)
* show character set command, [Character sets](#idm45831697492560)
* show databases command, [Using the mysql Command-Line Tool](#idm45831696793552)
* show index command, [Index Creation](#idm45831692429296)
* show table command, [Transaction Savepoints](#idm45831692966640)
* show tables command, [The Sakila Database](#idm45831696830560)
* sign() function, [Handling Signed Data](#idm45831694220384)
* simple case expressions, [Simple case Expressions](#ch11sim2)-[Simple case Expressions](#idm45831692825504)
* sin() function, [Performing Arithmetic Functions](#idm45831694272896)
* single quotes (' ')
  + - enclosing strings, [String Generation](#idm45831694660976)
    - escape sequence for, [Including single quotes](#ch7esc2)-[Including single quotes](#idm45831694587200)
* single-column grouping, [Single-Column Grouping](#idm45831693605216)
* single-parent hierarchy, [Nonrelational Database Systems](#idm45831697215696)
* smallint type, [Numeric Data](#idm45831696616752)
* sorting
  + - localized, with analytic functions, [Localized Sorting](#ch16ob2)-[Localized Sorting](#idm45831691647600)
    - query results (see order by clause)
* Spark, [SQL Unplugged](#idm45831696876976), [Introduction to Apache Drill](#idm45831691149456)
* Spark SQL, [Introduction to Apache Drill](#idm45831691147248)
* special characters in strings, [Including special characters](#ch7sp2)-[Including special characters](#idm45831694535440)
* sp\_executesql procedure, [Dynamic SQL Generation](#idm45831691749168)
* SQL, [What Is SQL?](#ch1sql)-[SQL Examples](#idm45831697259152)
  + - as nonprocedural, [SQL: A Nonprocedural Language](#idm45831697262304)
    - conditions in (see conditions; expressions; operators)
    - data statements, [SQL Statement Classes](#idm45831697053328), [SQL Statement Classes](#idm45831697020288)
      * + (see also delete statement; insert statement; select statement; update statement)
    - dynamic execution of, [Dynamic SQL Generation](#idm45831692328144)
    - dynamic generation of, [Dynamic SQL Generation](#ch15dg3)-[Dynamic SQL Generation](#idm45831691723264)
    - functions in (see functions)
    - future of, [Future of SQL](#idm45831691006896)
    - history of, [Preface](#idm45831697601056), [What Is SQL?](#idm45831697079296)
    - integrating with programming languages, [SQL: A Nonprocedural Language](#idm45831697004864)
    - interactive execution of, [SQL: A Nonprocedural Language](#idm45831696958416)
    - new technologies using, [SQL Unplugged](#idm45831696879744)
    - prevalence of, [Why Learn SQL?](#idm45831697410272)
    - pronunciation of, [What Is SQL?](#idm45831697062480)
    - relational model used by, [What Is SQL?](#idm45831697071424)
    - schema statements, [SQL Statement Classes](#idm45831697049888)
      * + (see also alter table statement; create table statement; drop table statement)
    - sets (see sets)
    - statement classes, [SQL Statement Classes](#ch1class)-[SQL Statement Classes](#idm45831697264320)
    - transaction statements, [SQL Statement Classes](#idm45831697046528), [What Is a Transaction?](#idm45831692645008)
      * + (see also commit statement; rollback statement; start statement)
* SQL in a Nutshell (O’Reilly), [String functions that return strings](#idm45831696750608)
* SQL integration toolkits, [SQL: A Nonprocedural Language](#idm45831696993024)
* SQL Server, [What Is MySQL?](#idm45831696901456)
  + - begin transaction command, [Starting a Transaction](#idm45831692636304)
    - char and varchar sizes, [Text data](#idm45831696646688)
    - charindx() function, [String functions that return numbers](#idm45831694484192)
    - coalesce() function, [The case Expression](#idm45831692900224)
    - concatenation operator (+), [Including special characters](#idm45831694550240), [String functions that return strings](#idm45831694405872)
    - convert() function, [Functions for generating dates](#idm45831693944064)
    - create index statement, [Index Creation](#idm45831692516544)
    - current date and time functions, [Functions for generating dates](#idm45831693923248)
    - date ranges allowed, [Temporal Data](#idm45831696501216)
    - dateadd() function, [Temporal functions that return dates](#idm45831693874272)
    - datediff() function, [Temporal functions that return numbers](#idm45831693816240)
    - datepart() function, [Temporal functions that return strings](#idm45831693835968)
    - default index type, [B-tree indexes](#idm45831692353136)
    - drop index statement, [Index Creation](#idm45831692409952)
    - for xml clause, [The insert statement](#idm45831696263360)
    - full-text indexes, [Text indexes](#idm45831692306128)
    - getutcdate() function, [Dealing with Time Zones](#idm45831694358592)
    - information\_schema schema, [Data About Data](#idm45831691933776)
    - len() function, [String functions that return numbers](#idm45831694515568)
    - locking approach, [Locking](#idm45831692671744)
    - locking granularities, [Lock Granularities](#idm45831694846352)
    - metadata access, [Data About Data](#idm45831691946416)
    - modulo operator (%), [Performing Arithmetic Functions](#idm45831694266448)
    - pivot clause, [Result Set Transformations](#idm45831692799152)
    - replace() function, [String functions that return strings](#idm45831694417072)
    - round() function, [Controlling Number Precision](#idm45831694214752)
    - save transaction, [Transaction Savepoints](#idm45831693214560)
    - set implicit\_transactions command, [Starting a Transaction](#idm45831692593712)
    - set showplan\_text on statement, [How Indexes Are Used](#idm45831692289200)
    - silent truncation of strings, [String Generation](#ch7sil2)-[String Generation](#idm45831694857792)
    - sp\_executesql procedure, [Dynamic SQL Generation](#idm45831691750704)
    - transaction approach, [Starting a Transaction](#idm45831692613872)
    - unique keyword, [Unique indexes](#idm45831692385904)
    - updatable view restrictions, [Updating Complex Views](#idm45831692808096)
* sql\_mode variable, [String Generation](#idm45831695261520)
* sqrt() function, [Performing Arithmetic Functions](#idm45831694271632)
* SQUARE language, [What Is SQL?](#idm45831697074960)
* SQuirrel, [SQL: A Nonprocedural Language](#idm45831696956944)
* start transaction command, [Starting a Transaction](#idm45831694702592)
* statement scope, [What Is a Subquery?](#idm45831693507552)
* storage engines
  + - choosing, [Transaction Savepoints](#ch12eng2)-[Transaction Savepoints](#idm45831692506592)
    - InnoDB, [Nonexistent Foreign Key](#idm45831696089840), [Constraints](#idm45831692555824)
* straight\_join keyword, [Joining Three or More Tables](#idm45831696888256)
* strcmp() function, [String functions that return numbers](#ch7cmp2)-[String functions that return numbers](#idm45831694787632)
* string functions, [String Manipulation](#ch7smf)-[String functions that return strings](#idm45831694349840)
* string literals, [String Generation](#ch7str2)-[Including single quotes](#idm45831694598832)
* strings
  + - appending characters to, [String functions that return strings](#idm45831694430192)
    - building from other data, [String functions that return strings](#idm45831694419824)
    - character sets for, [Character sets](#ch2cs)-[Character sets](#idm45831696694016)
    - comparing, [String functions that return numbers](#ch7cmp)-[String functions that return numbers](#idm45831694437696)
    - concatenating, [Including special characters](#ch7cat2)-[Including special characters](#idm45831694533072)
    - converting to temporal values, [String-to-date conversions](#ch7sdc2)-[Functions for generating dates](#idm45831693937392)
    - data types for, [Character Data](#idm45831696747440), [Working with String Data](#ch7dat)-[Working with String Data](#idm45831694669536)
    - enum type, [Step 3: Building SQL Schema Statements](#idm45831696304272)
    - escape sequence for, [Including single quotes](#ch7esc4)-[Including single quotes](#idm45831694584672)
    - extracting substrings from, [String functions that return strings](#ch7ext)-[String functions that return strings](#idm45831696749376)
    - fixed-length, [Character Data](#idm45831696745968)
    - generating, [String Generation](#ch7str)-[Including special characters](#idm45831694538224)
    - length of, [String functions that return numbers](#idm45831694520048)
    - silent truncation of, [String Generation](#ch7sil3)-[String Generation](#idm45831694856864)
    - special characters in, [Including special characters](#ch7sp)-[Including special characters](#idm45831694893632)
    - substrings, adding or replacing in, [String functions that return strings](#ch7rep)-[String functions that return strings](#idm45831694386144)
    - substrings, finding in, [String functions that return numbers](#idm45831694508336)
    - temporal data represented in, [String representations of temporal data](#ch7sd2)-[String representations of temporal data](#idm45831694399072)
    - variable-length, [Character Data](#idm45831696744432)
* str\_to\_date() function, [Functions for generating dates](#ch7sf)-[Functions for generating dates](#idm45831693933920)
* subpartition by keywords, [Composite partitioning](#idm45831691317488)
* subqueries, [Derived (subquery-generated) tables](#idm45831695806192), [What Is a Subquery?](#ch9sub)-[Data Manipulation Using Correlated Subqueries](#idm45831693322720)
  + - all operator with, [The all operator](#ch9all2)-[The all operator](#idm45831693477744)
    - any operator with, [The any operator](#ch9any2)-[The any operator](#idm45831693368640)
    - between operator with, [Correlated Subqueries](#idm45831693425008)
    - in case expressions, [Searched case Expressions](#ch11sub2)-[Searched case Expressions](#idm45831692848720), [Conditional Updates](#idm45831692743744)
    - containing statement or query for, [Derived (subquery-generated) tables](#idm45831695797584), [What Is a Subquery?](#idm45831693504224)
    - correlated, [Correlated Subqueries](#ch9corr)-[Data Manipulation Using Correlated Subqueries](#idm45831693271872)
    - data manipulation with, [Data Manipulation Using Correlated Subqueries](#ch9man)-[Data Manipulation Using Correlated Subqueries](#idm45831693270224)
    - equality conditions with, [Noncorrelated Subqueries](#ch9sca4)-[Noncorrelated Subqueries](#idm45831693453008)
    - exists operator with, [The exists Operator](#ch9ist2)-[The exists Operator](#idm45831693300880)
    - in from clause, [Subqueries as Data Sources](#ch9from)-[Task-oriented subqueries](#idm45831693247600)
    - in having clause, [The all operator](#idm45831693390736)
    - in and not in operators with, [The in and not in operators](#ch9in3)-[The in and not in operators](#idm45831693417728)
    - as join tables, [Using Subqueries as Tables](#ch5sub2)-[Using Subqueries as Tables](#idm45831694998896)
    - multicolumn, [Multicolumn Subqueries](#ch9mc)-[Multicolumn Subqueries](#idm45831693346128)
    - multiple-row, single-column, [Multiple-Row, Single-Column Subqueries](#ch9mr)-[The any operator](#idm45831693461248)
    - named, in with clause, [Common table expressions](#ch9cte3)-[Common table expressions](#idm45831693166672)
    - noncorrelated, [Noncorrelated Subqueries](#ch9non)-[Multicolumn Subqueries](#idm45831693602864)
    - null values handled with, [The all operator](#idm45831693397600)
    - in order by clause, [Subqueries as Expression Generators](#idm45831693151120)
    - scalar, [Noncorrelated Subqueries](#ch9sca)-[Noncorrelated Subqueries](#idm45831693456688), [Subqueries as Expression Generators](#ch9lar)-[Subqueries as Expression Generators](#idm45831693116288)
    - scope of, [What Is a Subquery?](#idm45831693497792)
    - in select clause, [Subqueries as Expression Generators](#idm45831693160432)
    - in values clause of insert statement, [Subqueries as Expression Generators](#idm45831693128128)
* substr() function, [String functions that return strings](#idm45831694368240)
* substring() function, [String functions that return strings](#ch7ext2)-[String functions that return strings](#idm45831694350944)
* sum() function, [Aggregate Functions](#idm45831693719552), [Reporting Functions](#ch16ag5)-[Window Frames](#idm45831691492544)
* surrogate keys, [The Relational Model](#idm45831697143728)
* system catalog (see data dictionary; metadata)

### T

* table aliases, [Defining Table Aliases](#idm45831695724784)
* table links, [Table Links](#ch3jo)-[Table Links](#idm45831695731104)
  + - (see also joins)
* table locks, [Lock Granularities](#idm45831692724592)
* table partitioning, [Table Partitioning](#idm45831691407232)
* tables, [The Relational Model](#idm45831697403344), [What Is SQL?](#idm45831697084352)
  + - aliases for, [Using the Same Table Twice](#idm45831694991680), [Self-Joins](#idm45831694962000)
    - altering, [Generating numeric key data](#idm45831696222896)
    - constraints on (see constraints)
    - creating, [Table Creation](#ch2tab)-[Step 3: Building SQL Schema Statements](#idm45831696243120)
    - deleting, [The Sakila Database](#idm45831696010224)
    - deleting rows from, [Deleting Data](#idm45831696122048), [Data Manipulation Using Correlated Subqueries](#idm45831693278976)
    - designing, [Table Creation](#ch2des)-[Step 2: Refinement](#idm45831696715328)
    - indexes for (see indexes)
    - inserting data, [Inserting Data](#ch2in)-[The insert statement](#idm45831696780192)
    - listing, [The Sakila Database](#idm45831696018272)
    - normalizing, [Step 2: Refinement](#ch2nor)-[Step 2: Refinement](#idm45831696590576)
    - private, [Data Security](#idm45831692118912)
    - schema statements for, [Step 3: Building SQL Schema Statements](#ch2sc)-[Step 3: Building SQL Schema Statements](#idm45831696245680)
    - temporary, [Temporary tables](#idm45831695790368)
    - types of, [Tables](#ch3tt2)-[Views](#idm45831695759488)
    - updating, [Updating Data](#idm45831696137840)
      * + (see also update statement)
    - viewing information about, [Step 3: Building SQL Schema Statements](#idm45831696284960), [The Sakila Database](#idm45831696006864), [information\_schema](#idm45831692364704)
* tan() function, [Performing Arithmetic Functions](#idm45831694270368)
* temporal data, [Working with Temporal Data](#idm45831694182912)
  + - adding date or time intervals to, [Temporal functions that return dates](#ch7ivl)-[Temporal functions that return dates](#idm45831693865712)
    - conversions to and from, [Conversion Functions](#ch7conv)-[Conversion Functions](#idm45831693794144)
    - converting strings to, [Invalid Date Conversions](#idm45831696067456), [String-to-date conversions](#ch7sdc)-[Functions for generating dates](#idm45831693946416)
    - current date or time, generating, [Functions for generating dates](#idm45831693932656)
    - data types for, [Temporal Data](#ch2tem)-[Temporal Data](#idm45831696445744), [String representations of temporal data](#idm45831694069088)
    - date formats, default, [Temporal Data](#idm45831696699152), [String representations of temporal data](#ch7sd3)-[String representations of temporal data](#idm45831694042992)
    - date formats, specifying in queries, [Invalid Date Conversions](#idm45831696117536)
    - date formats, specifying in str\_to\_date(), [Functions for generating dates](#idm45831694000096)
    - date ranges allowed, [Temporal Data](#idm45831696545680), [Temporal Data](#idm45831696504384)
    - generating, [Generating Temporal Data](#ch7dg)-[Functions for generating dates](#idm45831693940768)
    - interval types for, [Temporal functions that return dates](#idm45831694887248)
    - last day of month, finding, [Temporal functions that return dates](#idm45831693862896)
    - returning number of intervals from, [Temporal functions that return numbers](#ch7diff)-[Temporal functions that return numbers](#idm45831693818752)
    - returning strings from, [Temporal functions that return strings](#idm45831693848352)
    - string representations of, [String representations of temporal data](#ch7sd)-[String representations of temporal data](#idm45831694046512)
    - time zones, [Dealing with Time Zones](#ch7tz)-[Dealing with Time Zones](#idm45831694131024)
* temporary keyword, [Temporary tables](#idm45831695788832)
* text indexes, [Text indexes](#idm45831692347280)
* text type, [Text data](#idm45831696680976), [Working with String Data](#idm45831694674464)
* text types, [Text data](#ch2tt)-[Text data](#idm45831696643776)
* three-way outer joins, [Three-Way Outer Joins](#ch10tw2)-[Three-Way Outer Joins](#idm45831692998752)
* time type, [Temporal Data](#idm45831696537680), [Generating Temporal Data](#idm45831694125120), [String representations of temporal data](#idm45831694070352)
* time zones, [Dealing with Time Zones](#ch7tz2)-[Dealing with Time Zones](#idm45831694130128)
* times (see temporal data)
* timestamp type, [Temporal Data](#idm45831696540208), [String representations of temporal data](#idm45831694071616)
* tinyint type, [Numeric Data](#idm45831696617552)
* tinytext type, [Text data](#idm45831696682208)
* Toad Data Point, [SQL and Big Data](#idm45831692325040)
* Toad development tool, [Schema Generation Scripts](#idm45831691787360)
* to\_date() function, [Functions for generating dates](#idm45831693945104)
* Transact-SQL language, [SQL: A Nonprocedural Language](#idm45831696995488)
* transaction statements, [SQL Statement Classes](#idm45831697048032), [What Is a Transaction?](#idm45831692646272)
  + - (see also commit statement; rollback statement; start statement)
* transactions, [What Is a Transaction?](#ch12tr2)-[What Is a Transaction?](#idm45831692684432)
  + - autocommit mode for, [Starting a Transaction](#idm45831692599424)
    - deadlock detection for, [Ending a Transaction](#idm45831692605504)
    - ending, [Ending a Transaction](#ch12end)-[Ending a Transaction](#idm45831692554896)
    - savepoints for, [Transaction Savepoints](#ch12sav)-[Transaction Savepoints](#idm45831692482144)
    - schema statements not using, [Ending a Transaction](#idm45831692565008)
    - starting, [Starting a Transaction](#ch12sta)-[Starting a Transaction](#idm45831692586496)
* transforming result sets, [Result Set Transformations](#ch11tr3)-[Result Set Transformations](#idm45831692949264)
* tree structures (see B-tree indexes; hierarchical database systems)
* truncate() function, [Controlling Number Precision](#idm45831694340864)
* tuning queries, [How Indexes Are Used](#idm45831692275936)

### U

* Unicode Explained (Korpela), [Character sets](#idm45831696696224)
* union and union all operators, [Set Theory Primer](#idm45831694927840), [The union Operator](#ch6un)-[The union Operator](#idm45831694830496)
* unique constraints, [Constraints](#idm45831692253008)
* unique indexes, [Unique indexes](#ch13un)-[Unique indexes](#idm45831692379680)
* unique keyword, [Unique indexes](#idm45831692387200)
* Universal Time, [Dealing with Time Zones](#idm45831694160224)
* unsigned floating-point types, [Numeric Data](#idm45831696920896)
* unsigned integers, [Numeric Data](#idm45831696626432)
* updatable views, [Updatable Views](#ch14uv2)-[Updating Complex Views](#idm45831691993104)
* update statement, [Updating Data](#idm45831696138704)
  + - case expressions in, [Conditional Updates](#ch11up2)-[Conditional Updates](#idm45831693351824)
    - date formats, specifying in, [Invalid Date Conversions](#idm45831696732144)
    - subqueries in, [Data Manipulation Using Correlated Subqueries](#idm45831693293712)
* use command, [Using the mysql Command-Line Tool](#idm45831696792160)
* using subclause, [Inner Joins](#idm45831697315776)
* UTC (Coordinated Universal Time), [Dealing with Time Zones](#idm45831694173568)
* utc\_timestamp() function, [Dealing with Time Zones](#idm45831694152976)

### V

* values clause, [The insert statement](#ch2in3)-[The insert statement](#idm45831696158624), [Subqueries as Expression Generators](#idm45831693130000)
* varchar type, [Character Data](#idm45831696739104), [Working with String Data](#idm45831694682192)
* varchar2 data type, [Character Data](#idm45831696725488)
* variable-length strings, [Character Data](#idm45831696741632)
* versioning, [Locking](#idm45831694207936)
* vertical bar, double (||), concatenation operator, Oracle, [Including special characters](#idm45831694556976)
* vertical partitioning, [Table Partitioning](#idm45831691405024)
* views, [Views](#idm45831695770640), [What Are Views?](#ch17vi)
  + - complexity hidden by, [Hiding Complexity](#idm45831692074672)
    - data aggregation from, [Data Aggregation](#idm45831692450880)
    - data security from, [Data Security](#idm45831692125712)
    - displaying columns in, [What Are Views?](#idm45831692152416)
    - in information\_schema, list of, [information\_schema](#idm45831691892384)
      * + (see also metadata)
    - joins with, [What Are Views?](#idm45831692136896), [Joining Partitioned Data](#ch14vj)-[Joining Partitioned Data](#idm45831692277696)
    - reasons to use, [Why Use Views?](#ch14re)-[Joining Partitioned Data](#idm45831692158656)
    - updatable, [Updatable Views](#ch14uv)-[Updating Complex Views](#idm45831691991872)
    - viewing information about, [information\_schema](#idm45831692363200)
* virtual tables, [Views](#idm45831695769584)
  + - (see also views)
* VPD (Virtual Private Database), [Data Security](#idm45831692101696)

### W

* website resources (see online resources)
* where clause, [The where Clause](#ch3wh)-[The where Clause](#idm45831696736848)
  + - (see also conditions)
    - filter conditions in, [Filtering](#idm45831695581424)
    - older join syntax in, [The ANSI Join Syntax](#idm45831695077744)
* wildcards, for search expressions, [Using wildcards](#idm45831695312240)
* windows, [Data Windows](#ch16win3)-[Data Windows](#idm45831691720080), [Generating Multiple Rankings](#idm45831691584864), [Reporting Functions](#idm45831691538720), [Window Frames](#idm45831691516544)
* with clause, [Common table expressions](#ch9cte4)-[Common table expressions](#idm45831693165568)
* with cube keywords, [Generating Rollups](#idm45831693586400)
* with rollup keywords, [Generating Rollups](#ch8roll3)-[Generating Rollups](#idm45831693544048)
* write lock, [Locking](#idm45831692685360)

### X

* XML
  + - document databases using, [NoSQL and Document Databases](#idm45831691203776)
    - output from queries, [The insert statement](#idm45831696154128)
* --xml option, mysql command, [The insert statement](#idm45831696150640)

### Y

* YARN, [Hadoop](#idm45831691212368)
* year type, [Temporal Data](#idm45831696538944)

# About the Author

Alan Beaulieu has been designing and building custom databases for over 30 years. He runs his own consulting business specializing in the design, development, and performance tuning of very large databases, mostly in the Financial Services sector. In his free time, Alan enjoys spending time with his family, playing drums with his band, strumming his tenor ukulele, or finding the perfect scenic lunch spot while hiking with his wife. He holds a BS in Engineering from Cornell University.

# Colophon

The animal on the cover of Learning SQL, Third Edition, is an Andean marsupial tree frog (Gastrotheca riobambae). As its name suggests, this crepuscular and nocturnal frog is native to the western slopes of the Andes mountains and is widely distributed from the Riobamba basin to Ibarra in the north.

During courtship, the male calls (“wraaack-ack-ack”) to attract a female. If a gravid female is attracted to him, he climbs onto her back and performs a common frog mating hold called the nuptial amplexus. As the eggs emerge from the female’s cloaca, the male catches the eggs with his feet and fertilizes them while maneuvering them into a pouch on the female’s back. A female may incubate an average of 130 eggs, and development in the pouch lasts between 60 and 120 days. During incubation, swelling becomes visible, and lumps appear beneath the skin on the female’s back. When the tadpoles emerge from the pouch, the female tree frog deposits them into the water. Within two or three months the tadpoles metamorphose into froglets, and at seven months they are ready to mate (“wraaaack-ack-ack”).

Both the male and female tree frog have expanded digital discs on their fingers and toes that help them climb vertical surfaces such as trees. Adult males are two inches in length, while females reach two and a half inches, with coloration that naturally varies between shades of green and brown. The color of the juveniles may change from brown to green as they grow.

Populations of this frog have declined, and it is now classified on the IUCN Red List as endangered. It is under threat from agriculture, invasive species and pathogens, climate change, and pollution.

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