SQLite

DATABASE

What Is SQLite?

SQLite is a public-domain software package that provides a relational database management system, or RDBMS.

Relational database systems are used to store user-defined records in large tables. In addition to data storage and management,a database engine can process complex query commands that combine data from multiple tables to generate reports and data summaries

SQLite is lightweight when it comes to setup complexity, administrative overhead, and resource usage

SQLite is remarkably flexible in both where it can be run and how it can be used. This chapter will take a brief look at some of the roles SQLite is designed to fill. Some of these roles are similar to those taken by traditional client/server RDBMS products. Other roles take advantage of SQLite’s size and ease of use, offering solutions you might not consider with a full client/server database.

SQLite is capable of creating databases that are held entirely in memory. This is extremely useful for creating small, temporary databases that require no permanent storage.

In-memory databases are often used to cache results pulled from a more traditional RDBMS server. An application may pull a subset of data from the remote database, place it into a temporary database, and then process multiple detailed searches and refinements against the local copy. This is particularly useful when processing typeahead suggestions, or any other interactive element that requires very quick response times.

Archives and Data Stores

SQLite makes it very easy to package complex data sets into a single, easy-to-access, fully cross-platform file. Having all the data in a single file makes it much easier to distribute or download large, multi-table data stores, such as large dictionaries or geolocation references.

Unlike many RDBMS products, the SQLite library is able to access read-only database files. This allows data stores to be read directly from an optical disc or other read-only filesystem. This is especially useful for systems with limited hard drive space, such as video game consoles.

Client/Server Stand-in

SQLite works well as a “stand-in” database for those situations when a more robust RDBMS would normally be the right choice, were it available. SQLite can be especially useful for the demonstration and evaluation of applications and tools that normally depend on a database.

Generic SQL Engine

SQLite virtual tables allow a developer to define the contents of a table through code.

By defining a set of callback functions that fetch and return rows and columns, a developer can create a link between the SQLite data processing engine and any data source. This allows SQLite to run queries against the data source without importing the data into a standard table.

The SQLite code base supports all of these operating systems natively, and precompiled libraries and executables for all three environments are available from the SQLite website

SQLite Products

The SQLite project consists of four major products:

SQLite core

The SQLite core contains the actual database engine and public API. The core can be built into a static or dynamic library, or it can be built in directly to an application.

sqlite3 command-line tool

The sqlite3 application is a command-line tool that is built on top of the SQLite core. It allows a developer to issue interactive SQL commands to the SQLite core. It is extremely useful for developing and debugging queries.

Tcl extension

SQLite has a strong history with the Tcl language. This library is essentially a copy of the SQLite core with the Tcl bindings tacked on. When compiled into a library, this code exposes the SQLite interfaces to the Tcl language through the Tcl Extension Architecture (TEA). Outside of the native C API, these Tcl bindings are the only official programming interface supported directly by the SQLite team.

Building

There are a number of different ways to build SQLite, depending on what you're trying to build and where you would like it installed. If you are trying to integrate the SQLite core into a host application, the easiest way to do that is to simply copy *sqlite3.c* and *sqlite3.h* into your application's source directory. If you're using an IDE, the *sqlite3.c* file can simply be added to your application's project file and configured with the proper search paths and build directives. If you want to build a custom version of the SQLite library or sqlite3 utility, it is also easy to do that by hand.

Configure

If you’re using the Unix amalgamation distribution, you can build and install SQLite using the standard configure script. After downloading the distribution, it is fairly easy to unpack, configure, and build the source:

```
$ tar xzf sqlite-amalgamation-3.x.x.tar.gz
$ cd sqlite-3.x.x
$ ./configure
[...]
$ make
```

An sqlite3 Primer

Once you have some form of SQLite installed, the first step is normally to run sqlite3 and play around. The sqlite3 tool accepts SQL commands from an interactive prompt and passes those commands to the SQLite core for processing.

Even if you have no intention of distributing a copy of sqlite3 with your application, it is extremely useful to have a copy around for testing and debugging queries. If your application uses a customized build of the SQLite core, you will likely want to build a copy of sqlite3 using the same build parameters.

To get started, just run the SQLite command. If you provide a filename (such as test.db), sqlite3 will open (or create) that file. If no filename is given, sqlite3 will automatically open an unnamed temporary database

```
$ sqlite3 test.db
SQLite version 3.6.23.1
Enter ".help" for instructions
Enter SQL statements terminated with a ";"
sqlite>
```

The SQL Language

Structured Query Language, or *SQL*. Although sometimes pronounced “sequel,” the official pronunciation is to name each letter as “ess-cue-ell.” The SQL language is the main means of interacting with nearly all modern relational database systems. SQL provides commands to configure the tables, indexes, and other data structures within the database. SQL commands are also used to insert, update, and delete data records, as well as query those records to look up specific data values.

All interaction with a relational database is done through the SQL language. This is true when interactively typing commands or when using the programming API. In all cases, data is stored, modified, and retrieved through SQL commands.

Learning SQL

For people just getting started, the most important commands are CREATE TABLE, INSERT, and SELECT. These will let you create a table, insert some data into the table, and then query the data and display it.

Brief Background

Although the first official SQL specification was published in 1986 by the American National Standards Institute (ANSI), the language traces its roots back to the early 1970s and the pioneering relational database work that was being done at IBM. Current SQL standards are ratified and published by the International Standards Organization (ISO).

Declarative

The core of SQL is a *declarative language*. In a declarative language, you state what you want the results to be and allow the language processor to figure out how to deliver the desired results. Compare this to *imperative languages*, such as C, Java, Perl, or Python, where each step of a calculation or operation must be explicitly written out, leaving it up to the programmer to lead the program, step by step, to the correct conclusion.

Portability

SQL's biggest flaw is that formal standardization has almost always followed common implementations. Almost every database product (including SQLite) has custom extensions and enhancements to the core language that help differentiate it from other products, or expose features or control systems that are not covered by the core SQL standard. Often these enhancements are related to performance enhancements, and can be difficult to ignore.

Basic Syntax

SQL consists of a number of different commands, such as CREATE TABLE or INSERT. These commands are issued and processed one at a time.

Although it is customary to use all capital letters for SQL commands and keywords, SQL is a case-insensitive* language.

Three-Valued Logic

SQL allows any value to be assigned a NULL. NULL is not a value in itself (SQLite actually implements it as a unique valueless type), but is used as a marker or flag to represent unknown or missing data. The thought is that there are times when values for a specific row element may not be available or may not be applicable.

A NULL may not be a value, but it can be assigned to data elements that normally have values, and can therefore show up in expressions. The problem is that NULLs don’t interact well with other values. If a NULL represents an unknown that might be any possible value, how can we know if the expression NULL > 3 is true or false?

SQL Data Languages

SQL commands are divided into four major categories, or languages. Each language defines a subset of commands that serve a related purpose. The first language is the Data Definition Language, or DDL, which refers to commands that define the structure of tables, views, indexes, and other data containers and objects within the database. CREATE TABLE (used to define a new table) and DROP VIEW (used to delete a view) are examples of DDL commands.

The second category of commands is known as Data Manipulation Language, or DML. These are all of the commands that insert, update, delete, and query actual data values from the data structures defined by the DDL. INSERT (used to insert new values into a table) and SELECT (used to query or look up data from tables) are examples of DML commands.

Data Definition Language

The DDL is used to define the structure of data containers and objects within the database.

The most common of these containers and objects are tables, indexes, and

views. As you'll see, most objects are defined with a variation of the CREATE command,

such as CREATE TABLE or CREATE VIEW. The DROP command is used to delete an existing

object (and all of the data it might contain). Examples include DROP TABLE or DROP

INDEX. Because the command syntax is so different, statements like CREATE TABLE or

CREATE INDEX are usually considered to be separate commands, and not variations of a

single CREATE command

The basics

The most basic syntax for CREATE TABLE looks something like this:

```
CREATE TABLE table_name
(
column_name column_type,
[...]
);
```

A table name must be provided to identify the new table. After that, there is just a simple list of column names and their types. Table names come from a global namespace of all identifiers, including the names of tables, views, and indexes.

Column types

Most databases use strong, static column typing. This means that the elements of a column can only hold values compatible with the column’s defined type. SQLite utilizes a dynamic typing technique known as manifest typing. For each row value, manifest typing records the value’s type along with the value data. This allows nearly any element of any row to hold almost any type of value.

In the strictest sense, SQLite supports only five concrete datatypes. These are known as *storage classes*, and represent the different ways SQLite might choose to store data on disk. Every value has one of these five native storage classes:

NULL

A NULL is considered its own distinct type. A NULL type does not hold a value.

Literal NULLs are represented by the keyword NULL

Integer

A signed integer number. Integer values are variable length, being 1, 2, 3, 4, 6, or 8 bytes in length, depending on the minimum size required to hold the specific value. Integer have a range of −9,223,372,036,854,775,808 to +9,223,372, 036,854,775,807, or roughly 19 digits. Literal integers are represented by any bare series of numeric digits (without commas) that does not include a decimal point or exponent.

Float

A floating-point number, stored as an 8-byte value in the processor’s native format.

For nearly all modern processors, this is an IEEE 754 double-precision number.

Literal floating-point numbers are represented by any bare series of numeric digits

that include a decimal point or exponent.

Text

A variable-length string, stored using the database encoding (UTF-8, UTF-16BE, or UTF-16LE). Literal text values are represented using character strings in single quotes.

BLOB

A length of raw bytes, copied exactly as provided. Literal BLOBs are represented as hexadecimal text strings preceded by an x. For example, the notation x'1234ABCD' represents a 4-byte BLOB. BLOB stands for Binary Large OBject.

Each table column must have one of five type affinities:

Text

A column with a text affinity will only store values of type NULL, text, or BLOB.

If you attempt to store a value with a numeric type (float or integer) it will be

converted into a text representation before being stored as a text value type.

Numeric

A column with a numeric affinity will store any of the five types. Values with integer and float types, along with NULL and BLOB types, are stored without conversion. Any time a value with a text type is stored, an attempt is made to convert the value to a numeric type (integer or float). Assuming the conversion works, the value is stored in an appropriate numeric type. If the conversion fails, the text value is stored without any type of conversion.

Integer

A column with an integer affinity works essentially the same as a numeric affinity.

The only difference is that any value with a float type that lacks a fractional component will be converted into an integer type

Float

A column with a floating-point affinity also works essentially the same as a numeric affinity. The only difference is that most values with integer types are converted into floating-point values and stored as a float type.

None

A column with a none affinity has no preference over storage class. Each value is stored as the type provided, with no attempt to convert anything.

Column constraints

In addition to column names and types, a table definition can also impose constraints on specific columns or sets of columns. A more complete view of the CREATE TABLE command looks something like this:

```
CREATE TABLE table_name
(
column_name column_type column_constraints...,
[... ,]
table_constraints,
[...]
);
```

Primary keys

In addition to these other constraints, a single column (or set of columns) can be designated
as the PRIMARY KEY. Each table can have only one primary key. Primary keys
must be unique, so designating a column as PRIMARY KEY implies the UNIQUE constraint
as well, and will result in an automatic unique index being created. If a column is
marked both UNIQUE and PRIMARY KEY, only one index will be created

In SQLite, PRIMARY KEY does not imply NOT NULL. This is in contradiction to the SQL standard and is considered a bug, but the behavior is so long-standing that there are concerns about fixing it and breaking existing applications. As a result, it is always a good idea to explicitly mark at least one column from each PRIMARY KEY as NOT NULL.

Table constraints

Table definitions can also include table-level constraints. In general, table constraints and column constraints work the same way. Table-level constraints still operate on individual rows. The main difference is that using the table constraint syntax, you can apply the constraint to a group of columns rather than just a single column. It is perfectly legal to define a table constraint with only one column, effectively defining a column constraint. Multicolumn constraints are sometimes known as compound constraints

Consider a table that contains records of all the rooms in a multibuilding campus:

```
CREATE TABLE rooms
(
room_number INTEGER NOT NULL,
building_number INTEGER NOT NULL,
[...,]
PRIMARY KEY( room_number, building_number )
);
```

Tables from queries

You can also create a table from the output of a query. This is a slightly different CREATE TABLE syntax that creates a new table and preloads it with data, all in one command:

CREATE [TEMP] TABLE table_name AS SELECT query_statement;

Using this form, you do not designate the number of columns or their names or types. Rather, the query statement is run and the output is used to define the column names and preload the new table with data.

Altering tables

SQLite supports a limited version of the ALTER TABLE command. Currently, there are only two operations supported by ALTER TABLE: add column and rename. The add column variant allows you to add new columns to an existing table. It cannot remove them. New columns are always added to the end of the column list. Several other restrictions apply.

Dropping tables

The CREATE TABLE command is used to create tables and DROP TABLE is used to delete them. The DROP TABLE command deletes a table and all of the data it contains. The table definition is also removed from the database system catalogs.

The DROP TABLE command is very simple. The only argument is the name of the table you wish to drop:

DROP TABLE *table_name*;

Virtual tables

Virtual tables can be used to connect any data source to SQLite, including other databases.

A virtual table is created with the CREATE VIRTUAL TABLE command. Although

very similar to CREATE TABLE, there are important differences. For example, virtual tables

cannot be made temporary, nor do they allow for an IF NOT EXISTS clause. To drop a

virtual table, you use the normal DROP TABLE command.

Views

Views provide a way to package queries into a predefined object. Once created, views act more or less like read-only tables. Just like tables, new views can be marked as TEMP, with the same result. The basic syntax of the CREATE VIEW command is:

CREATE [TEMP] VIEW *view_name* AS SELECT *query_statement*

Row Modification Commands

INSERT

The INSERT command is used to create new rows in the specified table. There are two meaningful versions of the command. The first version uses a VALUES clause to specify a list of values to insert:

```
INSERT INTO table_name (column_name [, ...]) VALUES (new_value [, ...]);
```

UPDATE

The UPDATE command is used to assign new values to one or more columns of existing rows in a table. The command can update more than one row, but all of the rows must be part of the same table. The basic syntax is:

```
UPDATE table_name SET column_name=new_value [, ...] WHERE expression
```

DELETE

As you might guess, the DELETE command is used to delete or remove one or more rows from a single table. The rows are completely deleted from the table:

```
DELETE FROM table_name WHERE expression;
```

The Query Command

The final DML command to cover is the SELECT command. SELECT is used to extract or return values from the database. Almost any time you want to extract or return some kind of value, you’ll need to use the SELECT command. Generally, the returned values are derived from the contents of the database, but SELECT can also be used to return the value of simple expressions. This is a great way to test out expressions, for example:

```
sqlite> SELECT 1+1, 5*32, 'abc'||'def', 1>2;
1+1 5*32 'abc' || 'def' 1>2
---------- ---------- ------------- ----------
2 160 abcdef 0
```

Consider this table:

```
sqlite> CREATE TABLE tbl ( a, b, c, id INTEGER PRIMARY KEY );
sqlite> INSERT INTO tbl ( a, b, c ) VALUES ( 10, 10, 10 );
sqlite> INSERT INTO tbl ( a, b, c ) VALUES ( 11, 15, 20 );
sqlite> INSERT INTO tbl ( a, b, c ) VALUES ( 12, 20, 30 );
sqlite> SELECT * FROM tbl;
a b c id
---------- ---------- ---------- ----------
10 10 10 1
11 15 20 2
12 20 30 3
```

```
sqlite> SELECT a, c FROM tbl;
a c
---------- ----------
10 10
11 20
12 30
```

The SELECT Command

The SELECT command is used to extract data from the database. Any time you want to query or return user data stored in a database table, you’ll need to use the SELECT Command

SQL Tables

The main SQL data structure is the table. Tables are used for both storage and for data manipulation. We’ve seen how to define tables with the CREATE TABLE command, but let’s look at some of the details.

A table consists of a heading and a body. The heading defines the name and type (in SQLite, the affinity) of each column. Column names must be unique within the table. The heading also defines the order of the columns, which is fixed as part of the table definition

The SELECT Pipeline

The SELECT syntax tries to represent a generic framework that is capable of expressing many different types of queries. To achieve this, SELECT has a large number of optional clauses, each with its own set of options and formats.

The most general format of a standalone SQLite SELECT statement looks like this:

```
SELECT [DISTINCT] select_heading
FROM source_tables
WHERE filter_expression
GROUP BY grouping_expressions
HAVING filter_expression
ORDER BY ordering_expressions
LIMIT count
OFFSET count
```

CROSS JOIN

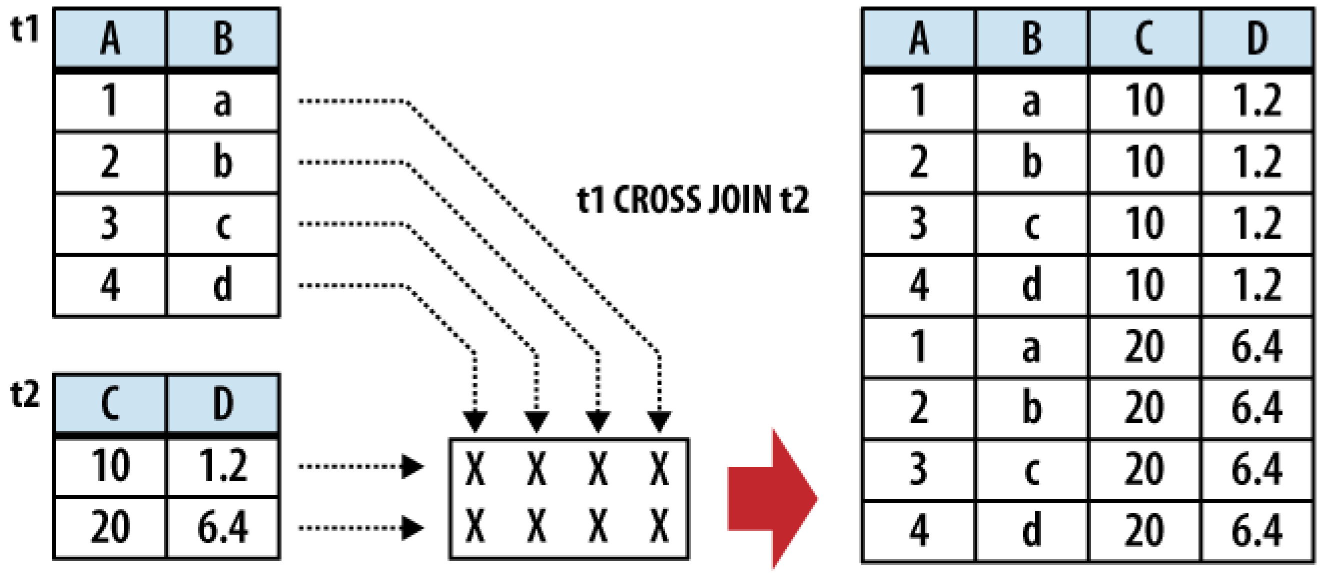
A CROSS JOIN matches every row of the first table with every row of the second table. If the input tables have x and y columns, respectively, the resulting table will have x+y columns. If the input tables have n and m rows, respectively, the resulting table will have n·m rows. In mathematics, a CROSS JOIN is known as a Cartesian product.

The syntax for a CROSS JOIN is quite simple:

```
SELECT ... FROM t1 CROSS JOIN t2 ...
```

shows how a CROSS JOIN is calculated.

Because CROSS JOINs have the potential to generate extremely large tables, care must be taken to only use them when appropriate.



t1

A	B
1	a
2	b
3	c
4	d

t2

C	D
10	1.2
20	6.4

A	B	C	D
1	a	10	1.2
2	b	10	1.2
3	c	10	1.2
4	d	10	1.2
1	a	20	6.4
2	b	20	6.4
3	c	20	6.4
4	d	20	6.4

If the input tables have *C* and *D* columns, respectively, a JOIN...ON will always result in *C+D* columns.

The conditional expression can be used to test for anything, but the most common type of expression tests for equality between similar columns in both tables. For example, in a business employee database, there is likely to be an employee table that contains (among other things) a name column and an eid column (employee ID number). Any other table that needs to associate rows to a specific employee will also have an eid column that acts as a pointer or reference to the correct employee. This relationship makes it very common to have queries with ON expressions similar to:

```
SELECT ... FROM employee JOIN resource ON employee.eid = resource.eid ...
```

This query will result in an output table where the rows from the resource table are correctly matched to their corresponding rows in the employee table.

This JOIN has two issues. First, that ON condition is a lot to type out for something so common. Second, the resulting table will have two eid columns, but for any given row, the values of those two columns will always be identical. To avoid redundancy and keep the phrasing shorter, inner join conditions can be declared with a USING expression.

This expression specifies a list of one or more columns:

```
SELECT ... FROM t1 JOIN t2 USING ( col1 ,... ) ...
```

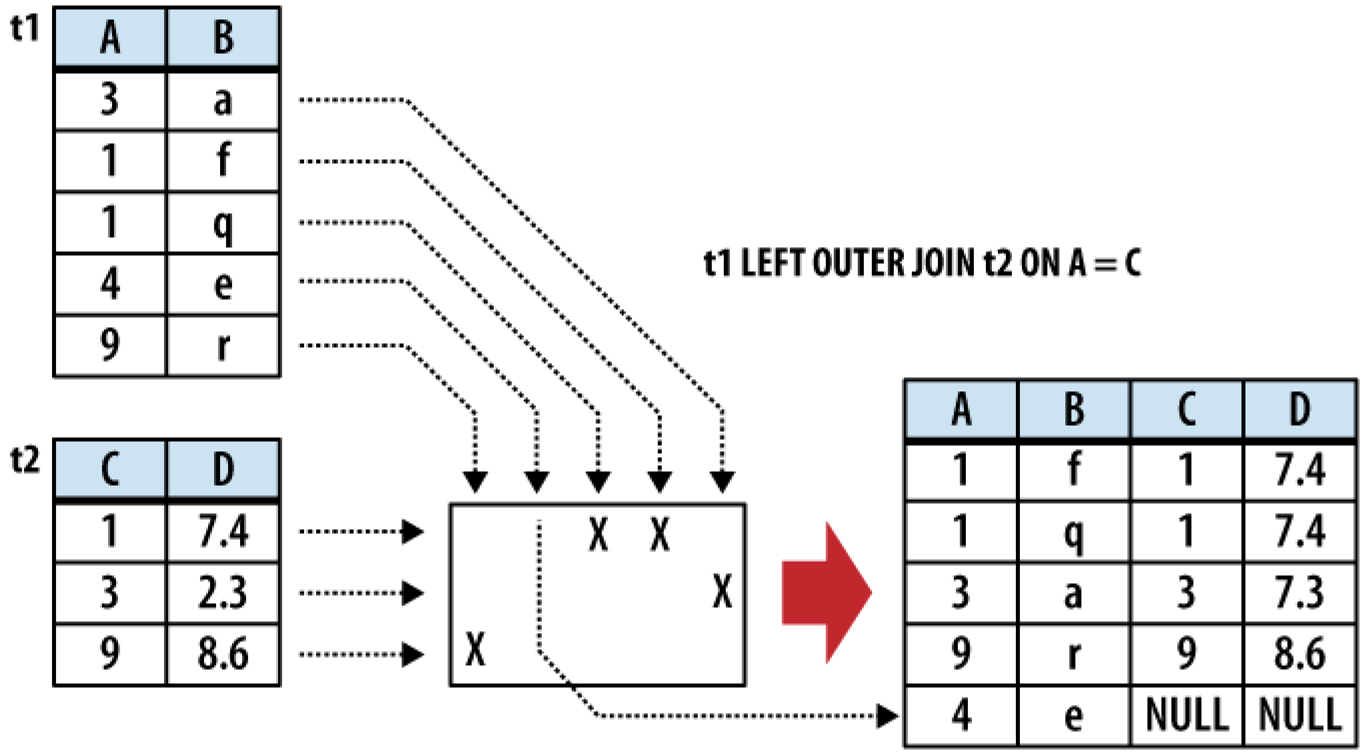
Queries from the employee database would now look something like this:

```
SELECT ... FROM employee JOIN resource USING ( eid ) ...
```

OUTER JOIN

The OUTER JOIN is an extension of the INNER JOIN. The SQL standard defines three types of OUTER JOINs: LEFT, RIGHT, and FULL. Currently, SQLite only supports the LEFT OUTER JOIN.

OUTER JOINs have a conditional that is identical to INNER JOINs, expressed using an ON, USING, or NATURAL keyword. The initial results table is calculated the same way. Once the primary JOIN is calculated, an OUTER join will take any unjoined rows from one or both tables, pad them out with NULLs, and append them to the resulting table. In the case of a LEFT OUTER JOIN, this is done with any unmatched rows from the first table (the table that appears to the left of the word JOIN)



t1

A	B
3	a
1	f
1	q
4	e
9	r

t2

C	D
1	7.4
3	2.3
9	8.6

t1 LEFT OUTER JOIN t2 ON A = C

A	B	C	D
1	f	1	7.4
1	q	1	7.4
3	a	3	7.3
9	r	9	8.6
4	e	NULL	NULL

Table aliases

Because the JOIN operator combines the columns of different tables into one, larger table, there may be cases when the resulting working table has multiple columns with the same name. To avoid ambiguity, any part of the SELECT statement can qualify any column reference with a source-table name. However, there are some cases when this is still not enough. For example, there are some situations when you need to join a table to itself, resulting in the working table having two instances of the same source-table. Not only does this make every column name ambiguous, it makes it impossible to distinguish them using the source-table name. Another problem is with subqueries, as they don’t have concrete source-table names.

To avoid ambiguity within the SELECT statement, any instance of a source-table, view, or subquery can be assigned an alias. This is done

with the AS keyword. For example, in the cause of a self-join, we can assign a unique alias for each instance of the same table:

SELECT ... FROM x AS x1 JOIN x AS x2 ON x1.col1 = x2.col2 ...

Or, in the case of a subquery:

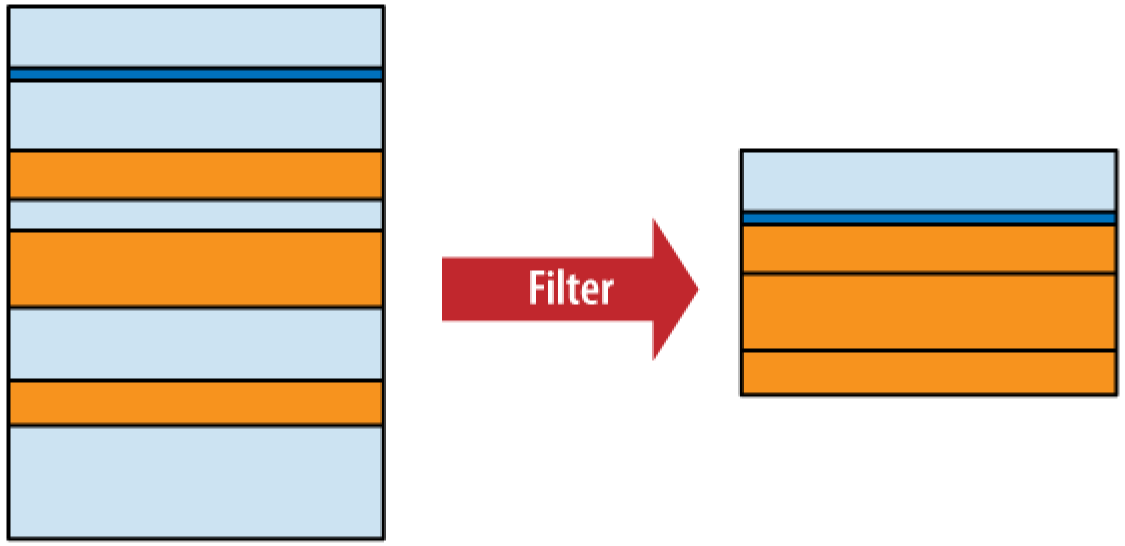
SELECT ... FROM (SELECT ...) AS sub ...

Technically, the AS keyword is optional, and each source-table name can simply be followed with an alias name. This can be quite confusing, however, so it is recommended you use the AS keyword.

If any of the subquery columns conflict with a column from a standard source table, you can now use the sub qualifier as a table name. For example, sub.col1. Once a table alias has been assigned, the original source-table name becomes invalid and cannot be used as a column qualifier. You must use the alias instead.

WHERE Clause

The WHERE clause is used to filter rows from the working table generated by the FROM clause. It is very similar to the WHERE clause found in the UPDATE and DELETE commands. An expression is provided that is evaluated for each row. Any row that causes the expression to evaluate to false or NULL is discarded. The resulting table will have the same number of columns as the original table


Filter

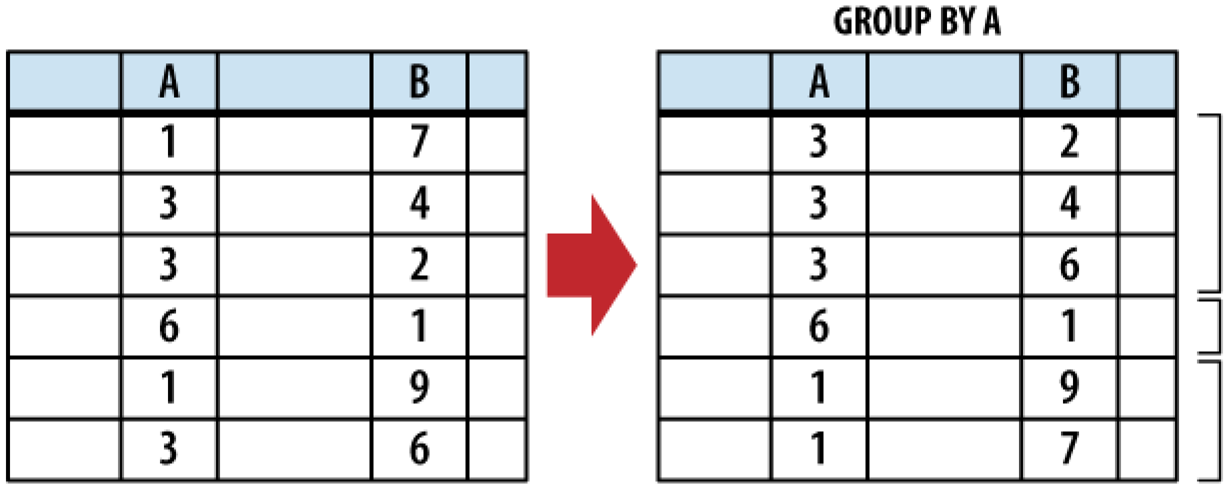
Some WHERE clauses can get quite complex, resulting in a long series of AND operators used to join sub-expressions together. Most filter for a specific row, however, searching for a specific key value.

GROUP BY Clause

The GROUP BY clause is used to collapse, or “flatten,” groups of rows. Groups can be counted, averaged, or otherwise aggregated together. If you need to perform any kind of inter-row operation that requires data from more than one row, chances are you’ll need a GROUP BY.

The GROUP BY clause provides a list of grouping expressions and optional collations. Very often the expressions are simple column references, but they can be arbitrary expressions. The syntax looks like this:

GROUP BY *grouping_expression* [COLLATE *collation_name*] [,...]



	A		B	
	1		7	
	3		4	
	3		2	
	6		1	
	1		9	
	3		6	

	A		B	
	3		2	
	3		4	
	3		6	
	6		1	
	1		9	
	1		7	

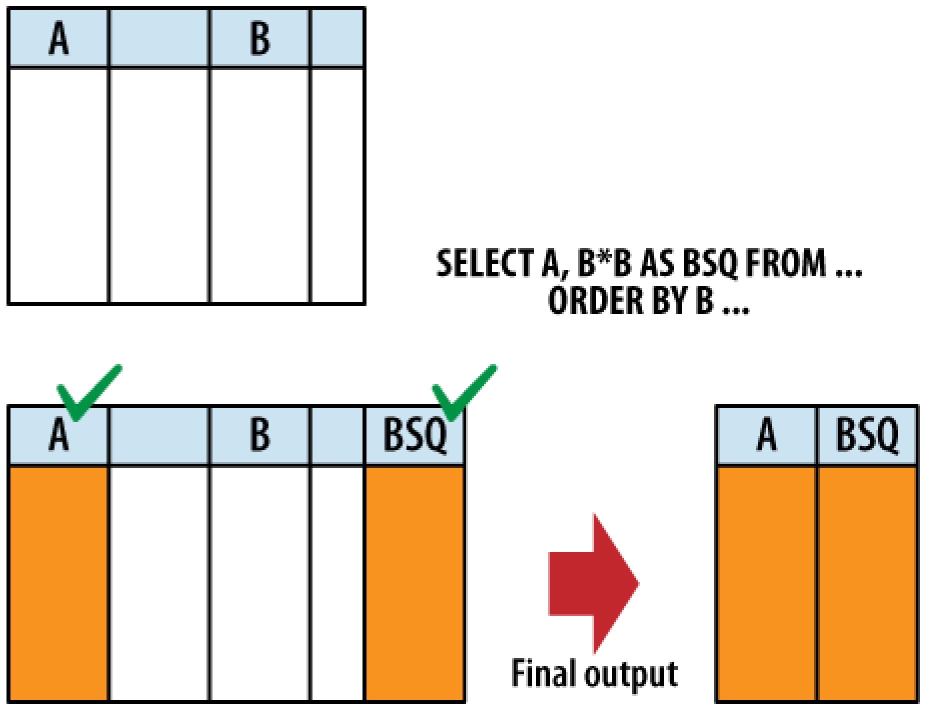
SELECT Header

The SELECT header is used to define the format and content of the final result table. Any column you want to appear in the final results table must be defined by an expression in the SELECT header. The SELECT heading is the only required step in the SELECT command

pipeline.The format of the header is fairly simple, consisting of a list of expressions. Each expression is evaluated in the context of each row, producing the final results table. Very often the expressions are simple column references, but they can be any arbitrary expression involving column references, literal values, or SQL functions. To generate the final query result, the list of expressions is evaluated once for each row in the working table.

Additionally, you can provide a column name using the AS keyword:

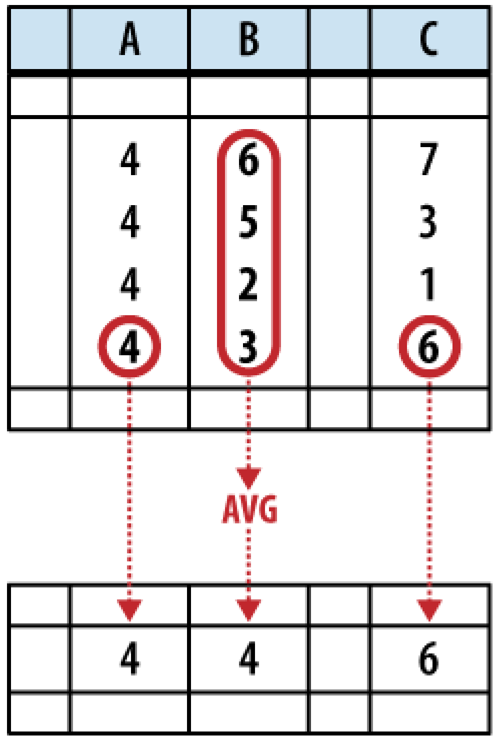
SELECT *expression* [AS *column_name*] [,...]


A
B
SELECT A, B*B AS BSQ FROM ...
ORDER BY B ...
A
B
BSQ
Final output
A
BSQ

In addition to the standard expressions, SELECT supports two wildcards. A simple asterisk (*) will cause every user-defined column from every source table in the FROM clause to be output. You can also target a specific table (or table alias) using the format *table_name*.*. Although both of these wildcards are capable of returning more than one column, they can be mixed along with other expressions in the expression list. Wildcards cannot use a column alias, since they often return more than one column.

Be aware that the SELECT wildcards will not return any automatically generated ROWID columns. To return both the ROWID and the user-defined columns, simply ask for them both:

SELECT ROWID, * FROM *table*;



SELECT A, AVG(B), C FROM…
GROUP BY A…

The SELECT header will flatten any row groups created by GROUP BY. This figure shows

how different columns from one row-group are flattened into an output row. Any value not computed by an aggregate function comes from the last row. Because column A was used as a GROUP BY expression, all the rows are known to have the same value, and it is safe to return. Column B is run through an aggregate function, and is also safe to return. Column C is not safe to return, as the order of the rows within a group is undefined.

In some cases, picking the value from a random row is not a bad thing. For example, if a SELECT header expression is also used as a GROUP BY expression, then we know that column has an equivalent value in every row of a group. No matter which row you choose, you will always get the same value.

Here are some examples. In this case all of the expressions are bare column references

to help make things clear:

SELECT col1, sum(col2) FROM tbl GROUP BY col1; -- well formed

```
CREATE TABLE tbl ( t );

INSERT INTO tbl VALUES ( 'ABC' );

INSERT INTO tbl VALUES ( 'abc' );

SELECT t FROM tbl GROUP BY t COLLATE NOCASE
```

HAVING Clause

Functionally, the HAVING clause is identical to the WHERE clause. The HAVING clause consists of a filter expression that is evaluated for each row of the working table. Any row that evaluates to false or NULL is filtered out and removed. The resulting table will have the same number of columns, but may have fewer rows.

LIMIT and OFFSET Clauses

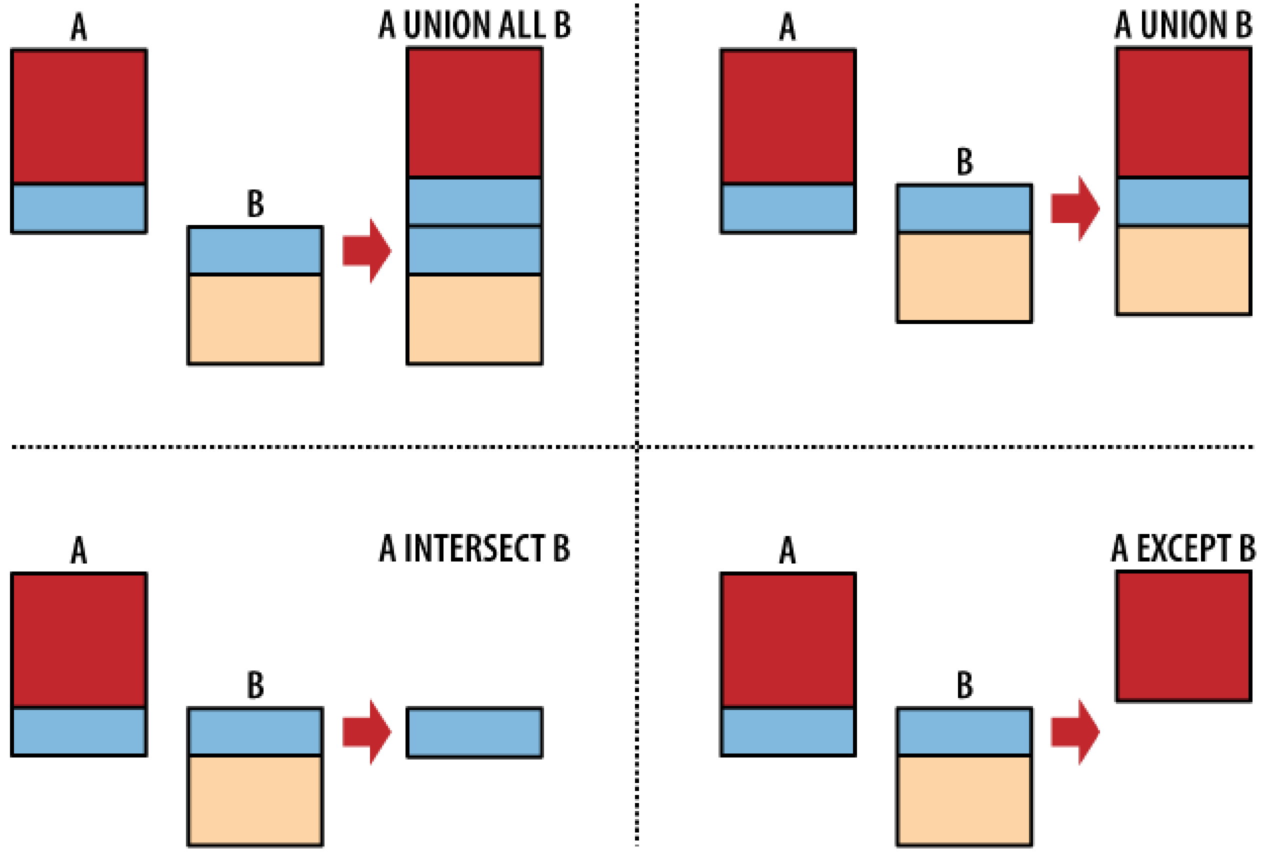
The LIMIT and OFFSET clauses allow you to extract a specific subset of rows from the final results table. LIMIT defines the maximum number of rows that will be returned, while OFFSET defines the number of rows to skip before returning the first row. If no OFFSET is provided, the LIMIT is applied to the top of the table. If a negative LIMIT is provided, the LIMIT is removed and will return the whole table.

There are three ways to define a LIMIT and OFFSET:

LIMIT *limit_count*

LIMIT *limit_count* OFFSET *offset_count*

LIMIT *offset_count*, *limit_count*


A
B
A UNION ALL B
A
B
A UNION B
A
B
A INTERSECT B
A
B
A EXCEPT B

Alternate JOIN Notation

There are two styles of join notation. The style shown earlier in this chapter is known as *explicit join notation*. It is named such because it uses the keyword JOIN to explicitly describe how each table is joined to the next. The explicit join notation is also known as *ANSI join notation*, as it was introduced when SQL went through the standardization process.

SELECT Examples

The SELECT command is very complex, and it can be difficult to see how these different clauses can be fit together into something useful. Some of this will become more obvious in the next chapter, when we look at standard database design practices, but to get you started, we’re going to look at several examples.

All of these examples will use this data:

```
CREATE TABLE x ( a, b );
INSERT INTO x VALUES ( 1, 'Alice' );
INSERT INTO x VALUES ( 2, 'Bob' );
INSERT INTO x VALUES ( 3, 'Charlie' );
```

Simple SELECTs

Let’s start with a simple select that returns all of the columns and rows in table x. The

SELECT * syntax returns all columns by default:

```
sqlite> SELECT * FROM x;

a b

---------- ----------

1 Alice

2 Bob

3 Charlie
```

We can also return expressions, rather than just columns:

```
sqlite> SELECT d, d*d AS dSquared FROM y;

d dSquared

---------- ------------

3.14159 9.8695877281

2.71828 7.3890461584

1.61803 2.6180210809
```

Simple JOINs

Now some joins. By default, the bare keyword JOIN indicates an INNER JOIN. However, when no additional condition is put on the JOIN, it reverts to a CROSS JOIN. As a result, all three of these queries produce the same results. The last line uses the implicit join notation

```
sqlite> SELECT * FROM x JOIN y;

sqlite> SELECT * FROM x CROSS JOIN y;

sqlite> SELECT * FROM x, y;

a b c d

---------- ---------- ---------- ----------

1 Alice 1 3.14159

1 Alice 1 2.71828

1 Alice 2 1.61803

2 Bob 1 3.14159

2 Bob 1 2.71828

2 Bob 2 1.61803

3 Charlie 1 3.14159

3 Charlie 1 2.71828

3 Charlie 2 1.61803
```

JOIN...ON

Next, a fairly simple inner join using a basic ON join condition:

```
sqlite> SELECT * FROM x JOIN y ON a = c;

a b c d

---------- ---------- ---------- ----------

1 Alice 1 3.14159

1 Alice 1 2.71828

2 Bob 2 1.61803
```

JOIN...USING, NATURAL JOIN

If we use a NATURAL JOIN or the USING syntax, the duplicate column will be eliminated.

Since both table x and table z have only column a in common, both of these statements

produce the same output:

```
sqlite> SELECT * FROM x JOIN z USING ( a );
sqlite> SELECT * FROM x NATURAL JOIN z;
a b e
---------- ---------- ----------
1 Alice 100
1 Alice 150
3 Charlie 300
```

OUTER JOIN

A LEFT OUTER JOIN will return the same results as an INNER JOIN, but will also include rows from table x (the left/first table) that were not matched:

```
sqlite> SELECT * FROM x LEFT OUTER JOIN z USING ( a );
a b e
---------- ---------- ----------
1 Alice 100
1 Alice 150
2 Bob [NULL]
3 Charlie 300
```

Compound JOIN

It is also possible to JOIN multiple tables together. In this case we join table x to table y, and then join the result to table z:

```
sqlite> SELECT * FROM x JOIN y ON x.a = y.c LEFT OUTER JOIN z ON y.c = z.a;
a b c d a e
---------- ---------- ---------- ---------- ---------- ----------
1 Alice 1 3.14159 1 100
1 Alice 1 3.14159 1 150
1 Alice 1 2.71828 1 100
1 Alice 1 2.71828 1 150
2 Bob 2 1.61803 [NULL] [NULL]
```

Self JOIN

Our last join example shows a self-join, where a table is joined against itself. This creates two unique instances of the same table and necessitates the use of table aliases:

```
sqlite> SELECT * FROM x AS x1 JOIN x AS x2 ON x1.a + 1 = x2.a;
a b a b
---------- ---------- ---------- ----------
1 Alice 2 Bob
2 Bob 3 Charlie
```

WHERE Examples

Moving on, the WHERE clause is used to filter rows. We can pick out a specific row:

```
sqlite> SELECT * FROM x WHERE b = 'Alice';
a b
---------- ----------
1 Alice
```

GROUP BY Examples

Now let’s look at a few GROUP BY statements. Here we group table z by the a column.

Since there are three unique values in z.a, the output has three rows. Only the grouping

a=1 has more than one row, however. We can see this in the count() values returned

by the second column:

```
sqlite> SELECT a, count(a) AS count FROM z GROUP BY a;
a count
---------- ----------
1 2
3 1
9 1
```

GROUP BY Examples

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```
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a count
---------- ----------
1 2
3 1
9 1
```

This is a similar query, only now the second output column represents the sum of all

the z.e values in each group:

```
sqlite> SELECT a, sum(e) AS total FROM z GROUP BY a;

a total

---------- ----------

1 250

3 300

9 900
```

We can even compute our own average and compare that to the avg() aggregate:

```
sqlite> SELECT a, sum(e), count(e),

...> sum(e)/count(e) AS expr, avg(e) AS agg

...> FROM z GROUP BY a;

a sum(e) count(e) expr agg

---------- ---------- ---------- ---------- ----------

1 250 2 125 125.0

3 300 1 300 300.0

9 900 1 900 900.0
```

Database Design

Relational databases have only one type of data container: the table. When designing any database, the main concern is defining the tables that make up the database and defining how those tables reference and interact with each other.

Designing tables for a database is a lot like designing classes or data structures for an application. Simple designs are largely driven by common sense, but as things get larger and more complex, it takes some experience and insight to keep the design clean and on target. Understanding basic design principles and standard approaches can be a big help.

Tables and Keys

Tables may look like simple two-dimensional grids of simple values, but a well-defined table has a fair amount of structure. Different columns can play different roles. Some columns act as unique identifiers that define the intent and purpose of each row. Other columns hold supporting data. Still other columns act as external references that link rows in one table to rows in another table. When designing a table, it is important to understand why each column is there, and what role each column is playing.

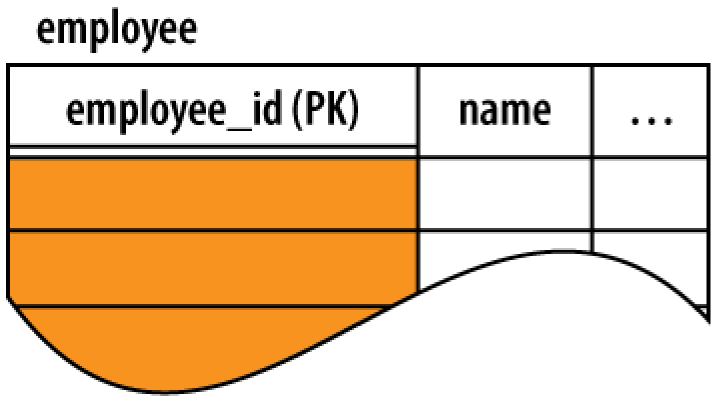
Keys Define the Table

When designing a table, you usually start by specifying the primary key. The primary key consists of one or more columns that uniquely identify each row of a table. In a sense, the primary key values represent the fundamental identity of each row in the table. The primary key columns identify what the table is all about. All the other columns should provide supporting data that is directly relevant to the primary key.

Sometimes the primary key is an actual unique data value, such as a room number or a hostname. Very often the primary key is simply an arbitrary identification number, such as an employee or student ID number. The important point is that primary keys must be unique over every *possible* entry in the table, not just the rows that happen to be in there right now. This is why names are normally not used as primary keys—in a large group of people, it is too easy to end up with duplicate (or very similar) names.

For example, this table definition defines the employee_id field to be a primary key:

```
CREATE TABLE employee (
employee_id INTEGER PRIMARY KEY NOT NULL,
name TEXT NOT NULL
/* ...etc... */
);
```

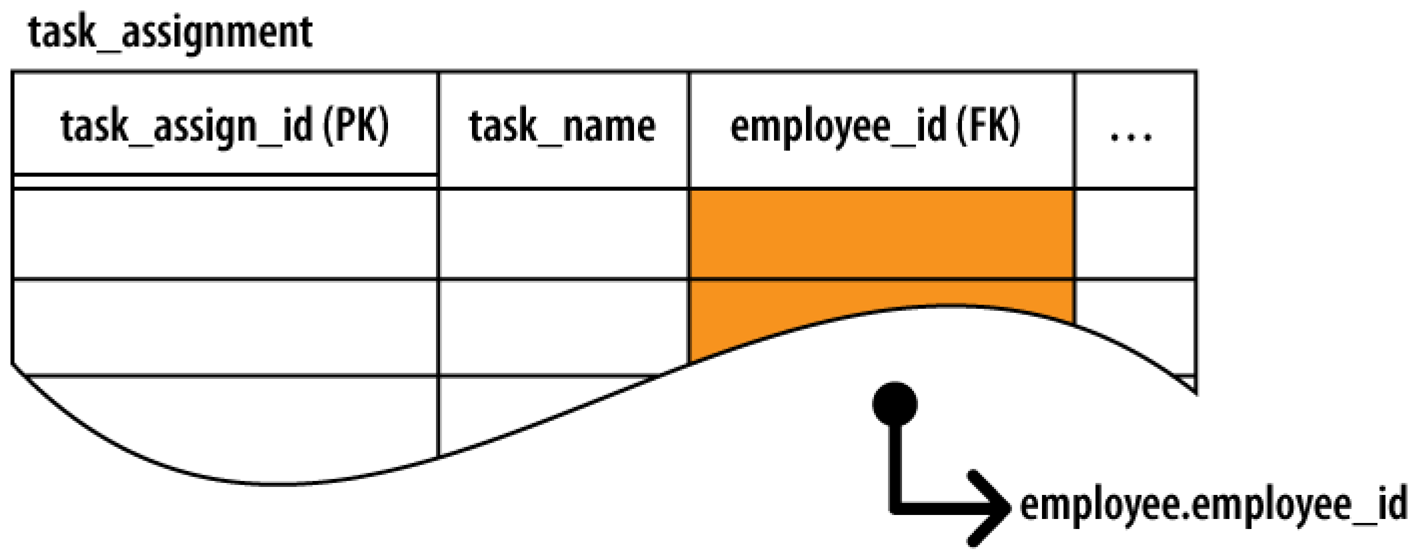

employee
employee_id (PK)
name
…

Foreign Keys

In addition to identifying each row in a table, primary keys are also central to joining tables together. Since the primary key acts as a unique row identifier, you can create a reference to a specific row by recording the row’s primary key. This is known as a *foreign key*. A foreign key is a copy or recording of a primary key, and is used as a reference or pointer to a different (or “foreign”) row, most often in a different table.

Like the primary key, columns that make up a foreign key can be identified within the CREATE TABLE command. In this example, we define the format of a task assignment. Each task gets assigned to a specific employee by referencing the employee_id field from the employee table:

```
CREATE TABLE task_assignment (
task_assign_id INTEGER PRIMARY KEY,
task_name TEXT NOT NULL,
employee_id INTEGER NOT NULL REFERENCES employee( employee_id )
/* ...etc... */
)
```


task_assignment
task_assign_id (PK)
task_name
employee_id (FK)
...
employee.employee_id

Foreign Key Constraints

Declaring foreign keys in the table definition allows the database to enforce foreign key constraints. *Foreign key constraints* are used to keep foreign key references in sync. Among other things, foreign key constraints can prevent “dangling references” by requiring that all foreign key values correctly match a row value from the columns of the referenced table. Foreign keys can also be set to NULL. A NULL clearly marks the foreign key as unassigned, which is a bit different than having an invalid value. In many cases, unassigned foreign keys don’t fit the design of the database. In that case, the foreign key columns should be declared with a NOT NULL constraint.

Generic ID Keys

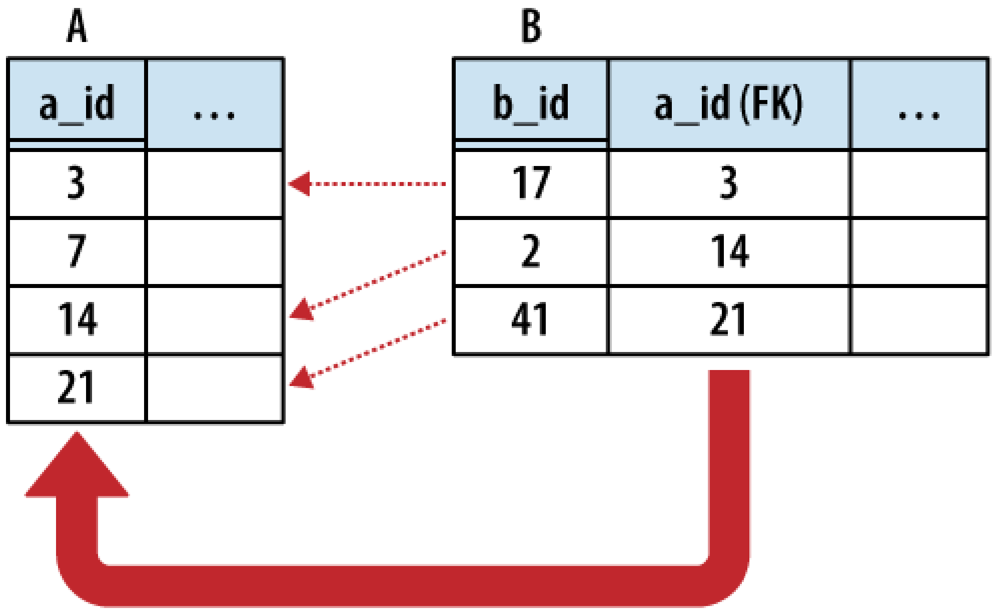
If you look at most database designs, you’ll notice that a large number of the tables have a generic ID column that is used as the primary key. The ID is typically an arbitrary integer value that is automatically assigned as new rows are inserted. The number may be incrementally assigned, or it might be assigned from a sequence mechanism that is guaranteed to never assign the same ID number twice.

Common Structures and Relationships

Database design has a small number of design structures and relationships that act as basic building blocks. Once you master how to use them and how to manipulate them, you can use these building blocks to build much larger and more complex data representations.

One-to-One Relationships

The most basic kind of inter-table relationship is the *one-to-one relationship*. As you can guess, this type of relationship establishes a reference from a single row in one table to a single row in another table.



A

a_id	…
3	
7	
14	
21	

B

b_id	a_id (FK)	…
17	3	
2	14	
41	21	

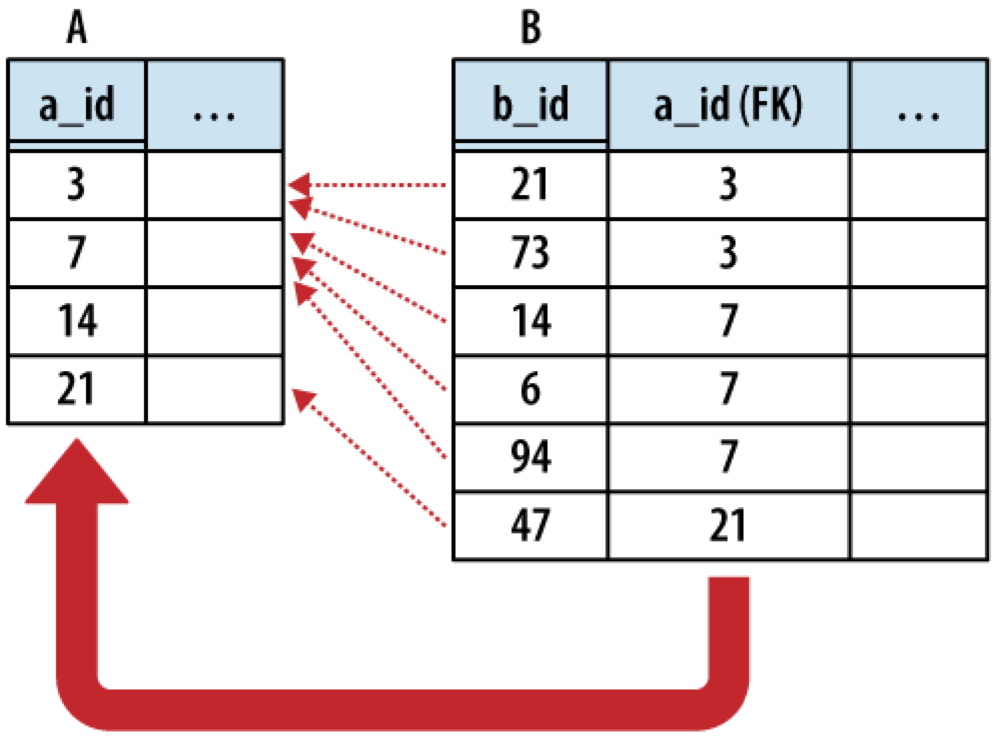
One-to-one relationships are commonly used to create *detail tables*. As the name implies, a detail table typically holds details that are linked to the records in a more prominent table. Detail tables can be used to hold data that is only relevant to a small subsection of the database application. Breaking the detail data apart from the main tables allows different sections of the database design to evolve and grow much more independently.

```
CREATE TABLE employee (
employee_id INTEGER NOT NULL PRIMARY KEY,
name TEXT NOT NULL
/* ...etc... */
);
CREATE TABLE employee_photo (
employee_id INTEGER NOT NULL PRIMARY KEY
REFERENCES employee,
photo_data BLOB
/* ...etc... */
);
```

One-to-Many Relationships

One-to-many relationships establish a link between a single row in one table to multiple rows in another table. This is done by expanding a one-to-one relationship, allowing one side to contain duplicate keys. One-to-many relationships are often used to associate lists or arrays of items back to a single row. For example, multiple shipping addresses can be linked to a single account. Unless otherwise specified, “many” usually means “zero or more.”

The only difference between a one-to-one relationship and a one-to-many relationship is that the one-to-many relationship allows for duplicate foreign key values. This allows multiple rows in one table (the many table) to refer back to a single row in another table (the One table). In building a one-to-many relationship, the foreign key must always be on the many side.



A

a_id	…
3	
7	
14	
21	

B

b_id	a_id (FK)	…
21	3	
73	3	
14	7	
6	7	
94	7	
47	21	

One example of a one-to-many relationship is music albums, and the songs they contain.

Each album has a list of songs associated with that album. For example:

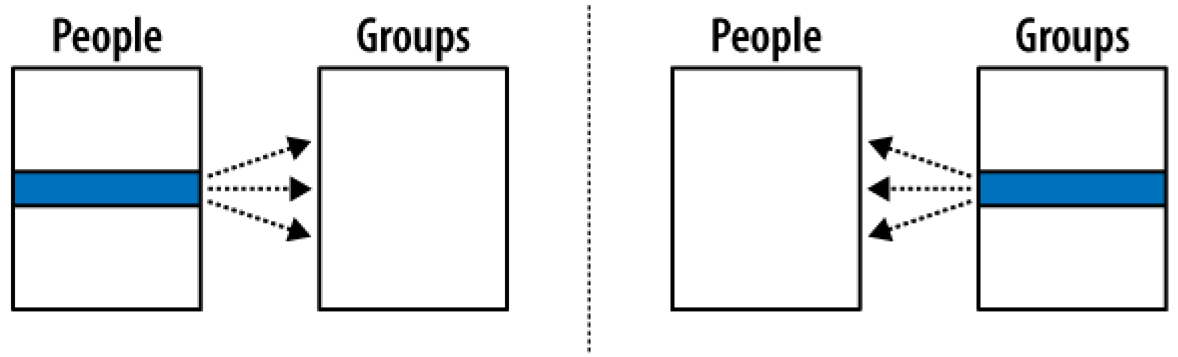
```
CREATE TABLE albums (
album_id INTEGER NOT NULL PRIMARY KEY,
album_name TEXT );
CREATE TABLE tracks (
track_id INTEGER NOT NULL PRIMARY KEY,
track_name TEXT,
track_number INTEGER,
track_length INTEGER, -- in seconds
album_id INTEGER NOT NULL REFERENCES albums );
```

```
INSERT INTO albums VALUES ( 1, "The Indigo Album" );

INSERT INTO tracks VALUES ( 1, "Metal Onion", 1, 137, 1 );

INSERT INTO tracks VALUES ( 2, "Smooth Snake", 2, 212, 1 );

INSERT INTO tracks VALUES ( 3, "Turn A", 3, 255, 1 );
```

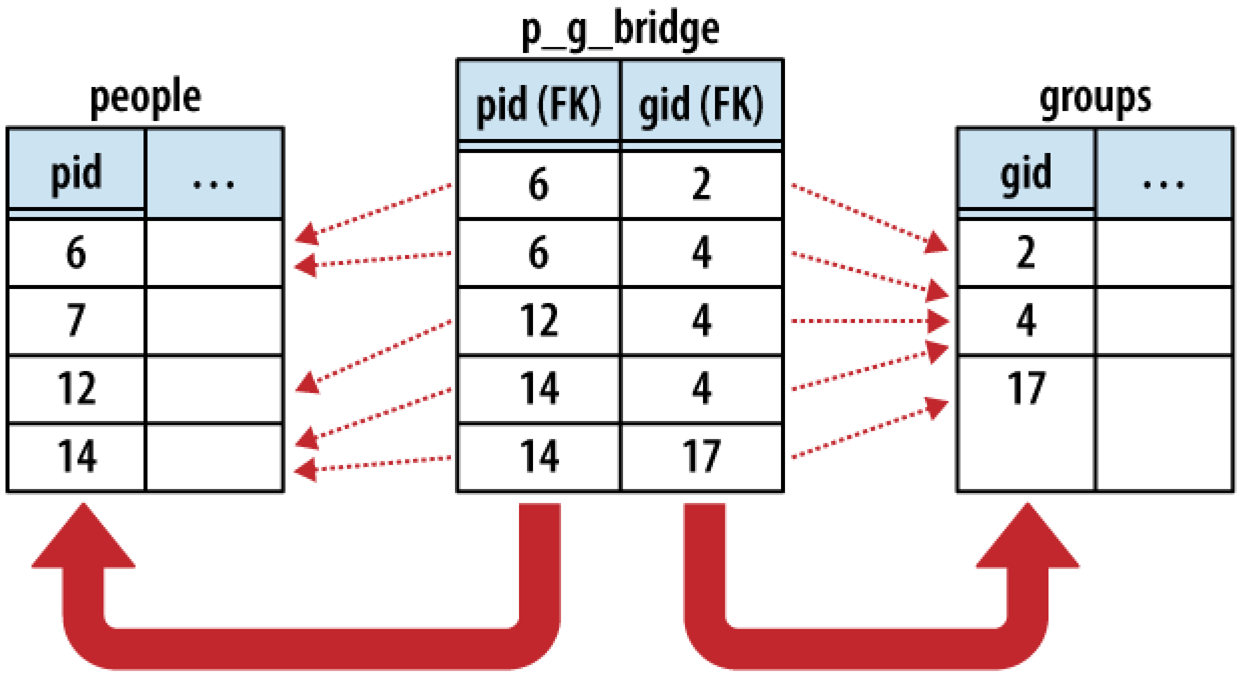
```
sqlite> SELECT album_name, track_name, track_number
...> FROM albums JOIN tracks USING ( album_id )
...> ORDER BY album_name, track_number;
album_name track_name track_number
------------ ---------- ------------
Morning Jazz In the Bed 1
Morning Jazz Water All 2
Morning Jazz Time Soars 3
Morning Jazz Liquid Awa 4
The Indigo A Metal Onio 1
The Indigo A Smooth Sna 2
The Indigo A Turn A 3
```

Many-to-Many Relationships

The next step is the many-to-many relationship. A many-to-many relationship associates one row in the first table to many rows in the second table while simultaneously allowing individual rows in the second table to be linked to multiple rows in the first table. In a sense, a many-to-many relationship is really two one-to-many relationships built across each other.


People
Groups
People
Groups

Many-to-many relationships are a bit more complex than other relationships. Although the tables have a many-to-many relationship with each other, the entries in both tables must remain unique. We cannot duplicate either person rows or group rows for the purpose of matching keys. This is a problem, since each foreign key can only reference one row. This makes it impossible for a foreign key of one table (such as a group) to refer to multiple rows of another table (such as people).



people

pid	…
6	
7	
12	
14	

p_g_bridge

pid (FK)	gid (FK)
6	2
6	4
12	4
14	4
14	17

groups

gid	…
2	
4	
17	

```
CREATE TABLE people ( pid INTEGER PRIMARY KEY, name TEXT, ... );
CREATE TABLE groups ( gid INTEGER PRIMARY KEY, name TEXT, ... );
CREATE TABLE p_g_bridge(
pid INTEGER NOT NULL REFERENCES people,
gid INTEGER NOT NULL REFERENCES groups,
PRIMARY KEY ( pid, gid )
)
```