



# Relational Databases and SQLite

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Python for Informatics: Exploring  
Information  
[www.pythonlearn.com](http://www.pythonlearn.com)



# SQLite Browser

# DB Browser for SQLite

The Official home of the DB Browser for SQLite

[View project on GitHub](#)

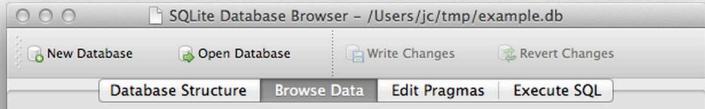
## // News

2015-07-07 - Added PortableApp version of 3.7.0. Thanks John. :)

2015-06-14 - Version 3.7.0 released. :)

2015-05-09 - Added PortableApp version of 3.6.0v3.

## // Screenshot



A screenshot of the SQLite Database Browser application window. The title bar reads "SQLite Database Browser - /Users/jc/tmp/example.db". The menu bar includes "File", "Edit", "View", "Tools", and "Help". The toolbar contains icons for "New Database", "Open Database", "Write Changes", and "Revert Changes". The main menu is "Database Structure". Below the toolbar, there are tabs for "Database Structure", "Browse Data", "Edit Pragmas", and "Execute SQL".

[Download 32-bit Windows .exe](#)

[Download 64-bit Windows .exe](#)

[Download PortableApp](#)

<http://sqlitebrowser.org/>

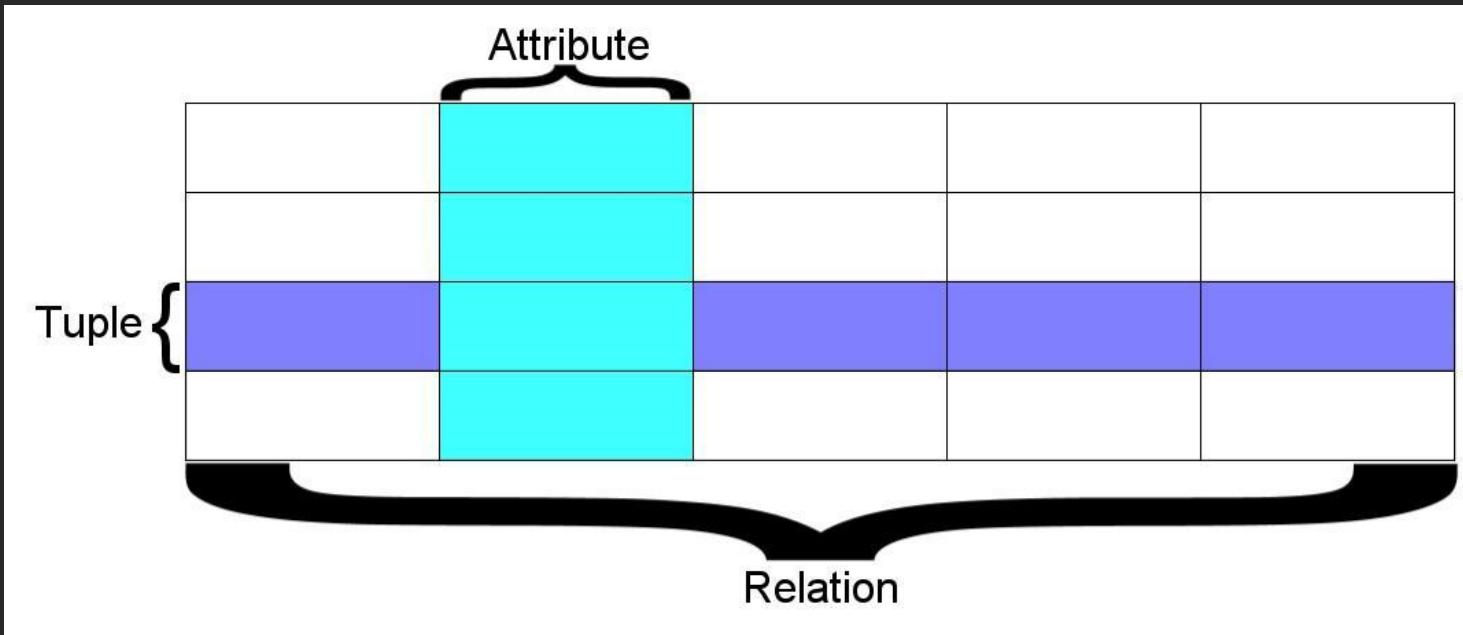
# **Relational Databases**

**Relational databases model data by storing rows and columns in tables. The power of the relational database lies in its ability to efficiently retrieve data from those tables and in particular where there are multiple tables and the relationships between those tables involved in the query.**

**[http://en.wikipedia.org/wiki/Relational\\_database](http://en.wikipedia.org/wiki/Relational_database)**

# Terminology

- **Database** - contains many tables
- **Relation (or table)** - contains tuples and attributes
- **Tuple (or row)** - a set of fields that generally represents an “object” like a person or a music track
- **Attribute (also column or field)** - one of possibly many elements of data corresponding to the object represented by the row



A **relation** is defined as a **set of tuples** that have the same **attributes**. A **tuple** usually represents **an object** and information about that object. **Objects** are typically physical objects or concepts. A **relation** is usually described as a **table**, which is organized into **rows** and **columns**. All the data referenced by an **attribute** are in the same domain and conform to the same constraints.  
(Wikipedia)

SIS02 - Database

New Open Save Print Import Copy Paste Format Undo Redo AutoSum Sort A-Z Sort Z-A Gallery Toolbox

Sheets Charts SmartArt Graphics WordArt

A B C D

1 About to Rock 3 354

2 Who Made Who 4 252

3

4

5

6

7

8

Tracks Albums Artists Genres +

**Columns / Attributes**

**Rows / Tuples**

**Tables / Relations**

# SQL

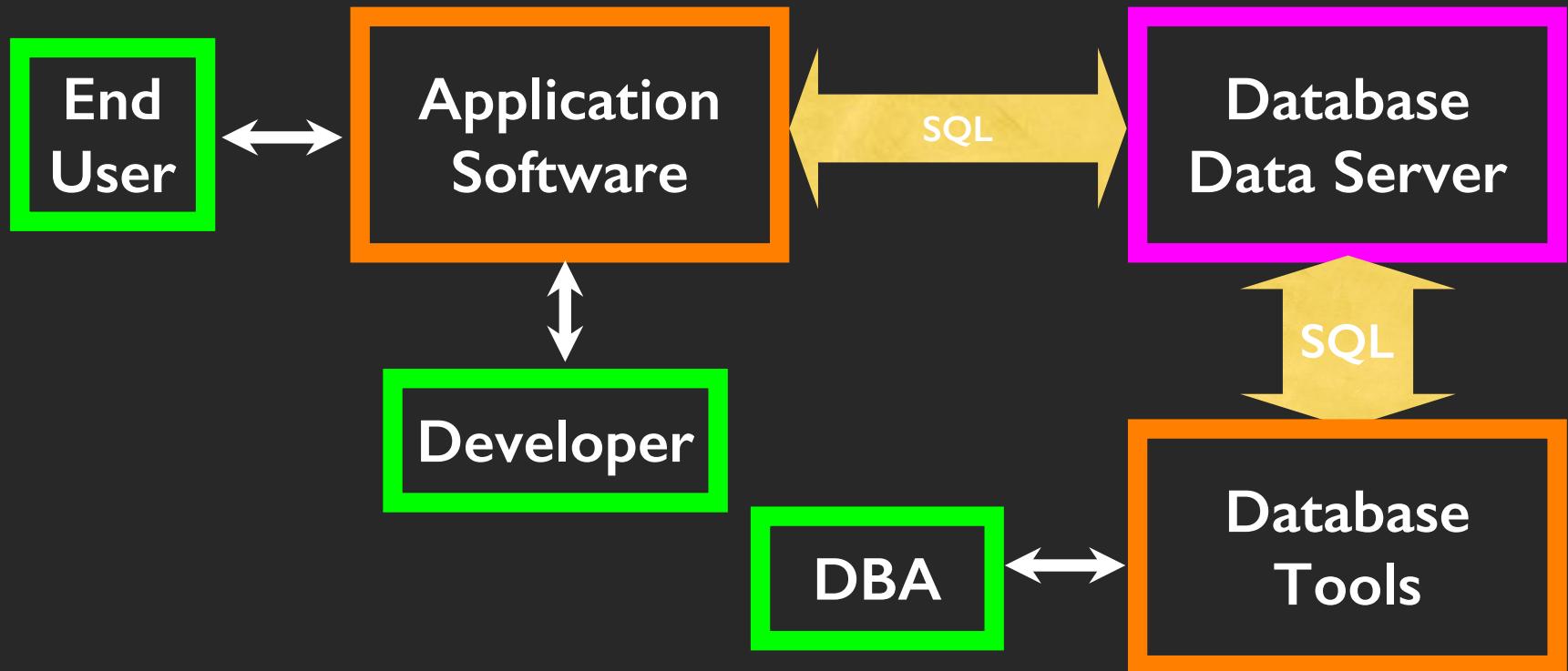
- **Structured Query Language** is the language we use to issue commands to the database
  - Create a table
  - Retrieve some data
  - Insert data
  - Delete data

<http://en.wikipedia.org/wiki/SQL>

# Two Roles in Large Projects

- **Application Developer** - Builds the logic for the application, the look and feel of the application - monitors the application for problems
- **Database Administrator** - Monitors and adjusts the database as the program runs in production
- Often both people participate in the building of the “Data model”

# Large Project Structure

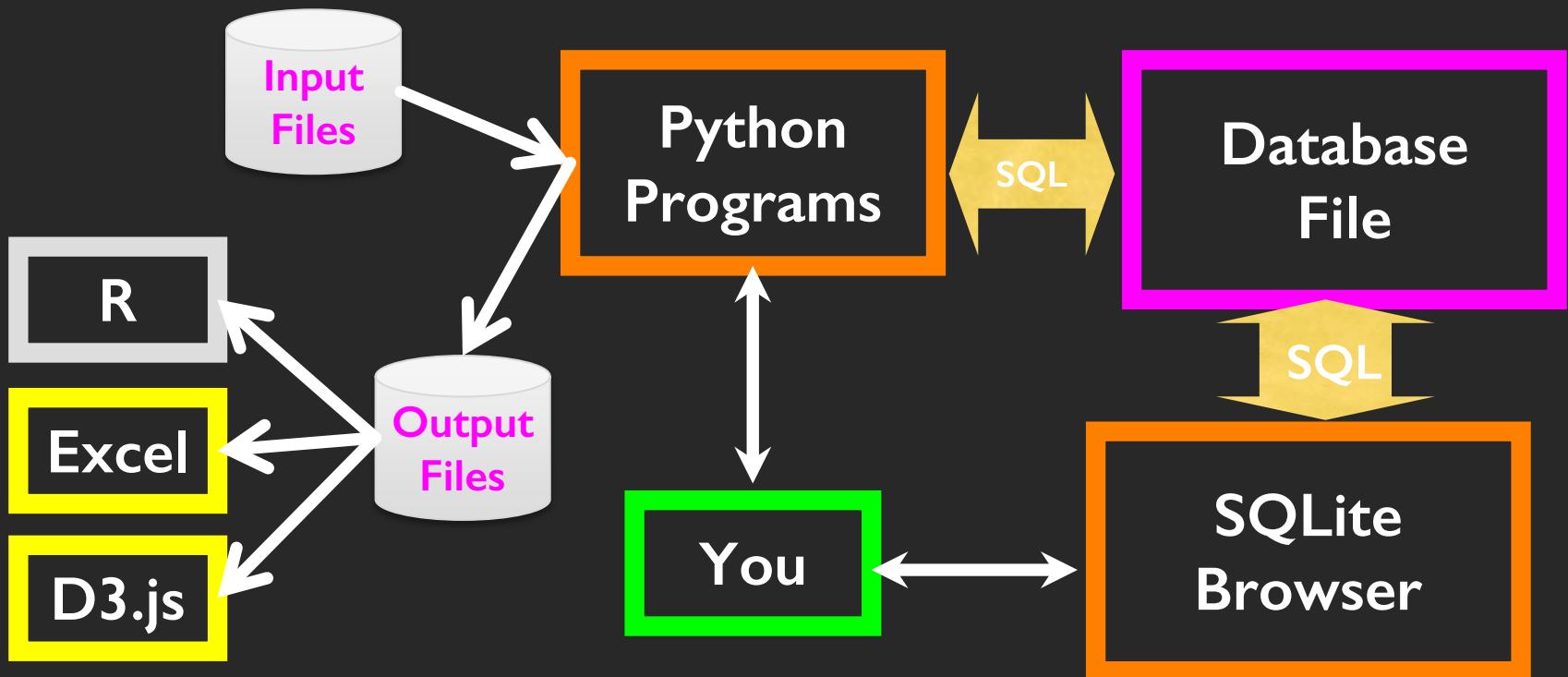


# Database Administrator (dba)

A database administrator (DBA) is a person responsible for the design, implementation, maintenance, and repair of an organization's database. The role includes the development and design of database strategies, monitoring and improving database performance and capacity, and planning for future expansion requirements. They may also plan, coordinate, and implement security measures to safeguard the database.

[http://en.wikipedia.org/wiki/Database\\_administrator](http://en.wikipedia.org/wiki/Database_administrator)

# Data Analysis Structure



# Database Model

A **database model** or **database schema** is the **structure or format of a database**, described in a **formal language supported by the database management system**. In other words, a “**database model**” is the **application of a data model when used in conjunction with a database management system**.

[http://en.wikipedia.org/wiki/Database\\_model](http://en.wikipedia.org/wiki/Database_model)

# Common Database Systems

- Three Major Database Management Systems in wide use
  - **Oracle** - Large, commercial, enterprise-scale, very very tweakable
  - **MySQL** - Simpler but very fast and scalable - commercial open source
  - **SqlServer** - Very nice - from Microsoft (also Access)
- Many other smaller projects, free and open source
  - HSQL, **SQLite**, Postgress, ...

# SQLite is in lots of software...



**Microsoft®**

**McAfee®**



**php**

**Google™**

**TOSHIBA**



<http://www.sqlite.org/famous.html>

# Writing SQL – Making a Database

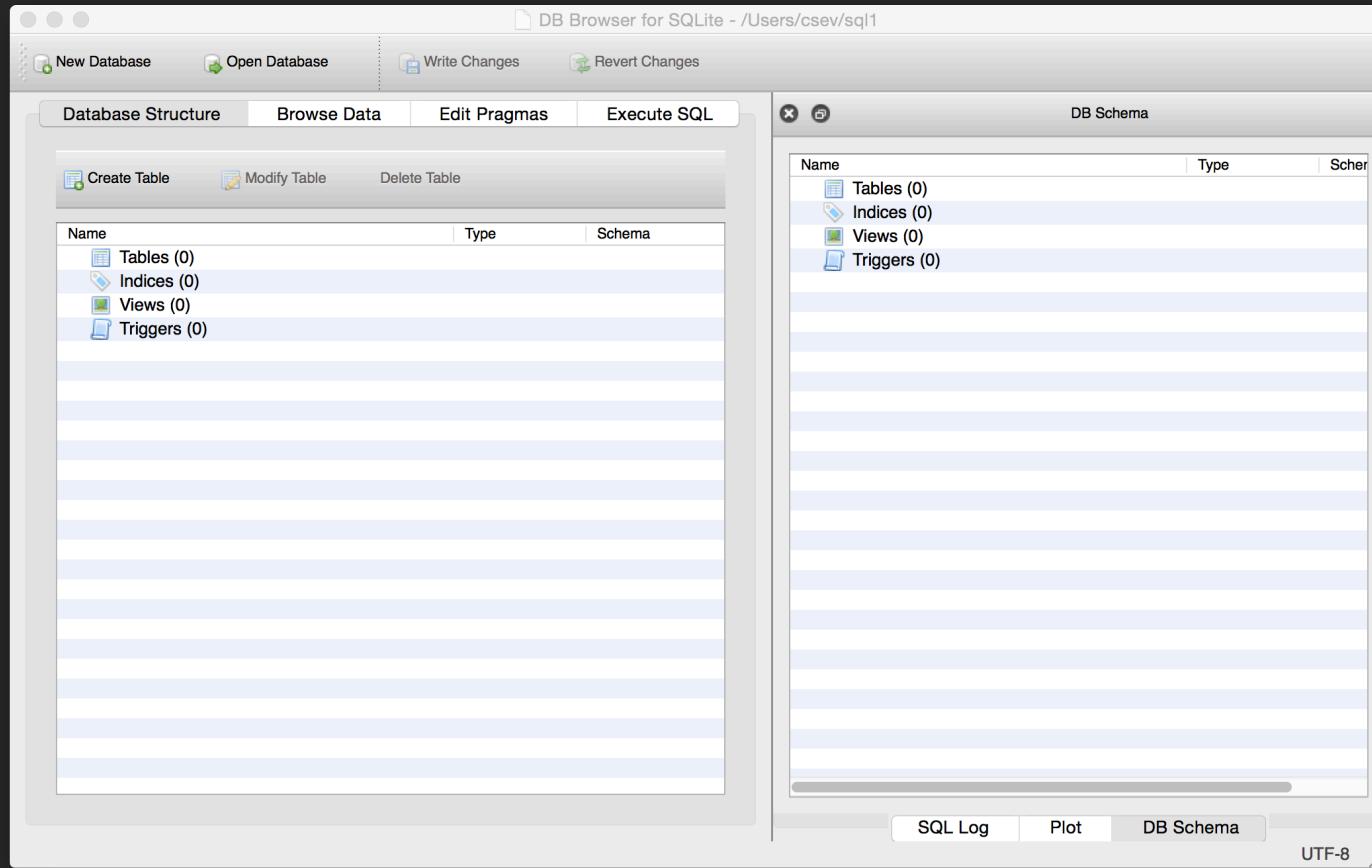
# SQLite Browser

- SQLite is a very popular database - it is free and fast and small
- SQLite Browser allows us to directly manipulate SQLite files
  - <http://sqlitebrowser.org/>

There is also a Firefox plugin to manipulate SQLite database

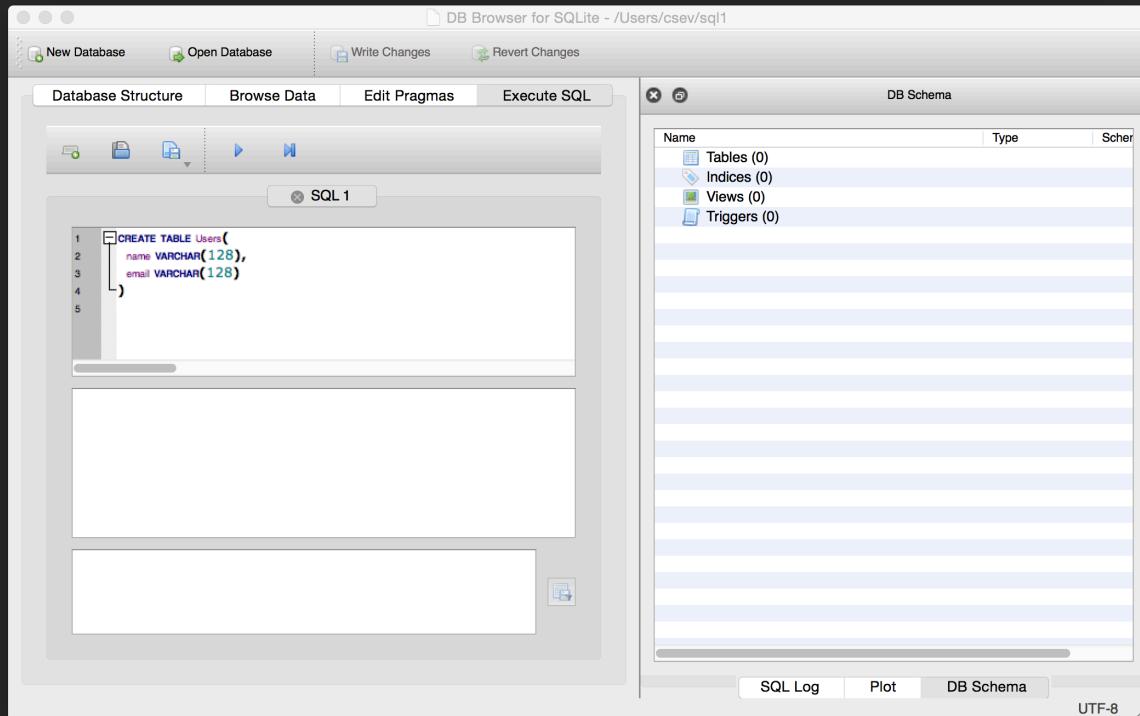
- <https://addons.mozilla.org/en-US/firefox/addon/sqlite-manager/>

SQLite is embedded in Python and a number of other languages



<http://sqlitebrowser.org/>

# Start Simple - A Single Table



```
CREATE TABLE Users(
    name VARCHAR(128),
    email VARCHAR(128)
)
```

DB Browser for SQLite - /Users/csev/sql1

New Database Open Database Write Changes Revert Changes

Database Structure Browse Data Edit Pragmas Execute SQL

Create Table Modify Table Delete Table

| Name         | Type | Schema   |
|--------------|------|--|
| Tables (1)   |      |  |
| Users        |      | CREATE TABLE Users(<br>name VARCHAR(128),<br>email VARCHAR(128)<br>) |
| Indices (0)  |      |  |
| Views (0)    |      |  |
| Triggers (0) |      |  |

DB Schema

| Name         | Type | Schema   |
|--------------|------|--|
| Tables (1)   |      |  |
| Users        |      | CREATE TABLE Users(<br>name VARCHAR(128),<br>email VARCHAR(128)<br>) |
| Indices (0)  |      |  |
| Views (0)    |      |  |
| Triggers (0) |      |  |

SQL Log Plot DB Schema

UTF-8

DB Browser for SQLite - /Users/csev/sql1

New Database Open Database Write Changes Revert Changes

Database Structure Browse Data Edit Pragmas Execute SQL

Table: **Users** New Record Delete Record

|   | name    | email         |
|---|---------|---------------|
| 1 | Chuck   | csev@umich... |
| 2 | Colleen | cvl@umich.edu |
| 3 | Ted     | ted@umich.... |
| 4 | Sally   | a1@umich.edu  |

Filter Filter

< < 0 - 0 of 0 > >| Go to: 1

DB Schema

| Name         | Type | Schema  |
|--------------|------|---|
| Tables (1)   |      |   |
| Users        |      | CREATE TABLE Users( name VARCHAR(128), email VARCHAR(128) ) |
| Indices (0)  |      |   |
| Views (0)    |      |   |
| Triggers (0) |      |   |

**Our table with four rows**

SQL Log Plot DB Schema

UTF-8

# SQL

- **Structured Query Language** is the language we use to issue commands to the database
  - Create a table
  - Retrieve some data
  - Insert data
  - Delete data

<http://en.wikipedia.org/wiki/SQL>

# SQL Insert

- The Insert statement inserts a row into a table

```
INSERT INTO Users (name, email) VALUES ('Kristin', 'kf@umich.edu')
```

DB Browser for SQLite - /Users/csev/sql1

New Database Open Database Write Changes Revert Changes

Database Structure Browse Data Edit Pragmas Execute SQL

SQL 1

```
1 INSERT INTO Users (name, email) VALUES ('Kristin', 'kf@umich.edu')
2
```

Query executed successfully: CREATE TABLE Users(
 name VARCHAR(128),
 email VARCHAR(128)
) (took 0ms)

DB Schema

| Name         | Type | Schema   |
|--------------|------|--|
| Tables (1)   |      |  |
| Users        |      | CREATE TABLE Users(<br>name VARCHAR(128),<br>email VARCHAR(128)<br>) |
| Indices (0)  |      |  |
| Views (0)    |      |  |
| Triggers (0) |      |  |

SQL Log Plot DB Schema

UTF-8

DB Browser for SQLite - /Users/csev/sql1

New Database Open Database Write Changes Revert Changes DB Browser for SQLite - /Users/csev/sql1

Database Structure New Database Open Database Write Changes Revert Changes

Database Structure Browse Data Edit Pragmas Execute SQL

Table: Users New Record Delete Record

1 INSERT INTO Us  
2

|   | name    | email         |
|---|---------|---------------|
| 1 | Chuck   | csev@umich... |
| 2 | Colleen | cvl@umich.edu |
| 3 | Ted     | ted@umich.... |
| 4 | Sally   | a1@umich.edu  |
| 5 | Kristin | kf@umich.edu  |

Query executed successfully.  
CREATE TABLE Users(  
 name VARCHAR(128),  
 email VARCHAR(128)  
) (took 0ms)

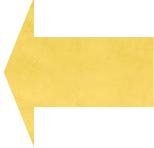
< < 1 - 5 of 5 > > Go to: 1

DB Schema

| Name         | Type | Schema   |
|--------------|------|--|
| Tables (1)   |      |  |
| Users        |      | CREATE TABLE Users(<br>name VARCHAR(128),<br>email VARCHAR(128)<br>) |
| Indices (0)  |      |  |
| Views (0)    |      |  |
| Triggers (0) |      |  |

SQL Log Plot DB Schema

UTF-8



# SQL Delete

- Deletes a row in a table based on a selection criteria

```
DELETE FROM Users WHERE email='ted@umich.edu'
```

DB Browser for SQLite - /Users/csev/sql1

New Database Open Database Write Changes Revert Changes

Database Structure Browse Data Edit Pragmas Execute SQL

SQL 1

```
1 DELETE FROM Users WHERE email='ted@umich.edu'
```

Query executed successfully: DELETE FROM Users WHERE email='ted@umich.edu'  
(took 0ms)

DB Schema

| Name         | Type | Schema   |
|--------------|------|--|
| Tables (1)   |      |  |
| Users        |      | CREATE TABLE Users(<br>name VARCHAR(128),<br>email VARCHAR(128)<br>) |
| Indices (0)  |      |  |
| Views (0)    |      |  |
| Triggers (0) |      |  |

SQL Log Plot DB Schema UTF-8

This screenshot shows the DB Browser for SQLite application interface. The main window title is "DB Browser for SQLite - /Users/csev/sql1". The top menu bar includes "New Database", "Open Database", "Write Changes", and "Revert Changes". Below the menu is a tab bar with "Database Structure", "Browse Data", "Edit Pragmas", and "Execute SQL" (which is currently selected). On the left, there's a toolbar with icons for file operations and a "SQL 1" button. The central area contains a SQL editor with the following content:

```
1 DELETE FROM Users WHERE email='ted@umich.edu'
```

Below the editor, a message box displays:

Query executed successfully: DELETE FROM Users WHERE email='ted@umich.edu'  
(took 0ms)

To the right, a "DB Schema" panel lists the database structure:

| Name         | Type | Schema   |
|--------------|------|--|
| Tables (1)   |      |  |
| Users        |      | CREATE TABLE Users(<br>name VARCHAR(128),<br>email VARCHAR(128)<br>) |
| Indices (0)  |      |  |
| Views (0)    |      |  |
| Triggers (0) |      |  |

The bottom of the window features a tab bar with "SQL Log", "Plot", "DB Schema" (selected), and "UTF-8".

The screenshot shows three windows of the DB Browser for SQLite application.

**Left Window (Database Structure):**

- Buttons: New Database, Open Database.
- Section: Database Structure.
- Table View:
  - Header: name, email.
  - Rows: 1 Chuck, csev@umich..., 2 Colleen, cvl@umich.edu, 3 Sally, a1@umich.edu, 4 Kristin, kf@umich.edu.
- Log: DELETE FROM Users;
- Message: Query executed successful (took 0ms).

**Middle Window (Browse Data):**

- Buttons: New Database, Open Database, Write Changes, Revert Changes.
- Section: Database Structure (selected), Browse Data, Edit Pragmas, Execute SQL.
- Table: Users
- Buttons: New Record, Delete Record.
- Table View (same data as the left window).
- Pagination: < > 1 - 4 of 4 Go to: 1.

**Right Window (DB Schema):**

- Section: DB Schema (selected).
- Table: Tables (1)
  - Users
- Details for Users table:

```
CREATE TABLE Users(
    name VARCHAR(128),
    email VARCHAR(128)
)
```
- Indices (0), Views (0), Triggers (0).

Bottom Navigation: SQL Log, Plot, DB Schema (selected).

Page Bottom: UTF-8

# SQL: Update

- Allows the updating of a field with a where clause

```
UPDATE Users SET name='Charles' WHERE  
email='csev@umich.edu'
```

DB Browser for SQLite - /Users/csev/sql1

New Database Open Database Write Changes Revert Changes

Database Structure Browse Data Edit Pragmas Execute SQL

SQL 1

```
1 UPDATE Users SET name='Charles' WHERE email='csev@umich.edu'
```

Query executed successfully: UPDATE Users SET name='Charles' WHERE email='csev@umich.edu' (took 0ms)

DB Schema

| Name         | Type | Schema   |
|--------------|------|--|
| Tables (1)   |      |  |
| Users        |      | CREATE TABLE Users(<br>name VARCHAR(128),<br>email VARCHAR(128)<br>) |
| Indices (0)  |      |  |
| Views (0)    |      |  |
| Triggers (0) |      |  |

SQL Log Plot DB Schema UTF-8

The screenshot shows the DB Browser for SQLite application interface. The main window title is "DB Browser for SQLite - /Users/csev/sql1". The top menu bar includes "New Database", "Open Database", "Write Changes", and "Revert Changes". Below the menu is a tab bar with "Database Structure", "Browse Data", "Edit Pragmas", and "Execute SQL" (which is currently selected). On the left, there's a toolbar with icons for creating a new database, opening an existing one, writing changes, and reverting them. A large central area contains a SQL editor titled "SQL 1" with the following code:

```
1 UPDATE Users SET name='Charles' WHERE email='csev@umich.edu'
```

Below the SQL editor, a message box displays the result of the query: "Query executed successfully: UPDATE Users SET name='Charles' WHERE email='csev@umich.edu' (took 0ms)". To the right of the SQL editor is a "DB Schema" panel. It has a tree view under the "Tables (1)" section, which shows a single table named "Users" with the following schema:

```
CREATE TABLE Users(  
name VARCHAR(128),  
email VARCHAR(128)  
)
```

The "DB Schema" tab is highlighted at the bottom of the window.

DB Browser for SQLite - /Users/csev/sql1

New Database Open Database Write Changes Revert Changes

Database Structure Browse Data Edit Pragmas Execute SQL

Table: Users New Record Delete Record

|   | name    | email         |
|---|---------|---------------|
| 1 | Charles | csev@umich... |
| 2 | Colleen | cvl@umich.edu |
| 3 | Sally   | a1@umich.edu  |
| 4 | Kristin | kf@umich.edu  |

Query executed successfully: UPDATE Users SET name='Charles' WHERE id=1 (took 0ms)

< < 1 - 4 of 4 > > Go to: 1

DB Schema

| Name         | Type  | Schema |
|--------------|---|--------|
| Tables (1)   |   |        |
| Users        | CREATE TABLE Users( name VARCHAR(128), email VARCHAR(128) ) |        |
| Indices (0)  |   |        |
| Views (0)    |   |        |
| Triggers (0) |   |        |

SQL Log Plot DB Schema

UTF-8

The screenshot shows two instances of DB Browser for SQLite running side-by-side. Both instances have the same database open, showing a table named 'Users' with four rows of data. In the bottom right corner of each window, there is a 'DB Schema' tab. A large yellow arrow points from the 'DB Schema' tab of the left instance to the 'Tables' section of its schema view. The schema view displays the CREATE TABLE statement for the 'Users' table. The table structure in the main view has columns 'name' and 'email'. The data in the table is as follows:

|   | name    | email         |
|---|---------|---------------|
| 1 | Charles | csev@umich... |
| 2 | Colleen | cvl@umich.edu |
| 3 | Sally   | a1@umich.edu  |
| 4 | Kristin | kf@umich.edu  |

The status bar at the bottom of both windows indicates 'UTF-8' encoding.

# Retrieving Records: Select

- The select statement retrieves a group of records - you can either retrieve all the records or a subset of the records with a WHERE clause

```
SELECT * FROM Users
```

```
SELECT * FROM Users WHERE email='csev@umich.edu'
```

DB Browser for SQLite - /Users/csev/sql1

New Database Open Database Write Changes Revert Changes

Database Structure Browse Data Edit Pragmas Execute SQL

SQL 1

```
1 SELECT * FROM Users
2
```

|   | name    | email          |
|---|---------|----------------|
| 1 | Charles | csev@umich.edu |
| 2 | Colleen | cvl@umich.edu  |
| 3 | Sally   | a1@umich.edu   |
| 4 | Kristin | kf@umich.edu   |

4 Rows returned from: SELECT \* FROM Users (took 0ms)

DB Schema

| Name         | Type | Schema   |
|--------------|------|--|
| Tables (1)   |      |  |
| Users        |      | CREATE TABLE Users(<br>name VARCHAR(128),<br>email VARCHAR(128)<br>) |
| Indices (0)  |      |  |
| Views (0)    |      |  |
| Triggers (0) |      |  |

SQL Log Plot DB Schema UTF-8

The screenshot shows the DB Browser for SQLite application interface. The main window has tabs for Database Structure, Browse Data, Edit Pragmas, and Execute SQL. The Execute SQL tab is active, displaying the results of a query: 'SELECT \* FROM Users'. The results are shown in a table with columns 'name' and 'email'. There are four rows of data: Charles (csev@umich.edu), Colleen (cvl@umich.edu), Sally (a1@umich.edu), and Kristin (kf@umich.edu). Below the table, it says '4 Rows returned from: SELECT \* FROM Users (took 0ms)'. To the right of the main window is a sidebar titled 'DB Schema' which lists the database's structure. It shows one table named 'Users' with the schema: CREATE TABLE Users(name VARCHAR(128), email VARCHAR(128)). It also shows that there are no indices, views, or triggers. At the bottom of the sidebar, there are tabs for SQL Log, Plot, and DB Schema, with DB Schema being the active tab. The status bar at the bottom right shows 'UTF-8'.

DB Browser for SQLite - /Users/csev/sql1

New Database Open Database Write Changes Revert Changes

Database Structure Browse Data Edit Pragmas Execute SQL

SQL 1

```
1 SELECT * FROM Users WHERE email='csev@umich.edu'
2
```

|   | name    | email          |
|---|---------|----------------|
| 1 | Charles | csev@umich.edu |

1 Rows returned from: SELECT \* FROM Users WHERE email='csev@umich.edu' (took 0ms)

DB Schema

| Name         | Type | Schema   |
|--------------|------|--|
| Tables (1)   |      |  |
| Users        |      | CREATE TABLE Users(<br>name VARCHAR(128),<br>email VARCHAR(128)<br>) |
| Indices (0)  |      |  |
| Views (0)    |      |  |
| Triggers (0) |      |  |

SQL Log Plot DB Schema UTF-8

The screenshot shows the DB Browser for SQLite application interface. The main window has tabs for 'Database Structure', 'Browse Data', 'Edit Pragmas', and 'Execute SQL'. The 'Execute SQL' tab is active, displaying the result of a query: 'SELECT \* FROM Users WHERE email='csev@umich.edu''. The result set contains one row: Charles, csev@umich.edu. On the right side, the 'DB Schema' tab is selected, showing the table 'Users' with its definition: 'CREATE TABLE Users(name VARCHAR(128), email VARCHAR(128))'. There are also sections for Indices, Views, and Triggers, all currently empty. At the bottom, there are tabs for 'SQL Log', 'Plot', and 'DB Schema', with 'DB Schema' being the active tab. The status bar at the bottom right shows 'UTF-8'.

# Sorting with ORDER BY

- You can add an **ORDER BY** clause to **SELECT** statements to get the results sorted in ascending or descending order

```
SELECT * FROM Users ORDER BY email
```

```
SELECT * FROM Users ORDER BY name
```

DB Browser for SQLite - /Users/csev/sql1

New Database Open Database Write Changes Revert Changes

Database Structure Browse Data Edit Pragmas Execute SQL

SQL 1

```
1 SELECT * FROM Users ORDER BY email
2
```

|   | name    | email          |
|---|---------|----------------|
| 1 | Sally   | a1@umich.edu   |
| 2 | Charles | csev@umich.edu |
| 3 | Colleen | cvl@umich.edu  |
| 4 | Kristin | kf@umich.edu   |

4 Rows returned from: SELECT \* FROM Users ORDER BY email (took 0ms)

DB Schema

| Name         | Type | Schema   |
|--------------|------|--|
| Tables (1)   |      |  |
| Users        |      | CREATE TABLE Users(<br>name VARCHAR(128),<br>email VARCHAR(128)<br>) |
| Indices (0)  |      |  |
| Views (0)    |      |  |
| Triggers (0) |      |  |

SQL Log Plot DB Schema

UTF-8

# SQL Summary

```
INSERT INTO Users (name, email) VALUES ('Kristin', 'kf@umich.edu')
```

```
DELETE FROM Users WHERE email='ted@umich.edu'
```

```
UPDATE Users SET name="Charles" WHERE email='csev@umich.edu'
```

```
SELECT * FROM Users
```

```
SELECT * FROM Users WHERE email='csev@umich.edu'
```

```
SELECT * FROM Users ORDER BY email
```

# This is not too exciting (so far)

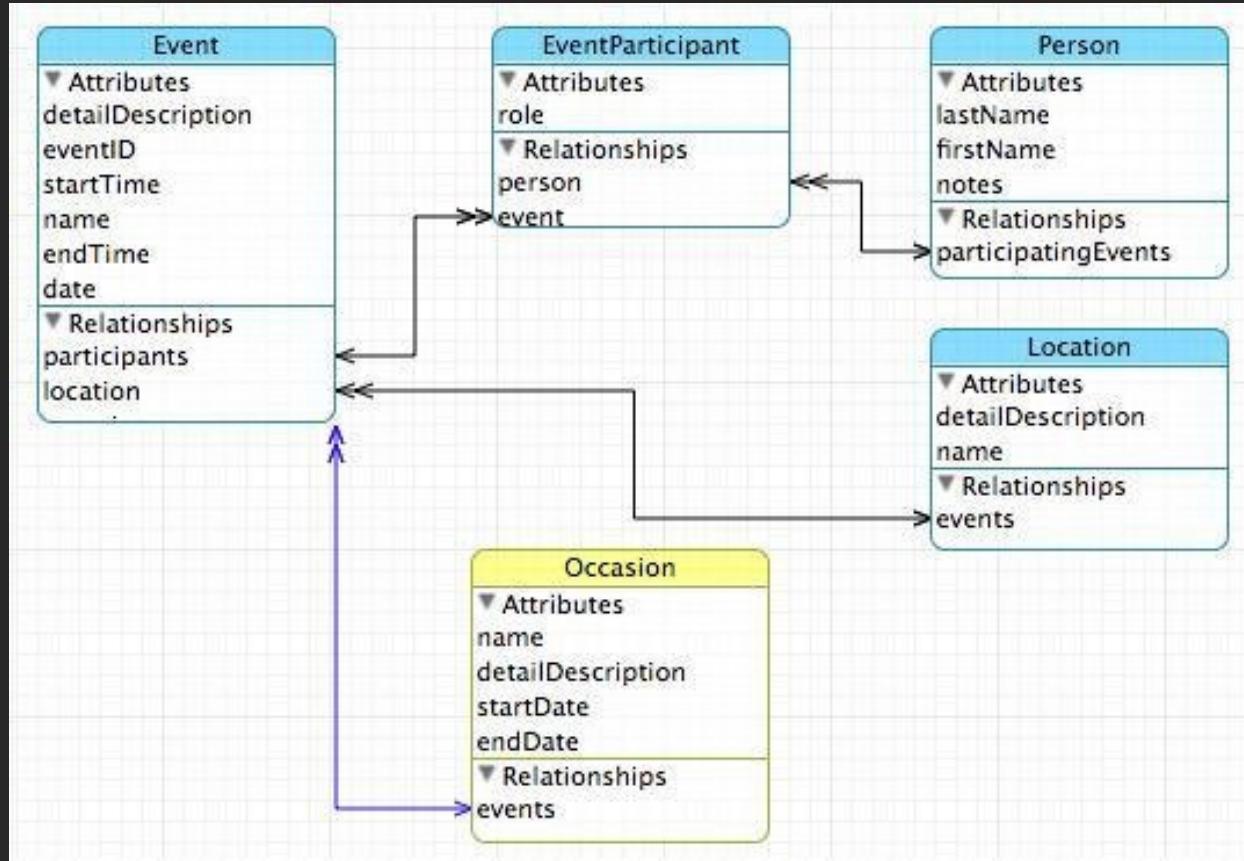
- Tables pretty much look like big fast programmable spreadsheets with rows, columns, and commands
- The power comes when we have more than one table and we can exploit the relationships between the tables

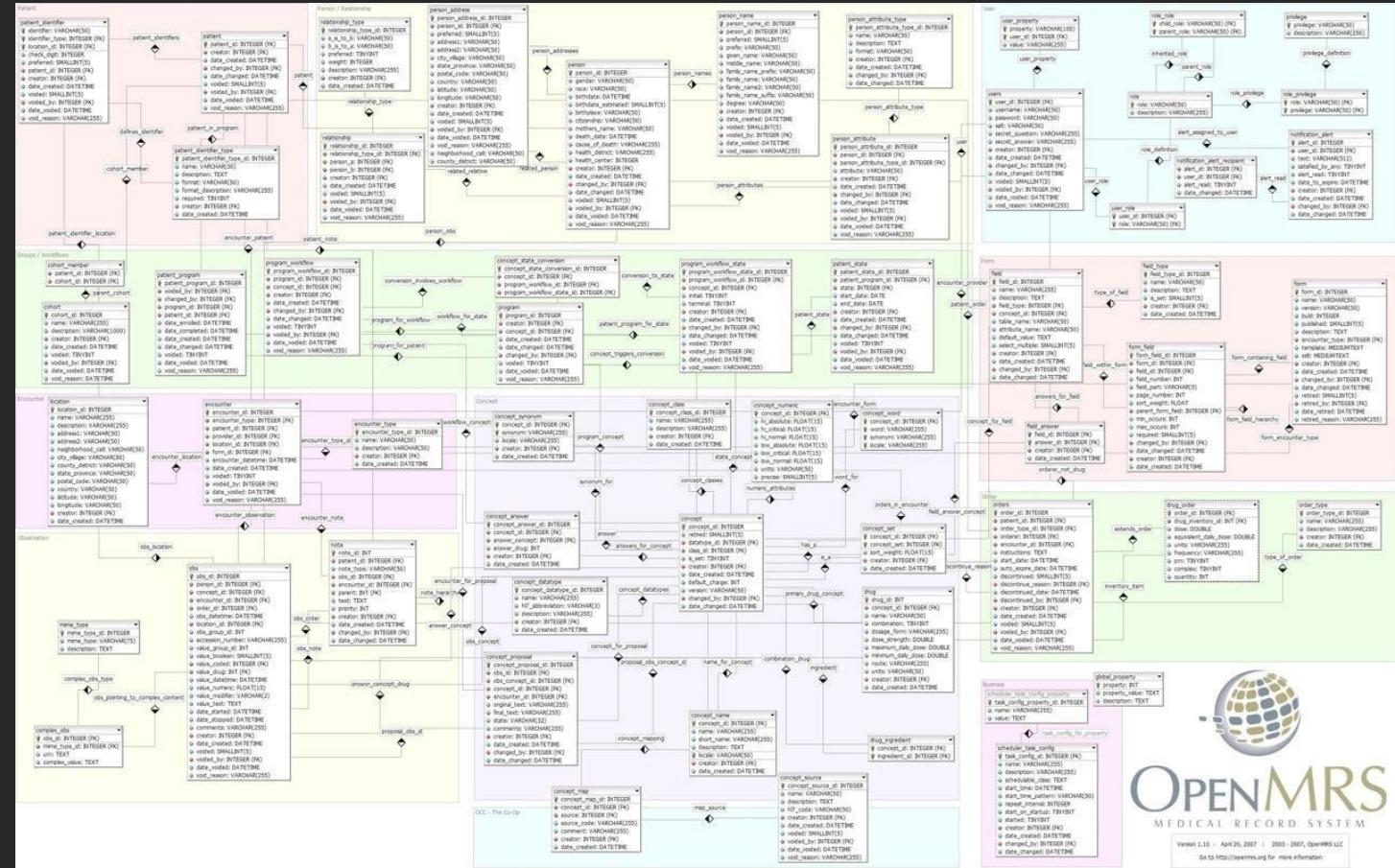
# Complex Data Models and Relationships

[http://en.wikipedia.org/wiki/Relational\\_model](http://en.wikipedia.org/wiki/Relational_model)

# Database Design

- Database design is an **art form** of its own with particular skills and experience
- Our goal is to avoid the really bad mistakes and design clean and easily understood databases
- Others may performance tune things later
- Database design starts with a picture...





# OPENMRS

MEDICAL RECORD SYSTEM

Version 1.10 - April 20, 2007 | 2003 - 2007, Open  
Go to <http://adrenalin.org> for more information

# Building a Data Model

- Drawing a picture of the data objects for our application and then figuring out how to represent the objects and their relationships
- Basic Rule: Don't put the same string data in twice - use a relationship instead
- When there is one thing in the “real world” there should be one copy of that thing in the database

| Track  | Len  | Artist        | Album                | Genre          | Rating | Count |
|--|------|---------------|----------------------|----------------|--------|-------|
| <input checked="" type="checkbox"/> Hells Bells                        | 5:13 | AC/DC         | Who Made Who         | Rock           | ★★★★★  | 61    |
| <input checked="" type="checkbox"/> Shake Your Foundations             | 3:54 | AC/DC         | Who Made Who         | Rock           | ★★★★★  | 70    |
| <input checked="" type="checkbox"/> Chase the Ace                      | 3:01 | AC/DC         | Who Made Who         | Rock           |        | 56    |
| <input checked="" type="checkbox"/> For Those About To Rock (We ...    | 5:54 | AC/DC         | Who Made Who         | Rock           | ★★★★★  | 61    |
| <input checked="" type="checkbox"/> Dúlamán                            | 3:43 | Altan         | Natural Wonders M... | New Age        |        | 31    |
| <input checked="" type="checkbox"/> Rode Across the Desert             | 4:10 | America       | Greatest Hits        | Easy Listen... | ★★★★★  | 23    |
| <input checked="" type="checkbox"/> Now You Are Gone                   | 3:08 | America       | Greatest Hits        | Easy Listen... | ★★★★★  | 18    |
| <input checked="" type="checkbox"/> Tin Man                            | 3:30 | America       | Greatest Hits        | Easy Listen... | ★★★★★  | 23    |
| <input checked="" type="checkbox"/> Sister Golden Hair                 | 3:22 | America       | Greatest Hits        | Easy Listen... | ★★★★★  | 24    |
| <input checked="" type="checkbox"/> Track 01                           | 4:22 | Billy Price   | Danger Zone          | Blues/R&B      | ★★★★★  | 26    |
| <input checked="" type="checkbox"/> Track 02                           | 2:45 | Billy Price   | Danger Zone          | Blues/R&B      | ★★★★★  | 18    |
| <input checked="" type="checkbox"/> Track 03                           | 3:26 | Billy Price   | Danger Zone          | Blues/R&B      | ★★★★★  | 22    |
| <input checked="" type="checkbox"/> Track 04                           | 4:17 | Billy Price   | Danger Zone          | Blues/R&B      | ★★★★★  | 18    |
| <input checked="" type="checkbox"/> Track 05                           | 3:50 | Billy Price   | Danger Zone          | Blues/R&B      | ★★★★★  | 21    |
| <input checked="" type="checkbox"/> War Pigs/Luke's Wall               | 7:58 | Black Sabbath | Paranoid             | Metal          | ★★★★★  | 25    |
| <input checked="" type="checkbox"/> Paranoid                           | 2:53 | Black Sabbath | Paranoid             | Metal          | ★★★★★  | 22    |
| <input checked="" type="checkbox"/> Planet Caravan                     | 4:35 | Black Sabbath | Paranoid             | Metal          | ★★★★★  | 25    |
| <input checked="" type="checkbox"/> Iron Man                           | 5:59 | Black Sabbath | Paranoid             | Metal          | ★★★★★  | 26    |
| <input checked="" type="checkbox"/> Electric Funeral                   | 4:53 | Black Sabbath | Paranoid             | Metal          | ★★★★★  | 22    |
| <input checked="" type="checkbox"/> Hand of Doom                       | 7:10 | Black Sabbath | Paranoid             | Metal          | ★★★★★  | 23    |
| <input checked="" type="checkbox"/> Rat Salad                          | 2:30 | Black Sabbath | Paranoid             | Metal          | ★★★★★  | 31    |
| <input checked="" type="checkbox"/> Jack the Stripper/Fairies Wear ... | 6:14 | Black Sabbath | Paranoid             | Metal          | ★★★★★  | 24    |
| <input checked="" type="checkbox"/> Bomb Squad (TECH)                  | 3:28 | Brent         | Brent's Album        |                |        | 1     |
| <input checked="" type="checkbox"/> clay techno                        | 4:36 | Brent         | Brent's Album        |                |        | 2     |
| <input checked="" type="checkbox"/> Heavy                              | 3:08 | Brent         | Brent's Album        |                |        | 1     |
| <input checked="" type="checkbox"/> Hi metal man                       | 4:20 | Brent         | Brent's Album        |                |        | 1     |
| <input checked="" type="checkbox"/> Mistro                             | 2:58 | Brent         | Brent's Album        |                |        | 1     |

# For each “piece of info”...

- Is the column an object or an attribute of another object?
  - Once we define objects, we need to define the relationships between objects.
- | Len    | Album   |                      |                |       |    |
|--------|---------|----------------------|----------------|-------|----|
| Genre  |         |                      |                |       |    |
| Artist | Rating  |                      |                |       |    |
| Track  |         |                      |                |       |    |
|        | Count   |                      |                |       |    |
| 5:13   | AC/DC   | Who Made Who         | Rock           | ★★★★★ | 61 |
| 3:54   | AC/DC   | Who Made Who         | Rock           | ★★★★★ | 70 |
| 3:01   | AC/DC   | Who Made Who         | Rock           |       | 56 |
| 5:54   | AC/DC   | Who Made Who         | Rock           | ★★★★★ | 61 |
| 3:43   | Altan   | Natural Wonders M... | New Age        |       | 31 |
| 4:10   | America | Greatest Hits        | Easy Listen... | ★★★★★ | 23 |
| 3:08   | America | Greatest Hits        | Easy Listen... | ★★★★★ | 18 |
| 2:20   | America | Greatest Hits        | Easy Listen... | ★★★★★ | 22 |

|   |      |         |                      |                |       |    |
|---|------|---------|----------------------|----------------|-------|----|
| <input checked="" type="checkbox"/> Hells Bells                     | 5:13 | AC/DC   | Who Made Who         | Rock           | ★★★★★ | 61 |
| <input checked="" type="checkbox"/> Shake Your Foundations          | 3:54 | AC/DC   | Who Made Who         | Rock           | ★★★★★ | 70 |
| <input checked="" type="checkbox"/> Chase the Ace                   | 3:01 | AC/DC   | Who Made Who         | Rock           |       | 56 |
| <input checked="" type="checkbox"/> For Those About To Rock (We ... | 5:54 | AC/DC   | Who Made Who         | Rock           | ★★★★★ | 61 |
| <input checked="" type="checkbox"/> Dúlamán                         | 3:43 | Altan   | Natural Wonders M... | New Age        |       | 31 |
| <input checked="" type="checkbox"/> Rode Across the Desert          | 4:10 | America | Greatest Hits        | Easy Listen... | ★★★★★ | 23 |
| <input checked="" type="checkbox"/> Now You Are Gone                | 3:08 | America | Greatest Hits        | Easy Listen... | ★★★★★ | 18 |
| <input checked="" type="checkbox"/> Tie Me                          | 2:20 | America | Greatest Hits        | Easy Listen... | ★★★★★ | 22 |

Track  
Album  
Artist  
Genre  
Rating  
Len  
Count

Artist

belongs-to

Album

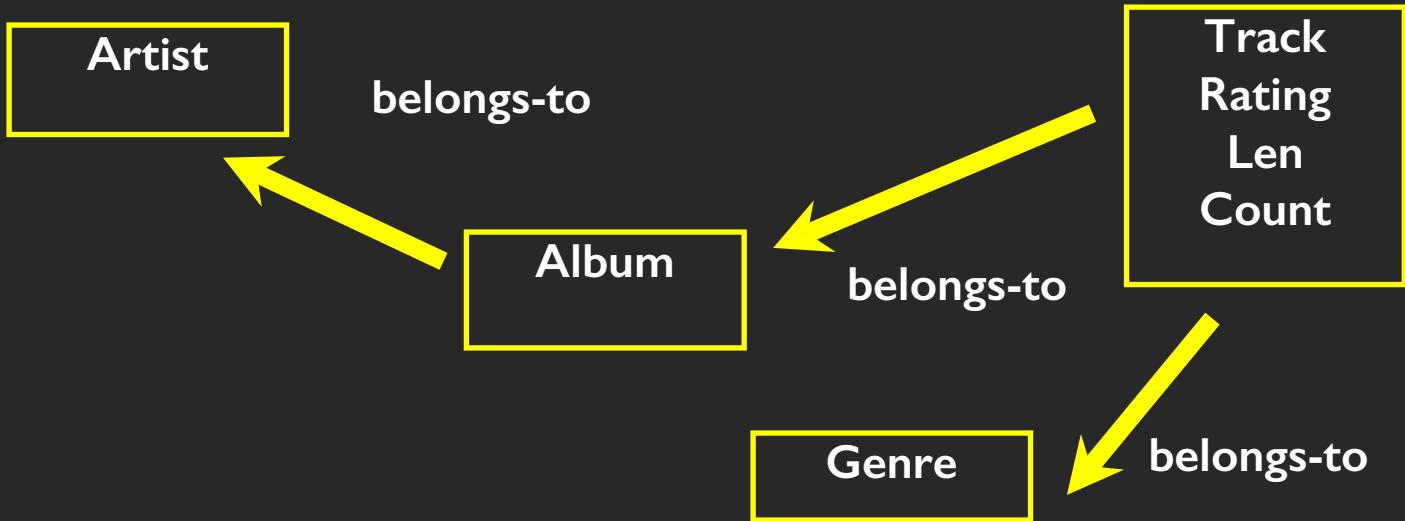
belongs-to

Genre

belongs-to

Track  
Rating  
Len  
Count

|   |      |         |                      |                |       |    |
|---|------|---------|----------------------|----------------|-------|----|
| <input checked="" type="checkbox"/> Hells Bells                     | 5:13 | AC/DC   | Who Made Who         | Rock           | ★★★★★ | 61 |
| <input checked="" type="checkbox"/> Shake Your Foundations          | 3:54 | AC/DC   | Who Made Who         | Rock           | ★★★★★ | 70 |
| <input checked="" type="checkbox"/> Chase the Ace                   | 3:01 | AC/DC   | Who Made Who         | Rock           |       | 56 |
| <input checked="" type="checkbox"/> For Those About To Rock (We ... | 5:54 | AC/DC   | Who Made Who         | Rock           | ★★★★★ | 61 |
| <input checked="" type="checkbox"/> Dúlamán                         | 3:43 | Altan   | Natural Wonders M... | New Age        |       | 31 |
| <input checked="" type="checkbox"/> Rode Across the Desert          | 4:10 | America | Greatest Hits        | Easy Listen... | ★★★★★ | 23 |
| <input checked="" type="checkbox"/> Now You Are Gone                | 3:08 | America | Greatest Hits        | Easy Listen... | ★★★★★ | 18 |
| <input checked="" type="checkbox"/> Tie Man                         | 2:20 | America | Greatest Hits        | Easy Listen... | ★★★★★ | 22 |



|   |      |         |                      |                |       |    |
|---|------|---------|----------------------|----------------|-------|----|
| <input checked="" type="checkbox"/> Hells Bells                     | 5:13 | AC/DC   | Who Made Who         | Rock           | ★★★★★ | 61 |
| <input checked="" type="checkbox"/> Shake Your Foundations          | 3:54 | AC/DC   | Who Made Who         | Rock           | ★★★★★ | 70 |
| <input checked="" type="checkbox"/> Chase the Ace                   | 3:01 | AC/DC   | Who Made Who         | Rock           |       | 56 |
| <input checked="" type="checkbox"/> For Those About To Rock (We ... | 5:54 | AC/DC   | Who Made Who         | Rock           | ★★★★★ | 61 |
| <input checked="" type="checkbox"/> Dúlamán                         | 3:43 | Altan   | Natural Wonders M... | New Age        |       | 31 |
| <input checked="" type="checkbox"/> Rode Across the Desert          | 4:10 | America | Greatest Hits        | Easy Listen... | ★★★★★ | 23 |
| <input checked="" type="checkbox"/> Now You Are Gone                | 3:08 | America | Greatest Hits        | Easy Listen... | ★★★★★ | 18 |
| <input checked="" type="checkbox"/> Tie Man                         | 2:20 | America | Greatest Hits        | Easy Listen... | ★★★★★ | 22 |

# Representing Relationships in a Database

# Database Normalization (3NF)

- There is \*tons\* of database theory - way too much to understand without excessive predicate calculus
  - Do not replicate data - reference data - point at data
  - Use integers for keys and for references
  - Add a special “key” column to each table which we will make references to. By convention, many programmers call this column “id”

[http://en.wikipedia.org/wiki/Database\\_normalization](http://en.wikipedia.org/wiki/Database_normalization)

|   |      |         |                      |                |  |    |
|---|------|---------|----------------------|----------------|--|----|
| <input checked="" type="checkbox"/> Hells Bells                     | 5:13 | AC/DC   | Who Made Who         | Rock           |  | 61 |
| <input checked="" type="checkbox"/> Shake Your Foundations          | 3:54 | AC/DC   | Who Made Who         | Rock           |  | 70 |
| <input checked="" type="checkbox"/> Chase the Ace                   | 3:01 | AC/DC   | Who Made Who         | Rock           |  | 56 |
| <input checked="" type="checkbox"/> For Those About To Rock (We ... | 5:54 | AC/DC   | Who Made Who         | Rock           |  | 61 |
| <input checked="" type="checkbox"/> Dúlamán                         | 3:43 | Altan   | Natural Wonders M... | New Age        |  | 31 |
| <input checked="" type="checkbox"/> Rode Across the Desert          | 4:10 | America | Greatest Hits        | Easy Listen... |  | 23 |
| <input checked="" type="checkbox"/> Now You Are Gone                | 3:08 | America | Greatest Hits        | Easy Listen... |  | 18 |
| <input type="checkbox"/> Tie Me                                     | 3:30 | America | Greatest Hits        | Easy Listen... |  | 22 |

We want to keep track of which band is the “**creator**” of each music track...  
**What album does this song “belong to”??**

**Which album is this song related to?**

# Integer Reference Pattern

We use integers to reference rows in another table

| id     | name        |
|--------|-------------|
| Filter | Filter      |
| 1      | Led Zepplin |
| 2      | AC/DC       |

Artist

| id     | artist_id | title        |
|--------|-----------|--------------|
| Filter | Filter    | Filter       |
| 1      | 2         | Who Made Who |
| 2      | 1         | IV           |

Album

# Key Terminology

Finding our way around....

# Three Kinds of Keys

- **Primary key** - generally an integer auto-increment field
- **Logical key** - What the outside world uses for lookup
- **Foreign key** - generally an integer key pointing to a row in another table



# Primary Key Rules

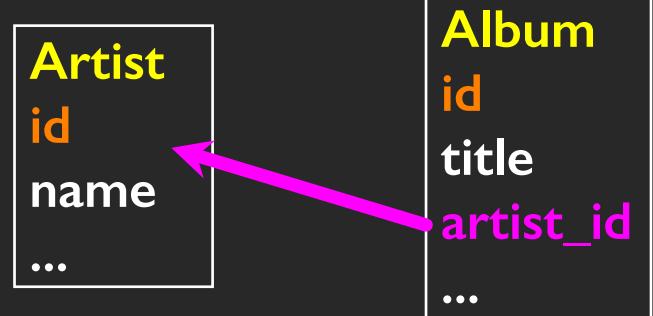
## Best practices

- Never use your **logical key** as the **primary key**
- **Logical keys** can and do change, albeit slowly
- **Relationships** that are based on matching string fields are less efficient than integers

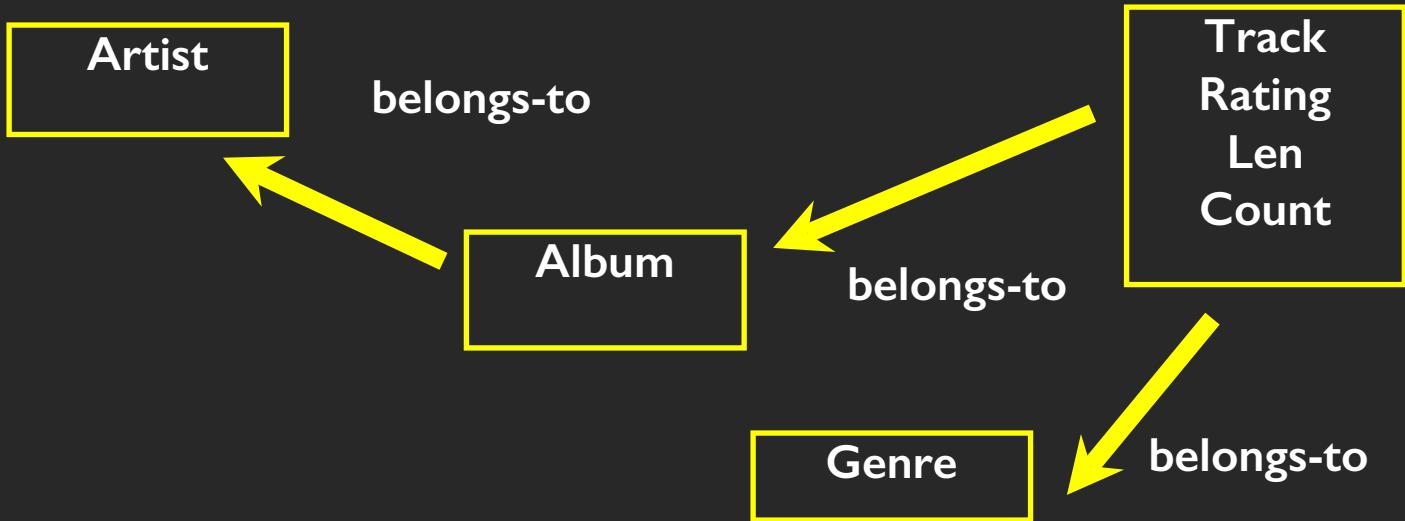
```
User
id
login
password
name
email
created_at
modified_at
login_at
```

# Foreign Keys

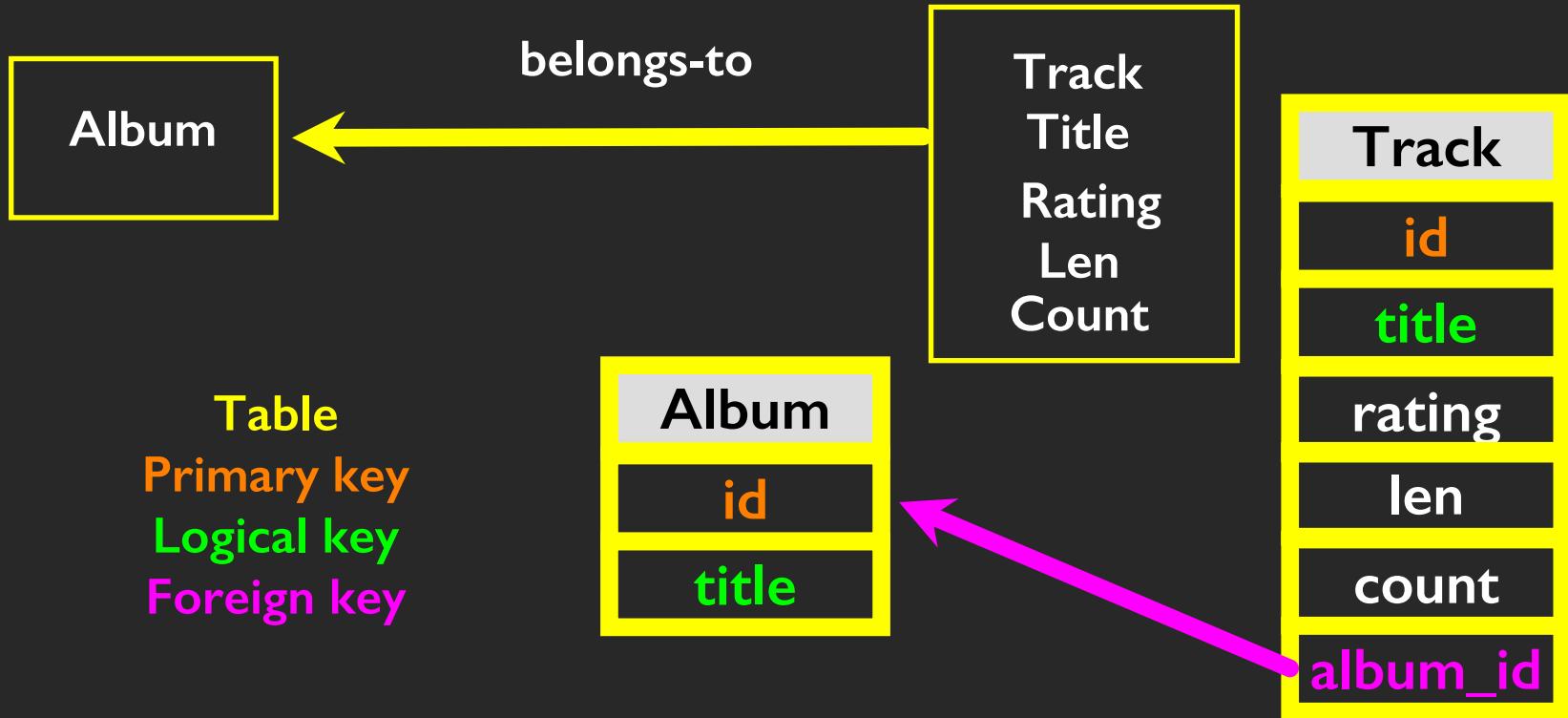
- A **foreign key** is when a table has a column that contains a key which points to the **primary key** of another table.
- When all primary keys are integers, then all foreign keys are integers - this is good - very good



# Relationship Building (in tables)



|   |      |         |                      |                |       |    |
|---|------|---------|----------------------|----------------|-------|----|
| <input checked="" type="checkbox"/> Hells Bells                     | 5:13 | AC/DC   | Who Made Who         | Rock           | ★★★★★ | 61 |
| <input checked="" type="checkbox"/> Shake Your Foundations          | 3:54 | AC/DC   | Who Made Who         | Rock           | ★★★★★ | 70 |
| <input checked="" type="checkbox"/> Chase the Ace                   | 3:01 | AC/DC   | Who Made Who         | Rock           |       | 56 |
| <input checked="" type="checkbox"/> For Those About To Rock (We ... | 5:54 | AC/DC   | Who Made Who         | Rock           | ★★★★★ | 61 |
| <input checked="" type="checkbox"/> Dúlamán                         | 3:43 | Altan   | Natural Wonders M... | New Age        |       | 31 |
| <input checked="" type="checkbox"/> Rode Across the Desert          | 4:10 | America | Greatest Hits        | Easy Listen... | ★★★★★ | 23 |
| <input checked="" type="checkbox"/> Now You Are Gone                | 3:08 | America | Greatest Hits        | Easy Listen... | ★★★★★ | 18 |
| <input checked="" type="checkbox"/> Tie Man                         | 2:20 | America | Greatest Hits        | Easy Listen... | ★★★★★ | 22 |



| Artist |  |
|--------|--|
| id     |  |
| name   |  |

Table

Primary key

Logical key

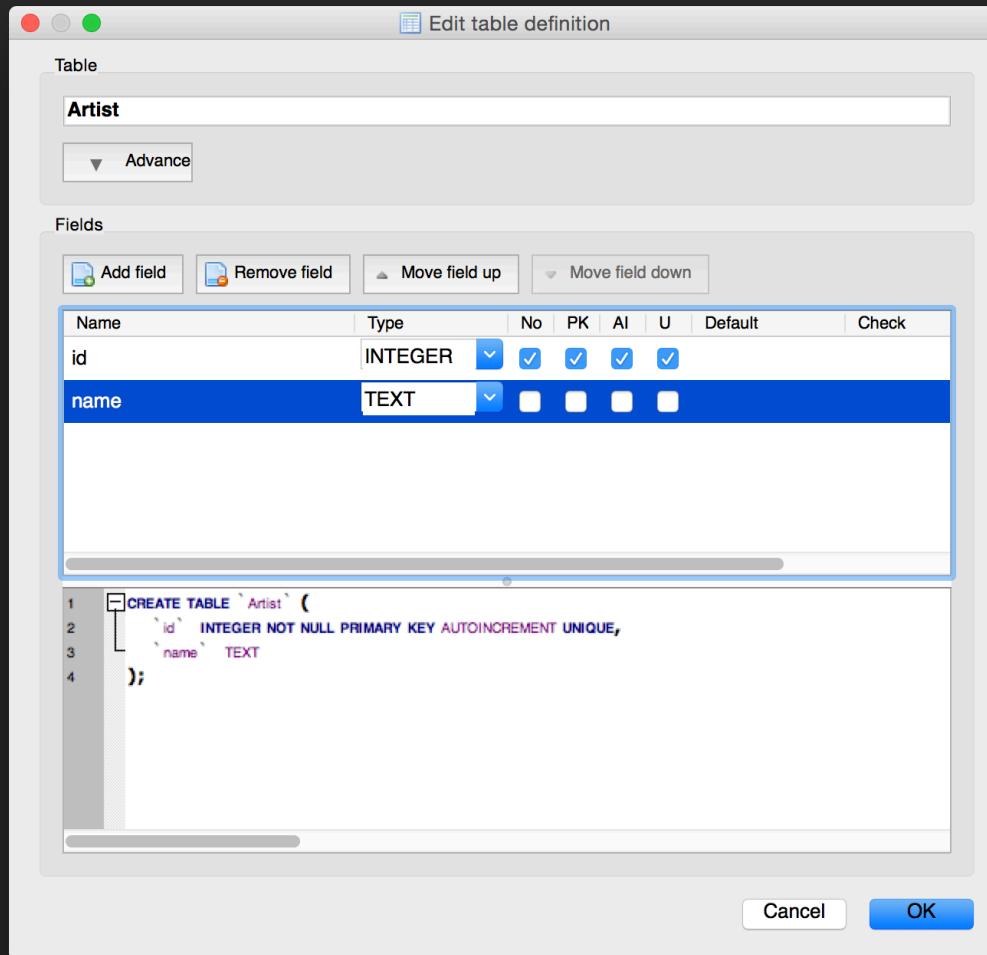
Foreign key

| Album     |  |
|-----------|--|
| id        |  |
| title     |  |
| artist_id |  |

| Genre |  |
|-------|--|
| id    |  |
| name  |  |

| Track    |  |
|----------|--|
| id       |  |
| title    |  |
| rating   |  |
| len      |  |
| count    |  |
| album_id |  |
| genre_id |  |

Naming FK artist\_id is a convention



DB Browser for SQLite - /Users/csev/Desktop/Music

New Database Open Database Write Changes Revert Changes

Database Structure Browse Data Edit Pragmas Execute SQL

SQL 1

```
1 CREATE TABLE Genre (
2     id INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT UNIQUE,
3     name TEXT
4 )
5
```

Query executed successfully: CREATE TABLE Genre (  
id INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT  
UNIQUE,  
name TEXT  
) (took 0ms)

Tables (2)

| Name            | Type | Schema  |
|-----------------|------|---|
| Artist          |      | CREATE TABLE `Artist` (<br>`id` ...<br>`name` TEXT<br>);<br>CREATE TABLE sqlite_sequ... |
| sqlite_sequence |      | CREATE TABLE `sqlite_sequ...  |

Indices (1)  
Triggers (0)

Views (0)

Plot DB Schema UTF-8

The screenshot shows the DB Browser for SQLite interface. On the left, there's a SQL editor window titled 'SQL 1' containing the SQL code for creating a 'Genre' table. The table has an auto-incrementing primary key 'id' and a text field 'name'. A message below the code indicates the query was executed successfully. On the right, the 'DB Schema' tab is active, displaying the database structure. It shows two tables: 'Artist' and 'sqlite\_sequence'. The 'Artist' table has columns 'id' (INTEGER) and 'name' (TEXT). Below the table definition, the schema for 'Artist' is shown as a CREATE TABLE statement. The 'sqlite\_sequence' table is also listed. There are sections for Indices, Triggers, and Views, all of which are currently empty.

```
CREATE TABLE Genre (
    id INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT UNIQUE,
    name TEXT
)
```

```
CREATE TABLE Album (
    id      INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT
UNIQUE,
    artist_id  INTEGER,
    title     TEXT
)
```

```
CREATE TABLE Track (
    id      INTEGER NOT NULL PRIMARY KEY
        AUTOINCREMENT UNIQUE,
```

```
    title TEXT,
    album_id  INTEGER,
    genre_id  INTEGER,
    len INTEGER, rating INTEGER, count INTEGER
)
```

DB Browser for SQLite - /Users/csev/Desktop/Music

Database Structure    Browse Data    Edit Pragmas    Execute SQL

Create Table    Modify Table    Delete Table

| Name       | Type | Schema   |
|------------|------|--|
| Tables (5) |      |  |
| Album      |      | <pre>CREATE TABLE "Album" (     `id` INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT UNIQUE,     `artist_id` INTEGER,     `title` TEXT )</pre>  |
| Artist     |      | <pre>CREATE TABLE `Artist` (     `id` INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT UNIQUE,     `name` TEXT )</pre>   |
| Genre      |      | <pre>CREATE TABLE Genre (     `id` INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT UNIQUE,     `name` TEXT )</pre>  |
| Track      |      | <pre>CREATE TABLE Track (     `id` INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT UNIQUE,     `title` TEXT,     `album_id` INTEGER,     `genre_id` INTEGER,     `len` INTEGER, rating INTEGER, count INTEGER )</pre> |

DB Schema

| Name                     | Schema   |
|--------------------------|--|
| Tables (5)               |  |
| Album                    | <pre>CREATE TABLE "Album" (     `id` INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT UNIQUE,</pre>  |
| Artist                   | <pre>CREATE TABLE `Artist` (     `id` INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT UNIQUE,</pre> |
| Genre                    | <pre>CREATE TABLE Genre (     `id` INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT UNIQUE,</pre>    |
| Track                    | <pre>CREATE TABLE Track (     `id` INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT UNIQUE,</pre>    |
| sqlite_sequence          | <pre>CREATE TABLE sqlite_sequence(name,seq)</pre>  |
| Indices (4)              |  |
| sqlite_autoindex_Album_1 |  |
| sqlite_autoindex_Track_1 |  |
| sqlite_autoindex_Track_2 |  |

Plot    DB Schema

UTF-8

DB Browser for SQLite - /Users/csev/Desktop/Music

New Database Open Database Write Changes Revert Changes

Database Structure Browse Data Edit Pragmas Execute SQL

SQL 1

```
1 insert into Artist (name) values ('AC/DC')
2
```

Query executed successfully: insert into Artist (name) values ('AC/DC') (took 0ms)

DB Schema

Name Schema

Tables (5)

- Album CREATE TABLE Album (  
  id INTEGER NOT NULL P...
- Artist CREATE TABLE `Artist` (  
  `id` INTEGER NOT NULL P...
  - id INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT
  - name TEXT
- Genre CREATE TABLE Genre (  
  id INTEGER NOT NULL P...
- Track CREATE TABLE Track (  
  id INTEGER NOT NULL P...

sqlite\_sequence CREATE TABLE sqlite\_sequence(name,seq)

Indices (4)

- sqlite\_auto...
- sqlite\_auto...
- sqlite\_auto...
- sqlite\_auto...

Views (0)

Triggers (0)

Plot DB Schema

UTF-8

The screenshot shows the DB Browser for SQLite interface. On the left, there's a SQL editor window with a query to insert 'AC/DC' into the 'Artist' table. Below it, a message indicates the query was executed successfully. On the right, the 'DB Schema' tab is selected, displaying the database structure with five tables: Album, Artist, Genre, Track, and sqlite\_sequence. The Artist table is expanded to show its columns: id (INTEGER PRIMARY KEY AUTOINCREMENT) and name (TEXT). The status bar at the bottom right shows 'UTF-8'.

insert into Artist (name) values ('Led Zepplin')  
insert into Artist (name) values ('AC/DC')

DB Browser for SQLite - /Users/csev/Desktop/Music

New Database Open Database Write Changes

Database Structure Browse Data Edit Pragmas

SQL 1

1 insert into Artist (name) values ('AC/DC')  
2

Query executed successfully: insert into Artist (name) values ('AC/DC') (took 0ms)

DB Browser for SQLite - /Users/csev/Desktop/Music

New Database Open Database Write Changes Revert Changes

Database Structure Browse Data Edit Pragmas Execute SQL

Table: Artist New Record Delete Record

|   | id | name         |
|---|----|--------------|
| 1 | 1  | Led Zeppelin |
| 2 | 2  | AC/DC        |

DB Schema

Name Schema

Tables (5)

- Album CREATE TABLE Album (id INTEGER NOT NULL PRI...)
- Artist CREATE TABLE `Artist` (id INTEGER NOT NULL PRI...)
- Genre CREATE TABLE Genre (id INTEGER NOT NULL PRI...)
- Track CREATE TABLE Track (id INTEGER NOT NULL PRI...)
- sqlite\_sequence CREATE TABLE sqlite\_sequence(name,seq)

Indices (4)

- sqlite\_autoindex\_1
- sqlite\_autoindex\_2
- sqlite\_autoindex\_3
- sqlite\_autoindex\_4

Views (0)

Triggers (0)

Plot DB Schema

UTF-8

insert into Artist (name) values ('Led Zeppelin')  
insert into Artist (name) values ('AC/DC')

DB Browser for SQLite - /Users/csev/Desktop/Music

New Database Open Database Write Changes Revert Changes

Database Structure Browse Data Edit Pragmas Execute SQL

Table: Genre New Record Delete Record

|   | id | name  |
|---|----|-------|
| 1 | 1  | Rock  |
| 2 | 2  | Metal |

Filter Filter

1 < 1 - 2 of 2 > > Go to: 1

DB Schema

Name Schema

Tables (5)

- Album CREATE TABLE Album (id INTEGER NOT NULL PRIMARY KEY, name TEXT)
- Artist CREATE TABLE `Artist` (`id` INTEGER NOT NULL PRIMARY KEY, `name` TEXT)
- Genre CREATE TABLE Genre (id INTEGER NOT NULL PRIMARY KEY, name TEXT)
- Track CREATE TABLE Track (id INTEGER NOT NULL PRIMARY KEY, name TEXT)
- sqlite\_sequence CREATE TABLE sqlite\_sequence(name,seq)

Indices (4)

- sqlite\_autoindex\_Album\_1
- sqlite\_autoindex\_Artist\_1
- sqlite\_autoindex\_Genre\_1
- sqlite\_autoindex\_Track\_1

Views (0)

Triggers (0)

Plot DB Schema

UTF-8

insert into Genre (name) values ('Rock')  
insert into Genre (name) values ('Metal')

DB Browser for SQLite - /Users/csev/Desktop/Music

New Database Open Database Write Changes Revert Changes

Database Structure Browse Data Edit Pragmas Execute SQL

Table: Album New Record Delete Record

|   | <b>id</b> | <b>artist_id</b> | <b>title</b> |
|---|-----------|------------------|--------------|
| 1 | 1         | 2                | Who Made Who |
| 2 | 2         | 1                | IV           |

< < 1 - 2 of 2 > >

Go to: 1

UTF-8

```
insert into Album (title, artist_id) values ('Who Made Who', 2)
insert into Album (title, artist_id) values ('IV', 1)
```

```
insert into Track (title, rating, len, count, album_id, genre_id)
    values ('Black Dog', 5, 297, 0, 2, 1)
```

```
insert into Track (title, rating, len, count, album_id, genre_id)
    values ('Stairway', 5, 482, 0, 2, 1)
```

```
insert into Track (title, rating, len, count, album_id, genre_id)
    values ('About to Rock', 5, 313, 0, 1, 2)
```

```
insert into Track (title, rating, len, count, album_id, genre_id)
    values ('Who Made Who', 5, 207, 0, 1, 2)
```

| id |        | title         | album_id | genre_id | len    | rating | count  |
|----|--------|---------------|----------|----------|--------|--------|--------|
|    | Filter | Filter        | Filter   | Filter   | Filter | Filter | Filter |
| 1  | 1      | Black Dog     | 2        | 1        | 297    | 5      | 0      |
| 2  | 2      | Stairway      | 2        | 1        | 482    | 5      | 0      |
| 3  | 3      | About to Rock | 1        | 2        | 313    | 5      | 0      |
| 4  | 4      | Who Made Who  | 1        | 2        | 207    | 5      | 0      |

# We have relationships!

| id     | title         | album_id | genre_id | len    | rating | count  |
|--------|---------------|----------|----------|--------|--------|--------|
| Filter | Filter        | Filter   | Filter   | Filter | Filter | Filter |
| 1      | Black Dog     | 2        | 1        | 297    | 5      | 0      |
| 2      | Stairway      | 2        | 1        | 482    | 5      | 0      |
| 3      | About to Rock | 1        | 2        | 313    | 5      | 0      |
| 4      | Who Made Who  | 1        | 2        | 207    | 5      | 0      |

Track

Album

| id     | artist_id | title        |
|--------|-----------|--------------|
| Filter | Filter    | Filter       |
| 1      | 2         | Who Made Who |
| 2      | 1         | IV           |

Artist

| id     | name         |
|--------|--------------|
| Filter | Filter       |
| 1      | Led Zeppelin |
| 2      | AC/DC        |

| id     | name   |
|--------|--------|
| Filter | Filter |
| 1      | Rock   |
| 2      | Metal  |

Genre

# Using Join Across Tables

[http://en.wikipedia.org/wiki/Join\\_\(SQL\)](http://en.wikipedia.org/wiki/Join_(SQL))

# Relational Power

- By removing the replicated data and replacing it with references to a single copy of each bit of data we build a “**web**” of information that the relational database can read through very quickly - even for very large amounts of data
- Often when you want some data it comes from a number of tables linked by these **foreign keys**

# The JOIN Operation

- The JOIN operation **links across several tables** as part of a select operation
- You must tell the JOIN **how to use the keys** that make the connection between the tables using an **ON clause**

The diagram illustrates a database query execution. It shows three tables:

- Album** table (top): Contains columns `id`, `artist_id`, and `title`. Data rows: (1, 2, "Who Made Who") and (2, 1, "IV").
- Artist** table (middle): Contains columns `id` and `name`. Data rows: (1, "AC/DC") and (2, "Led Zepplin").
- Result Table** (bottom): Contains columns `title` and `name`. Data rows: (1, "Who Made Who") and (2, "IV").

A pink arrow points from the `Artist` table to the `Artist` column in the Result Table. Two yellow arrows point from the `Album` and `Artist` tables to their respective columns in the Result Table.

select `Album.title, Artist.name` from `Album` join `Artist` on `Album.artist_id = Artist.id`

What we want  
to see

The tables that  
hold the data

How the tables  
are linked

The diagram illustrates a database join operation across three tables:

- Album Table:** Contains columns `id`, `artist_id`, and `title`. It has two rows:
  - Row 1: `id` = 1, `artist_id` = 2, `title` = "Who Made Who"
  - Row 2: `id` = 2, `artist_id` = 1, `title` = "IV"
- Artist Table:** Contains columns `id` and `name`. It has two rows:
  - Row 1: `id` = 1, `name` = "Led Zepplin"
  - Row 2: `id` = 2, `name` = "AC/DC"
- Resulting Table:** Contains columns `title`, `artist_id`, `id`, and `name`. It has two rows:
  - Row 1: `title` = "Who Made Who", `artist_id` = 2, `id` = 2, `name` = "AC/DC"
  - Row 2: `title` = "IV", `artist_id` = 1, `id` = 1, `name` = "Led Zepplin"

```
select Album.title, Album.artist_id, Artist.id, Artist.name
from Album join Artist on Album.artist_id = Artist.id
```

|    | title         | name  |
|----|---------------|-------|
| id |               |       |
| 1  | Black Dog     | Rock  |
| 2  | Stairway      | Rock  |
| 3  | About to Rock | Metal |
| 4  | Who Made Who  | Metal |

| id     | title         | album_id | genre_id | len    | rating | count  |
|--------|---------------|----------|----------|--------|--------|--------|
| Filter | Filter        | Filter   | Filter   | Filter | Filter | Filter |
| 1      | Black Dog     | 2        | 1        | 297    | 5      | 0      |
| 2      | Stairway      | 2        | 1        | 482    | 5      | 0      |
| 3      | About to Rock | 1        | 2        | 313    | 5      | 0      |
| 4      | Who Made Who  | 1        | 2        | 207    | 5      | 0      |

| id     | name   |
|--------|--------|
| Filter | Filter |
| 1      | Rock   |
| 2      | Metal  |

select Track.title, Genre.name from Track join Genre on Track.genre\_id = Genre.id

What we want  
to see

The tables that  
hold the data

How the tables  
are linked

|   | title         | genre_id | id | name  |
|---|---------------|----------|----|-------|
| 1 | Black Dog     | 1        | 1  | Rock  |
| 2 | Black Dog     | 1        | 2  | Metal |
| 3 | Stairway      | 1        | 1  | Rock  |
| 4 | Stairway      | 1        | 2  | Metal |
| 5 | About to Rock | 2        | 1  | Rock  |
| 6 | About to Rock | 2        | 2  | Metal |
| 7 | Who Made Who  | 2        | 1  | Rock  |
| 8 | Who Made Who  | 2        | 2  | Metal |

```
SELECT Track.title,  
Track.genre_id,  
Genre.id, Genre.name  
FROM Track JOIN Genre
```

Joining two tables without an **ON** clause gives all possible combinations of rows.

# It can get complex...

```
select Track.title, Artist.name, Album.title, Genre.name from  
Track join Genre join Album join Artist on Track.genre_id =  
Genre.id and Track.album_id = Album.id and Album.artist_id =  
Artist.id
```

|   | title         | name        | title        | name  |
|---|---------------|-------------|--------------|-------|
| 1 | Black Dog     | Led Zepplin | IV           | Rock  |
| 2 | Stairway      | Led Zepplin | IV           | Rock  |
| 3 | About to Rock | AC/DC       | Who Made Who | Metal |
| 4 | Who Made Who  | AC/DC       | Who Made Who | Metal |

What we want  
to see

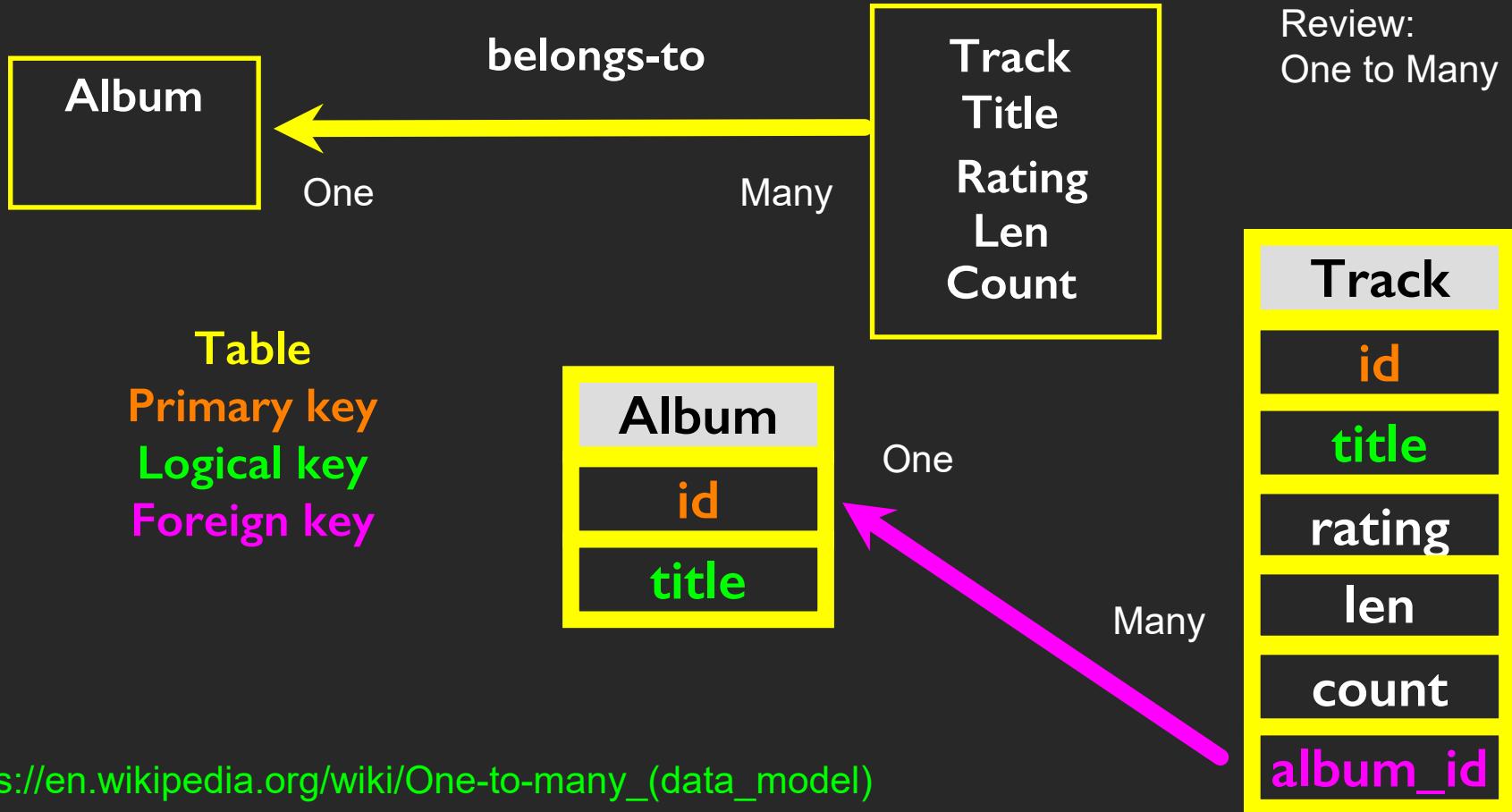
The tables which  
hold the data

How the tables  
are linked

|   |      |             |                      |                |       |    |
|---|------|-------------|----------------------|----------------|-------|----|
| <input checked="" type="checkbox"/> Hells Bells                       | 5:13 | AC/DC       | Who Made Who         | Rock           | ★★★★★ | 61 |
| <input checked="" type="checkbox"/> Shake Your Foundations            | 3:54 | AC/DC       | Who Made Who         | Rock           | ★★★★★ | 70 |
| <input checked="" type="checkbox"/> Chase the Ace                     | 3:01 | AC/DC       | Who Made Who         | Rock           |       | 56 |
| <input checked="" type="checkbox"/> For Those About To Rock (We ...   | 5:54 | AC/DC       | Who Made Who         | Rock           | ★★★★★ | 61 |
| <input checked="" type="checkbox"/> Dúlamán                           | 3:43 | Altan       | Natural Wonders M... | New Age        |       | 31 |
| <input checked="" type="checkbox"/> Rode Across the Desert            | 4:10 | America     | Greatest Hits        | Easy Listen... | ★★★★★ | 23 |
| <input checked="" type="checkbox"/> Now You Are Gone                  | 3:08 | America     | Greatest Hits        | Easy Listen... | ★★★★★ | 18 |
| <input checked="" type="checkbox"/> Tin Man                           | 3:30 | America     | Greatest Hits        | Easy Listen... | ★★★★★ | 23 |
| <input checked="" type="checkbox"/> Sister Golden Hair                | 3:22 | America     | Greatest Hits        | Easy Listen... | ★★★★★ | 24 |
| <input checked="" type="checkbox"/> Track 01                          | 4:22 | Billy Price | Danger Zone          | Blues/R&B      | ★★★★★ | 26 |
| <input checked="" type="checkbox"/> Track 02                          | 2:45 | Billy Price | Danger Zone          | Blues/R&B      | ★★★★★ | 18 |
| <input checked="" type="checkbox"/> Track 03                          | 3:26 | Billy Price | Danger Zone          | Blues/R&B      | ★★★★★ | 22 |
| <input checked="" type="checkbox"/> Track 04                          |      |             |                      |                |       | 18 |
| <input checked="" type="checkbox"/> Track 05                          |      |             |                      |                |       | 21 |
| <input checked="" type="checkbox"/> War Pigs/Luke's Wall              |      |             |                      |                |       | 25 |
| <input checked="" type="checkbox"/> Paranoid                          |      |             |                      |                |       | 22 |
| <input checked="" type="checkbox"/> Planet Caravan                    |      |             |                      |                |       | 25 |
| <input checked="" type="checkbox"/> Iron Man                          |      |             |                      |                |       | 26 |
| <input checked="" type="checkbox"/> Electric Funeral                  |      |             |                      |                |       | 22 |
| <input checked="" type="checkbox"/> Hand of Doom                      |      |             |                      |                |       | 23 |
| <input checked="" type="checkbox"/> Rat Salad                         |      |             |                      |                |       | 31 |
| <input checked="" type="checkbox"/> Jack the Stripper/Fairies Wear .. |      |             |                      |                |       | 24 |
| <input checked="" type="checkbox"/> Bomb Squad (TECH)                 |      |             |                      |                |       | 1  |
| <input checked="" type="checkbox"/> clay techno                       |      |             |                      |                |       | 2  |
| <input checked="" type="checkbox"/> Heavy                             |      |             |                      |                |       | 1  |
| <input checked="" type="checkbox"/> Hi metal man                      | 4:20 | Brent       | Brent's Album        |                |       | 1  |
| <input checked="" type="checkbox"/> Mistro                            | 2:58 | Brent       | Brent's Album        |                |       | 1  |

# Many-To-Many Relationships

[https://en.wikipedia.org/wiki/Many-to-many\\_\(data\\_model\)](https://en.wikipedia.org/wiki/Many-to-many_(data_model))





One

One

Many

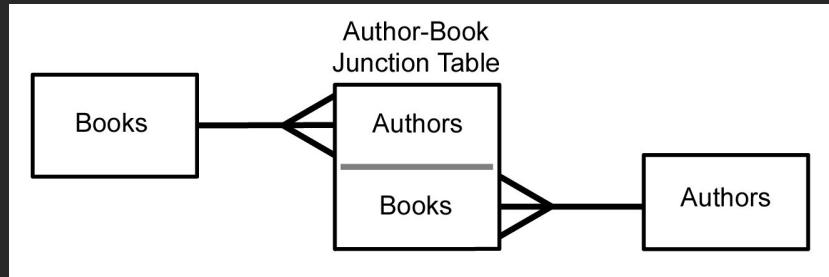
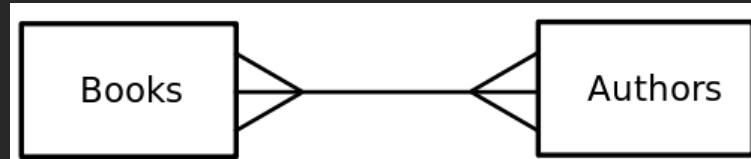
# Many

|   | id     | name   |
|---|--------|--------|
|   | Filter | Filter |
| 1 |        | Rock   |
| 2 |        | Metal  |

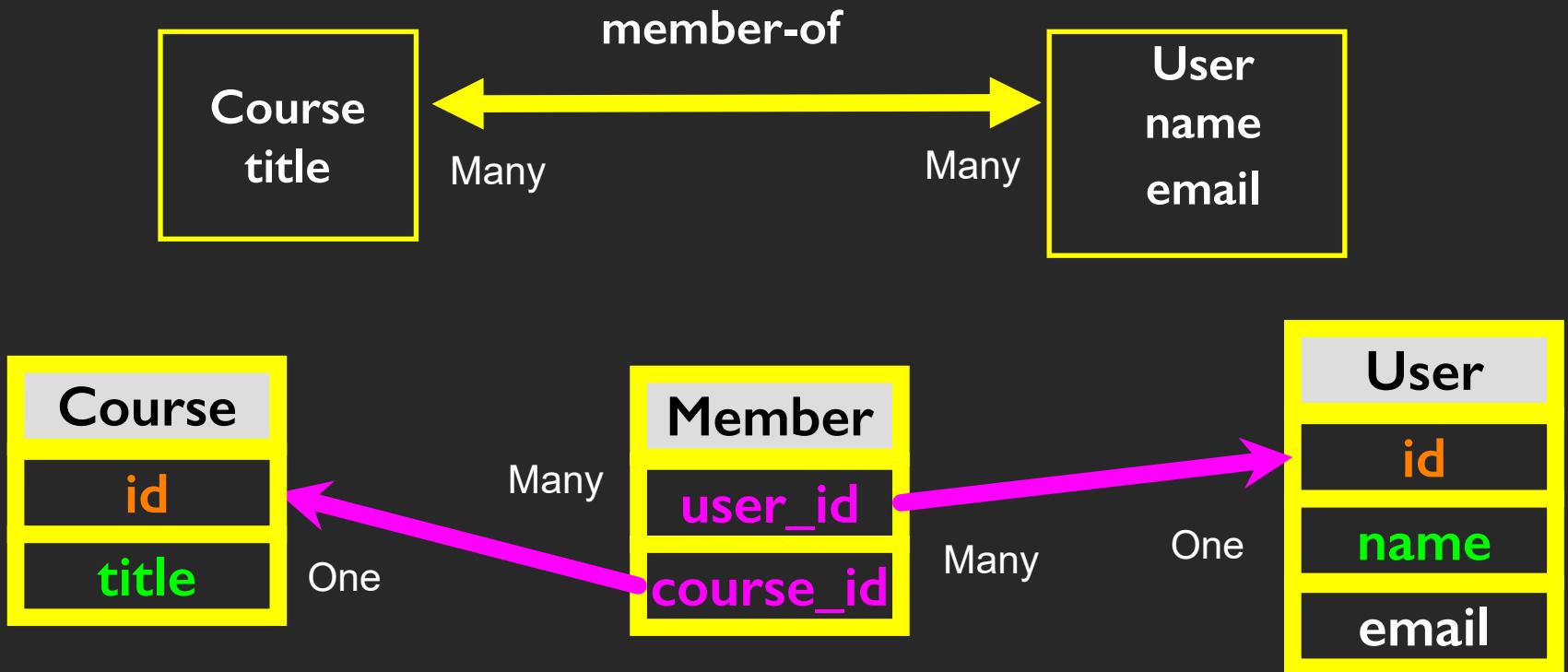
| <a href="#">id</a> | <a href="#">title</a> | <a href="#">album_id</a> | <a href="#">genre_id</a> | <a href="#">len</a> | <a href="#">rating</a> | <a href="#">count</a> |
|--------------------|-----------------------|--------------------------|--------------------------|---------------------|------------------------|-----------------------|
| Filter             | Filter                | Filter                   | Filter                   | Filter              | Filter                 | Filter                |
| 1                  | Black Dog             | 2                        | 1                        | 297                 | 5                      | 0                     |
| 2                  | Stairway              | 2                        | 1                        | 482                 | 5                      | 0                     |
| 3                  | About to Rock         | 1                        | 2                        | 313                 | 5                      | 0                     |
| 4                  | Who Made Who          | 1                        | 2                        | 207                 | 5                      | 0                     |

# Many to Many

- Sometimes we need to model a relationship that is many-to-many
- We need to add a "connection" table with two foreign keys
- There is usually no separate primary key



[https://en.wikipedia.org/wiki/Many-to-many\\_\(data\\_model\)](https://en.wikipedia.org/wiki/Many-to-many_(data_model))



# Start with a Fresh Database

```
CREATE TABLE User (
    id      INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT UNIQUE,
    name    TEXT,
    email   TEXT
)
```

```
CREATE TABLE Course (
    id      INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT UNIQUE,
    title   TEXT
)
```

```
CREATE TABLE Member (
    user_id     INTEGER,
    course_id   INTEGER,
    role        INTEGER,
    PRIMARY KEY (user_id, course_id)
)
```

DB Browser for SQLite - /Users/csev/Desktop/si502\_database

New Database Open Database Write Changes Revert Changes

Database Structure Browse Data Edit Pragmas Execute SQL

Create Table Modify Table Delete Table

| Name                      | Type | Schema  |
|---------------------------|------|---|
| Tables (4)                |      |   |
| Course                    |      | CREATE TABLE Course (<br>id INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT UNIQUE,<br>title TEXT<br>)             |
| Member                    |      | CREATE TABLE Member (<br>user_id INTEGER,<br>course_id INTEGER,<br>PRIMARY KEY (user_id, course_id)<br>)      |
| User                      |      | CREATE TABLE User (<br>id INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT UNIQUE,<br>name TEXT,<br>email TEXT<br>) |
| sqlite_sequence           |      | CREATE TABLE sqlite_sequence(name,seq)  |
| Indices (3)               |      |   |
| sqlite_autoindex_Course_1 |      |   |
| sqlite_autoindex_Member_1 |      |   |
| sqlite_autoindex_User_1   |      |   |
| Views (0)                 |      |   |
| Triggers (0)              |      |   |

UTF-8

# Insert Users and Courses

```
INSERT INTO User (name, email) VALUES ('Jane', 'jane@tsugi.org');  
INSERT INTO User (name, email) VALUES ('Ed', 'ed@tsugi.org');  
INSERT INTO User (name, email) VALUES ('Sue', 'sue@tsugi.org');  
  
INSERT INTO Course (title) VALUES ('Python');  
INSERT INTO Course (title) VALUES ('SQL');  
INSERT INTO Course (title) VALUES ('PHP');
```

DB Browser for SQLite - /Users/csev/Desktop/si502\_database

New Database Open Database Write Changes Revert Changes

Database

Table: Course

|   | id | title  |
|---|----|--------|
| 1 | 1  | Python |
| 2 | 2  | SQL    |
| 3 | 3  | PHP    |

< < 1 - 3 of 3 > >|

New Database Open Database Write Changes Revert Changes

Database Structure Browse Data Edit Pragmas Execute SQL

Table: User

|   | id | name | email          |
|---|----|------|----------------|
| 1 | 1  | Jane | jane@tsugi.org |
| 2 | 2  | Ed   | ed@tsugi.org   |
| 3 | 3  | Sue  | sue@tsugi.org  |

New Record Delete Record

< < 1 - 3 of 3 > >| Go to: 1

UTF-8

# Insert Memberships

| <a href="#">id</a> | <a href="#">name</a> | <a href="#">email</a> |
|--------------------|----------------------|-----------------------|
| Filter             | Filter               | Filter                |
| 1                  | Jane                 | jane@tsugi.org        |
| 2                  | Ed                   | ed@tsugi.org          |
| 3                  | Sue                  | sue@tsugi.org         |

| <a href="#">id</a> | <a href="#">title</a> |
|--------------------|-----------------------|
| Filter             | Filter                |
| 1                  | Python                |
| 2                  | SQL                   |
| 3                  | PHP                   |

```
INSERT INTO Member (user_id, course_id, role) VALUES (1, 1, 1);
INSERT INTO Member (user_id, course_id, role) VALUES (2, 1, 0);
INSERT INTO Member (user_id, course_id, role) VALUES (3, 1, 0);

INSERT INTO Member (user_id, course_id, role) VALUES (1, 2, 0);
INSERT INTO Member (user_id, course_id, role) VALUES (2, 2, 1);

INSERT INTO Member (user_id, course_id, role) VALUES (2, 3, 1);
INSERT INTO Member (user_id, course_id, role) VALUES (3, 3, 0);
```

DB Browser for SQLite - /Users/csev/Desktop/si502\_database

New Database Open Database Write Changes Revert Changes

Database Structure Browse Data Edit Pragmas Execute SQL

Table: Member New Record Delete Record

|   | user_id | course_id | role |
|---|---------|-----------|------|
| 1 | 1       | 1         | 1    |
| 2 | 2       | 1         | 0    |
| 3 | 3       | 1         | 0    |
| 4 | 1       | 2         | 0    |
| 5 | 2       | 2         | 1    |
| 6 | 2       | 3         | 1    |
| 7 | 3       | 3         | 0    |

< < 1 - 7 of 7 > >| Go to: 1 UTF-8

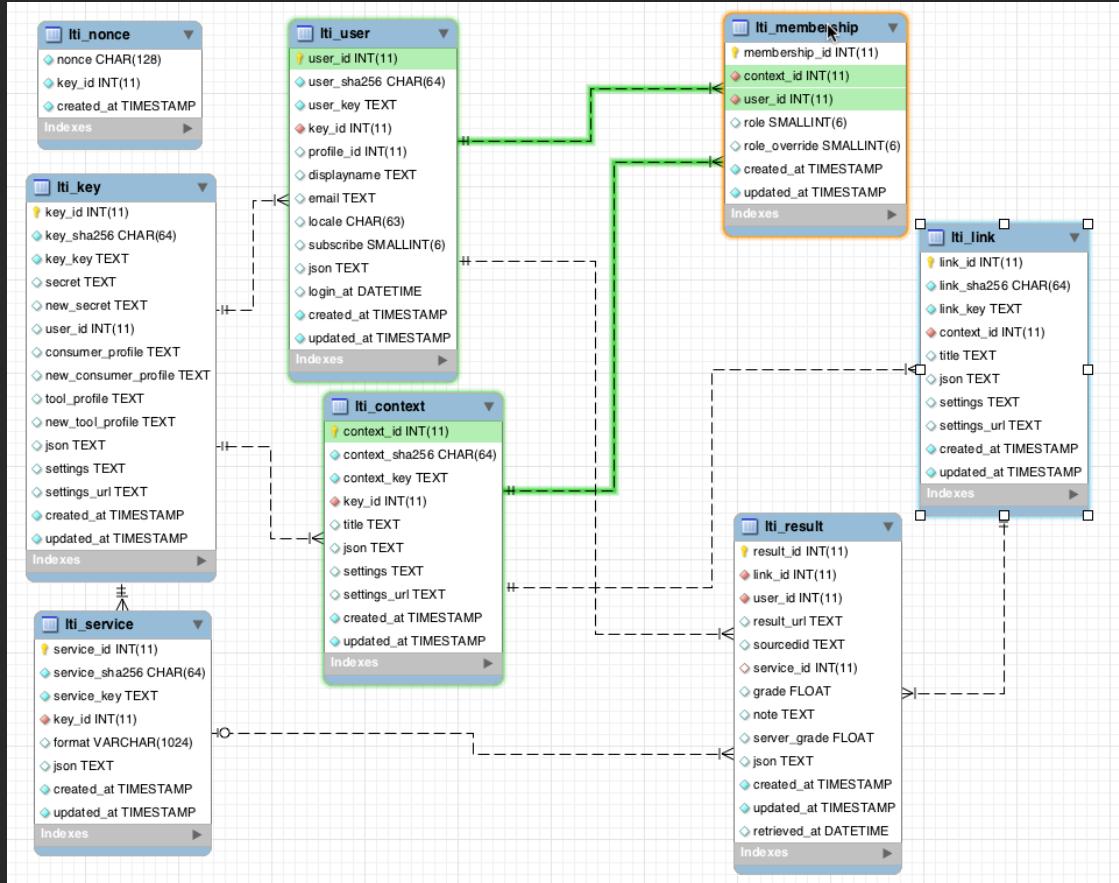
| <b>id</b> | <b>name</b> | <b>email</b>   |
|-----------|-------------|----------------|
| Filter    | Filter      | Filter         |
| 1         | Jane        | jane@tsugi.org |
| 2         | Ed          | ed@tsugi.org   |
| 3         | Sue         | sue@tsugi.org  |

| <b>user_id</b> | <b>course_id</b> | <b>role</b> |
|----------------|------------------|-------------|
| Filter         | Filter           | Filter      |
| 1              | 1                | 1           |
| 2              | 1                | 0           |
| 3              | 1                | 0           |
| 1              | 2                | 0           |
| 2              | 2                | 1           |
| 2              | 3                | 1           |
| 3              | 3                | 0           |

| <b>id</b> | <b>title</b> |
|-----------|--------------|
| Filter    | Filter       |
| 1         | Python       |
| 2         | SQL          |
| 3         | PHP          |

| <b>name</b> | <b>role</b> | <b>title</b> |
|-------------|-------------|--------------|
| 2 Sue       | 0           | PHP          |
| 3 Jane      | 1           | Python       |
| 4 Ed        | 0           | Python       |
| 5 Sue       | 0           | Python       |
| 6 Ed        | 1           | SQL          |

```
SELECT User.name, Member.role, Course.title  
FROM User JOIN Member JOIN Course  
ON Member.user_id = User.id AND Member.course_id = Course.id  
ORDER BY Course.title, Member.role DESC, User.name
```



# Complexity Enables Speed

- Complexity makes speed possible and allows you to get very fast results as the data size grows
- By normalizing the data and linking it with integer keys, the overall amount of data which the relational database must *scan* is far lower than if the data were simply flattened out
- It might seem like a tradeoff - spend some time designing your database so it continues to be fast when your application is a success

# Additional SQL Topics

- **Indexes** improve access performance for things like string fields
- **Constraints** on data - (cannot be NULL, etc..)
- **Transactions** - allow SQL operations to be grouped and done as a unit

# Summary

- Relational databases allow us to **scale** to very large amounts of data
- The key is to have **one copy of any data** element and use relations and joins to link the data to multiple places
- This greatly **reduces the amount of data which must be scanned** when doing complex operations across large amounts of data
- Database and SQL design is a bit of an **art form**



## Acknowledgements / Contributions



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Initial Development: Charles Severance, University of Michigan School of Information

... Insert new Contributors here