

Relational Databases and SQLite

Charles Severance



Python for Informatics: Exploring
Information

www.pythonlearn.com



SQLite Browser

DB Browser
for SQLite

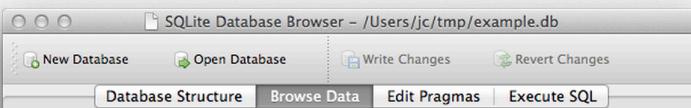
The Official home of the DB Browser for
SQLite

[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



Download 32-bit
Windows .exe

Download 64-bit
Windows .exe

Download
PortableApp

<http://sqlitebrowser.org/>

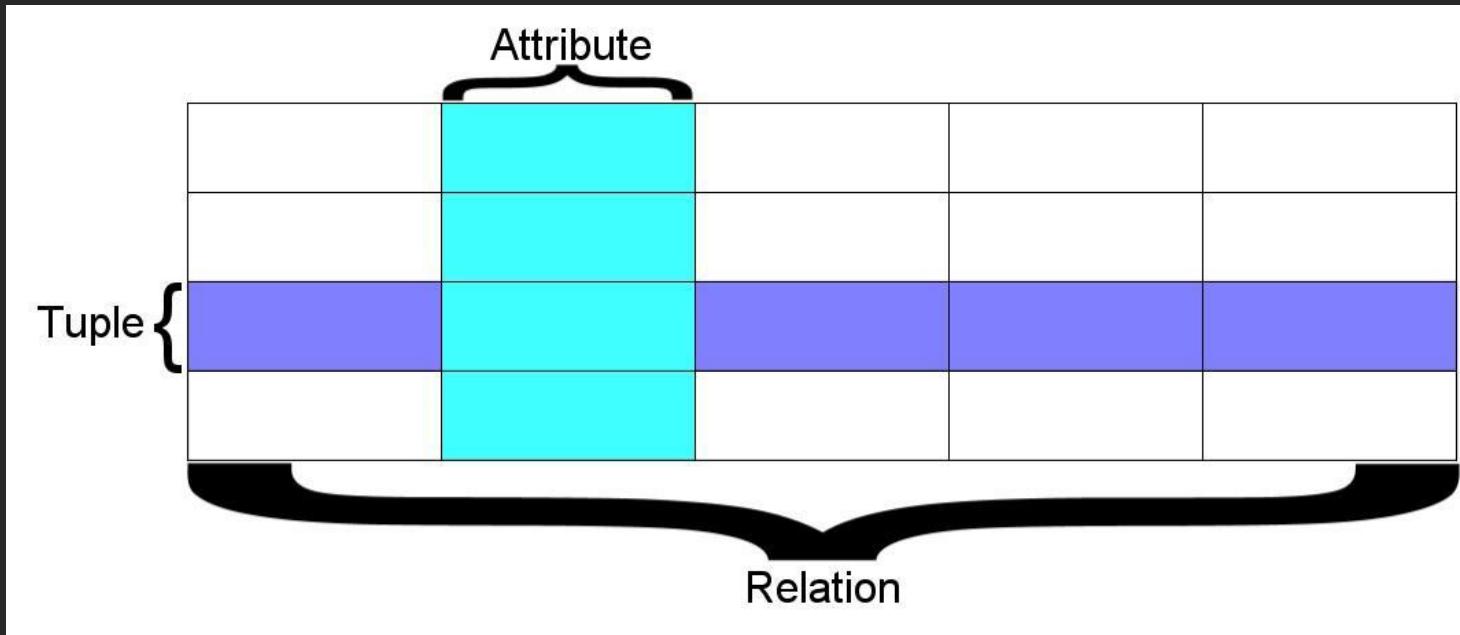
Relational Databases

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

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)

The image shows a screenshot of Microsoft Excel with a title bar "SI502 - Database". The menu bar includes "New", "Open", "Save", "Print", "Import", "Copy", "Paste", "Format", "Undo", "Redo", "AutoSum", "Sort A-Z", "Sort Z-A", "Gallery", and "Toolbox". Below the menu is a ribbon with tabs "Sheets", "Charts", "SmartArt Graphics", and "WordArt". The worksheet area has columns labeled A, B, C, D and rows labeled 1, 2, 3, 4, 5, 6, 7, 8. A vertical column header on the left lists "Tracks", "Albums", "Artists", and "Genres". A blue box highlights the first four rows of data:

	TITLE	RATING	LEN
1	About to Rock	3	354
2	Who Made Who	4	252
3			
4			
5			
6			
7			
8			

Blue text annotations are overlaid on the image:

- "Columns / Attributes" is positioned above the first four rows.
- "Rows / Tuples" is positioned to the right of the fourth row.
- "Tables / Relations" is positioned below the fourth row.

SQL

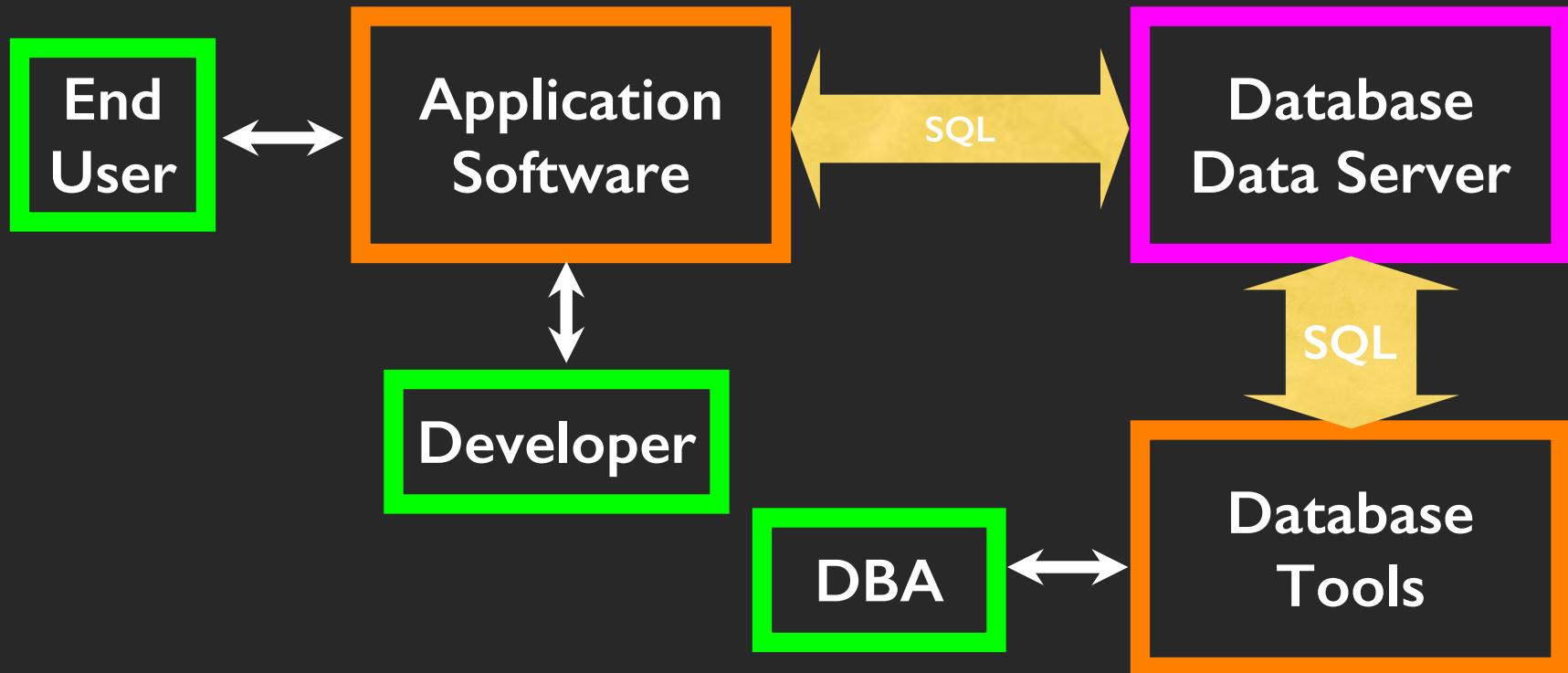
- **Structured Query Language** is the language we use to issue commands to the database
 - Create a table
 - Retrieve some data
 - Insert data
 - Delete data

<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

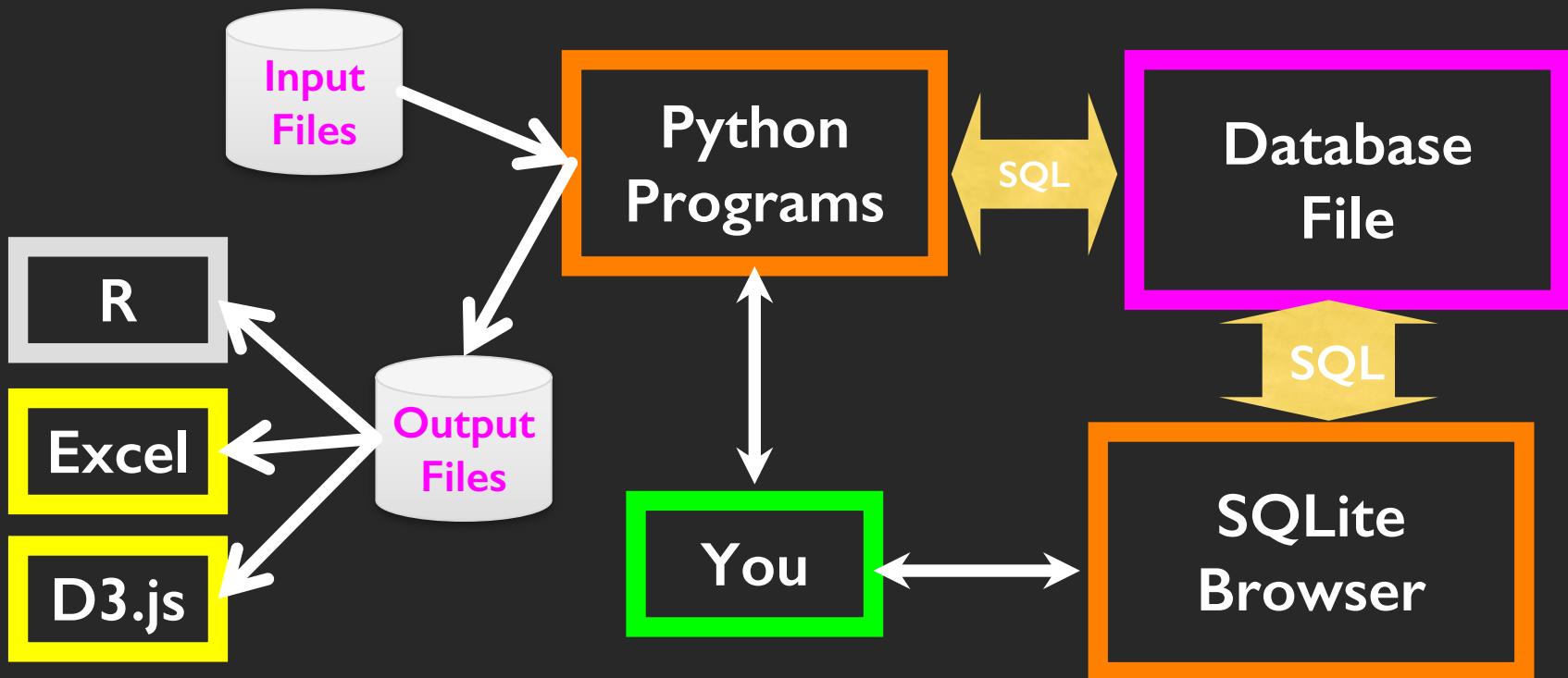


Database Administrator (dba)

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

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



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...



TOSHIBA



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



Writing SQL – Making a Database

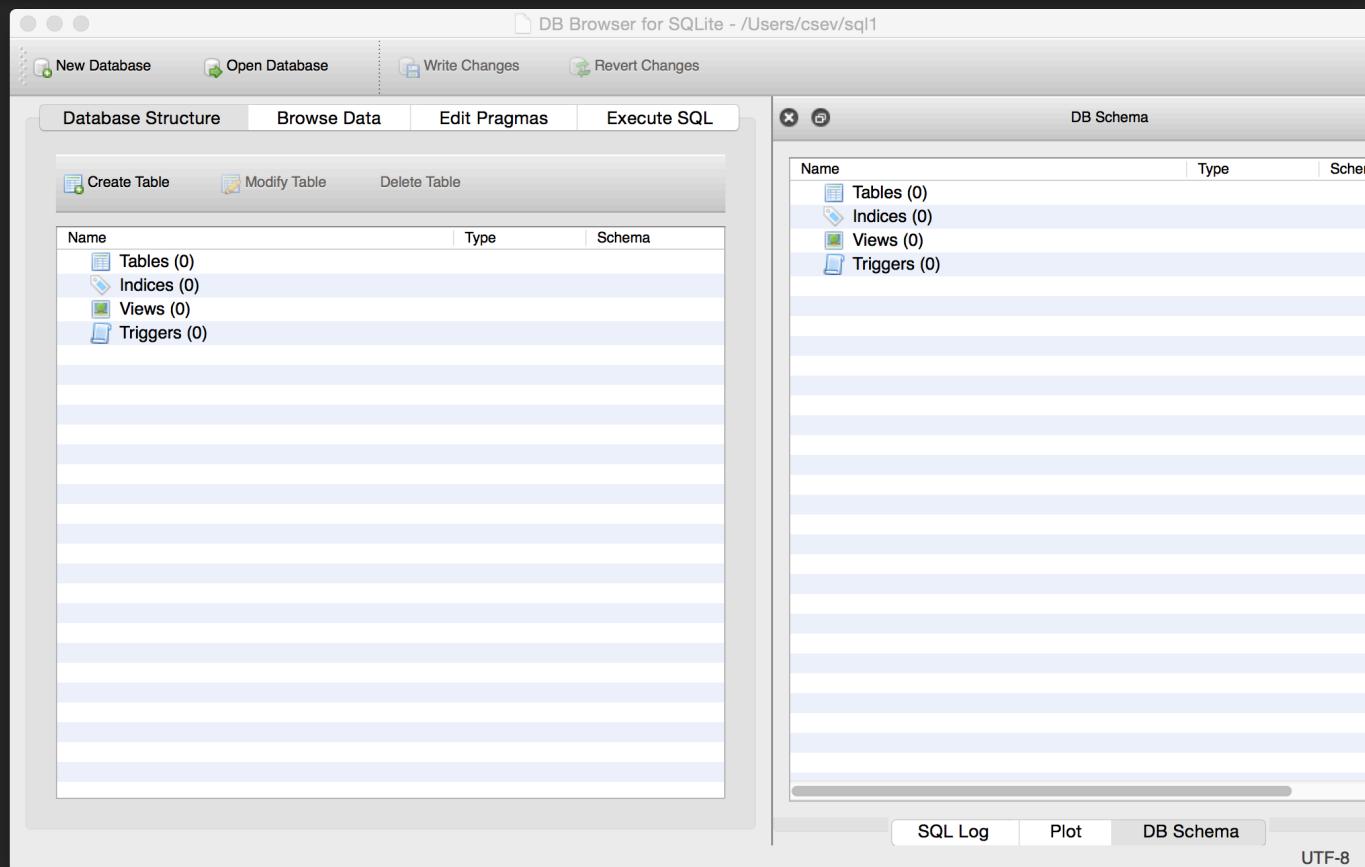
SQLite Browser

- 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

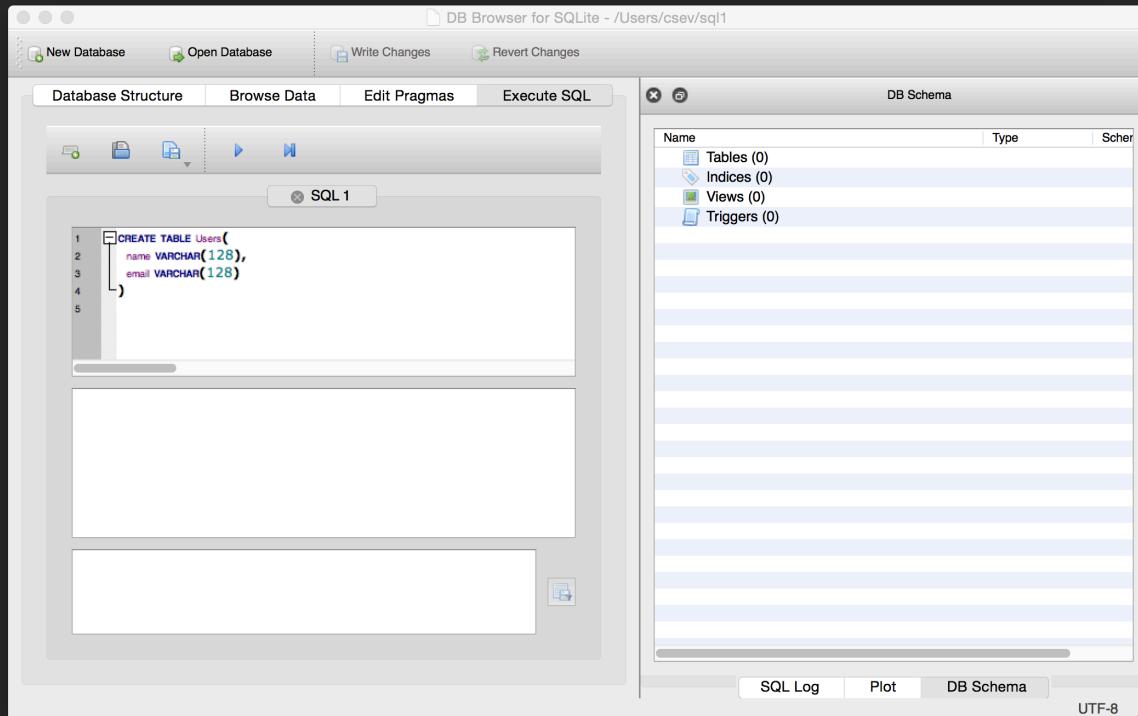
- <https://addons.mozilla.org/en-US/firefox/addon/sqlite-manager/>

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

DB Schema

Name	Type	Schema
Tables (1)		CREATE TABLE Users(name VARCHAR(128), email VARCHAR(128))
Users		
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
```

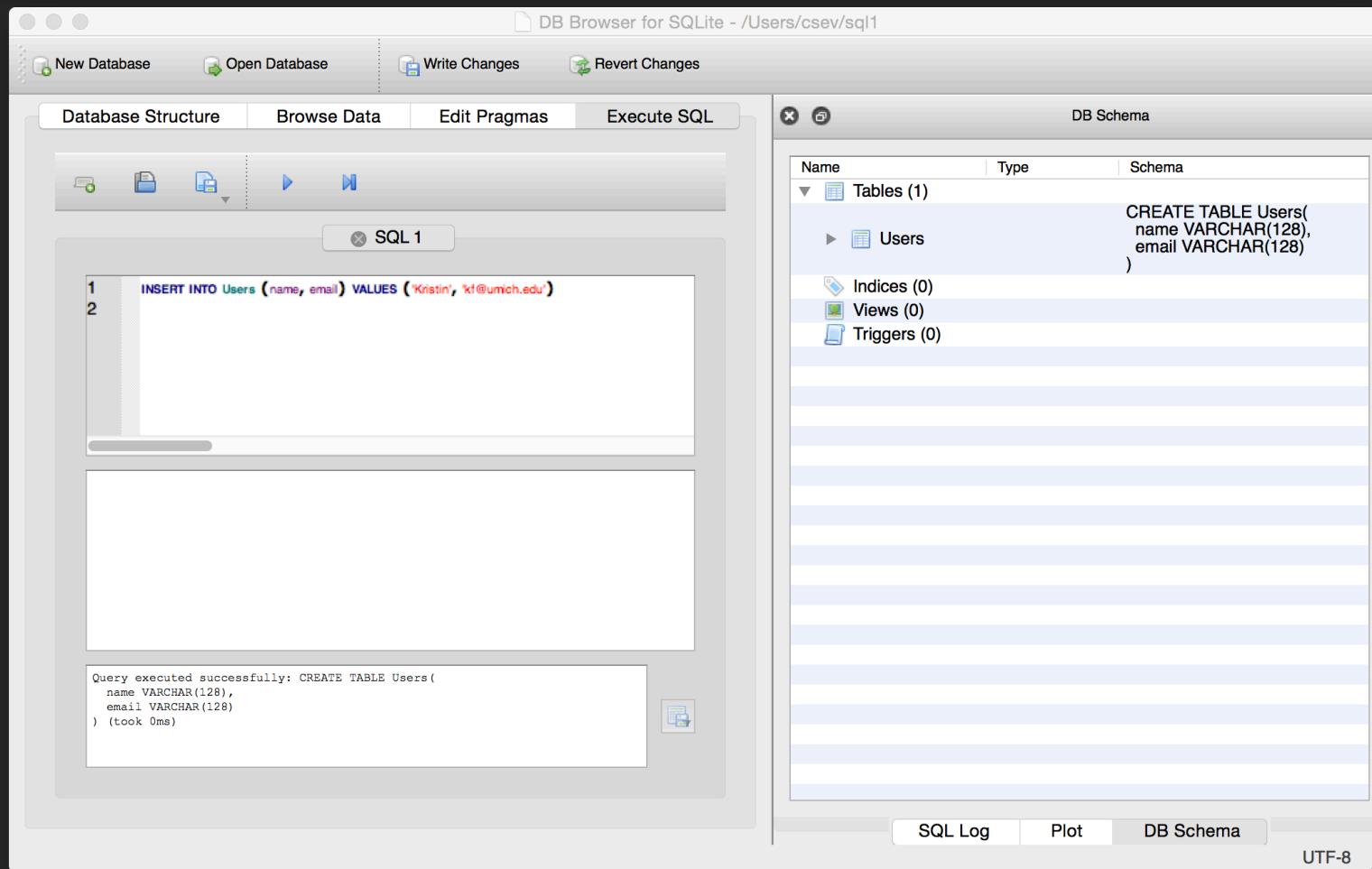
Query executed successfully: CREATE TABLE Users(
 name VARCHAR(128),
 email VARCHAR(128)
) (took 0ms)

DB Schema

Name	Type	Schema
Tables (1)		
Users		CREATE TABLE Users(name VARCHAR(128), email VARCHAR(128))
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) CREATE TABLE Users(
 name VARCHAR(128),
 email VARCHAR(128)
)

Indices (0)
Views (0)
Triggers (0)

SQL Log Plot DB Schema

UTF-8

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



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(name VARCHAR(128), email VARCHAR(128))
Indices (0)		
Views (0)		
Triggers (0)		

SQL Log Plot DB Schema UTF-8

The screenshot shows the DB Browser for SQLite application interface. On the left, there's a SQL editor window containing a single line of code: 'DELETE FROM Users WHERE email='ted@umich.edu''. Below the code, a message indicates the query was executed successfully and took 0ms. On the right, a 'DB Schema' window displays the current database structure. It shows one table named 'Users' with two columns: 'name' and 'email', both defined as VARCHAR(128). There are also sections for Indices, Views, and Triggers, all currently empty. The bottom of the screen features a navigation bar with tabs for SQL Log, Plot, and DB Schema, with DB Schema being the active tab.

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

Main Window: The central window displays the "Database Structure" tab. It shows a table named "Users" with columns "name" and "email". The data is as follows:

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

A yellow arrow points from the "DB Schema" window to the "Users" row in the table.

Left Sidebar: Shows options for "New Database" and "Open Database". A message "DELETE FROM Users" is visible.

Bottom Status: Shows the message "Query executed successful (took 0ms)".

DB Schema Window: The rightmost window shows the database schema. It lists one table, "Users", with the following CREATE TABLE statement:

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

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

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

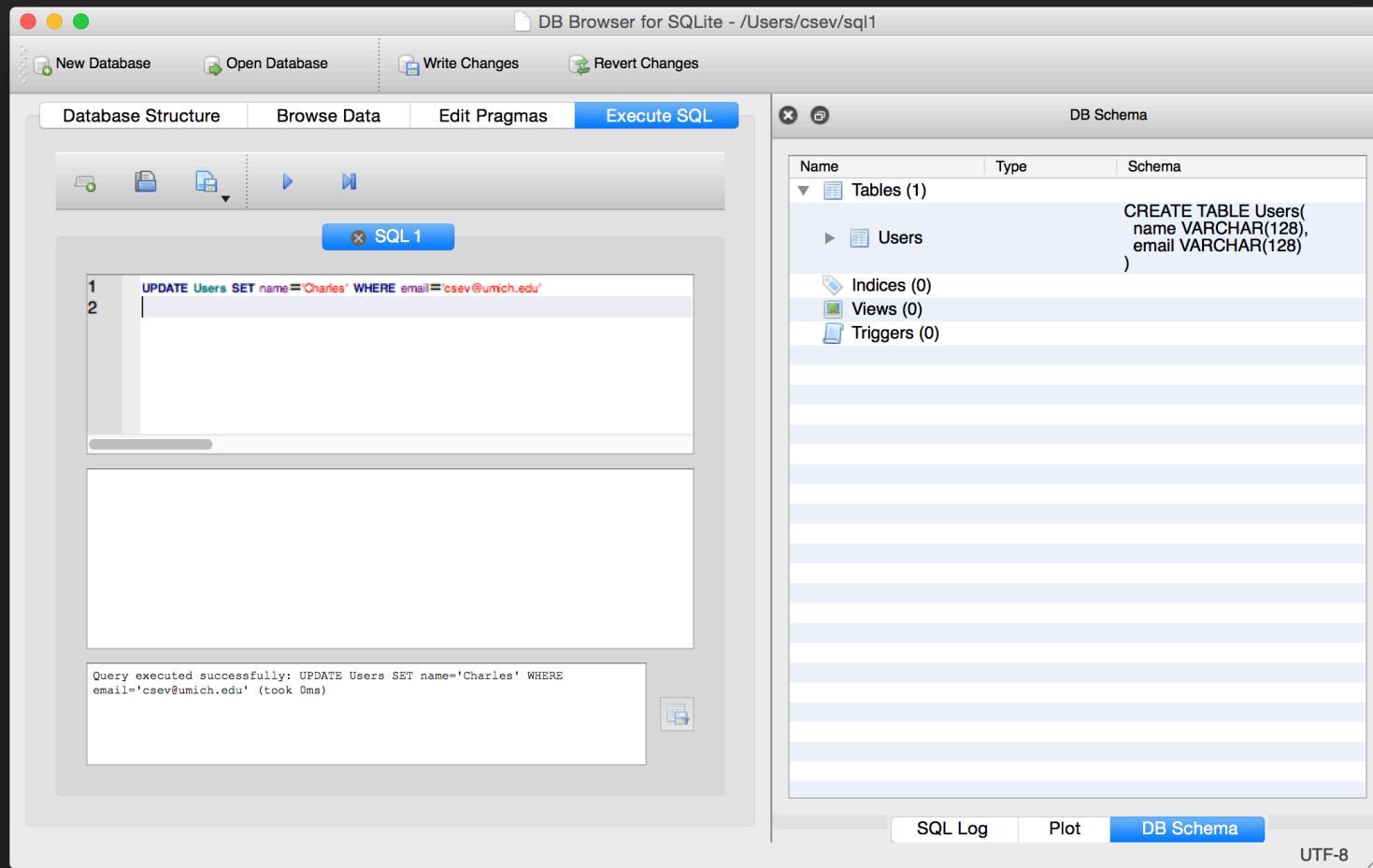
```
1 UPDATE Users SET name='Charles' WHERE email='csev@umich.edu'
2
```

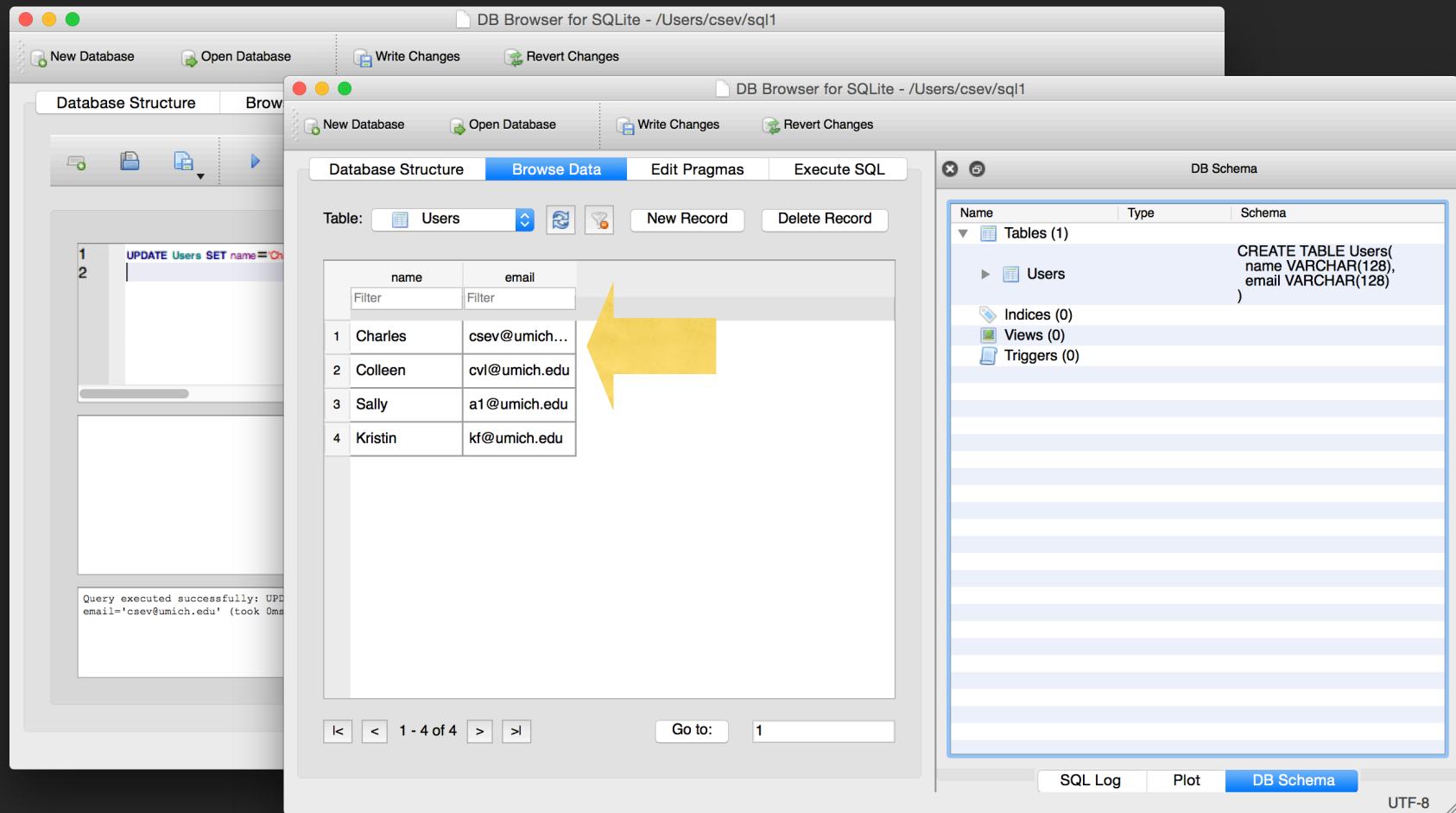
Query executed successfully: UPDATE Users SET name='Charles' WHERE email='csev@umich.edu' (took 0ms)

DB Schema

Name	Type	Schema
Tables (1)		
Users		CREATE TABLE Users(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. The left instance displays a successful UPDATE query:

```
1 UPDATE Users SET name='Charles' WHERE id=1
2
```

The right instance shows the resulting data in the 'Browse Data' tab:

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

A yellow arrow points from the 'Tables (1)' section of the DB Schema tab on the right to the 'Users' table in the central window, indicating the connection between the schema definition and the data.

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

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(name VARCHAR(128), email VARCHAR(128))
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

SQL 1

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

	name	email
1	Charles	csev@umich.edu

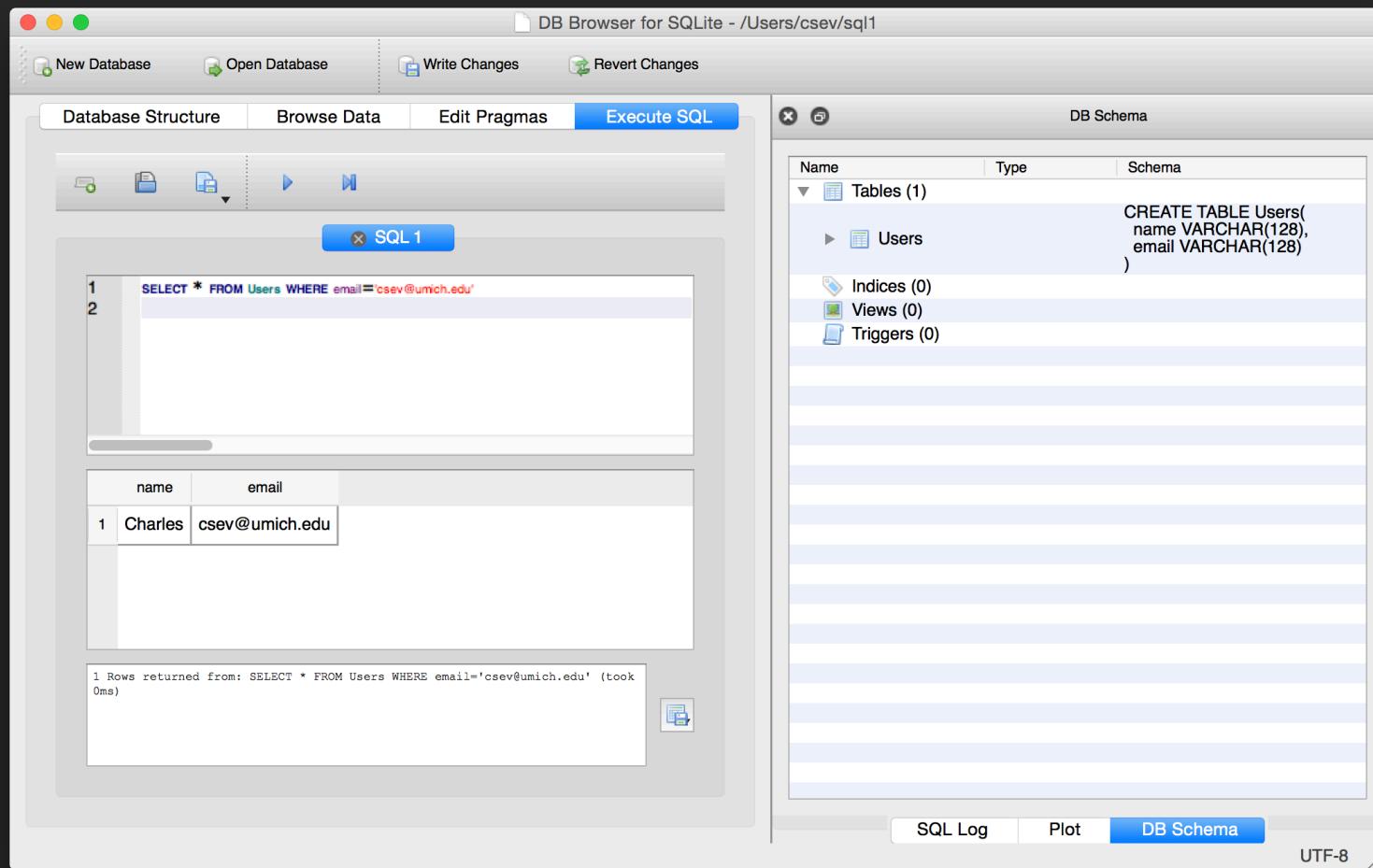
1 Rows returned from: SELECT * FROM Users WHERE email='csev@umich.edu' (took 0ms)

DB Schema

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

SQL Log Plot DB Schema

UTF-8

The screenshot shows the DB Browser for SQLite application interface. On the left, the main workspace contains a SQL editor window titled "SQL 1" with the query "SELECT * FROM Users WHERE email='csev@umich.edu'". Below it is a table viewer showing one row: name "Charles" and email "csev@umich.edu". A status message at the bottom indicates "1 Rows returned from: SELECT * FROM Users WHERE email='csev@umich.edu' (took 0ms)". On the right, a "DB Schema" panel displays the database structure with a single table named "Users" defined by the SQL command: CREATE TABLE Users(name VARCHAR(128), email VARCHAR(128)). The "DB Schema" tab is currently selected at the bottom.

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

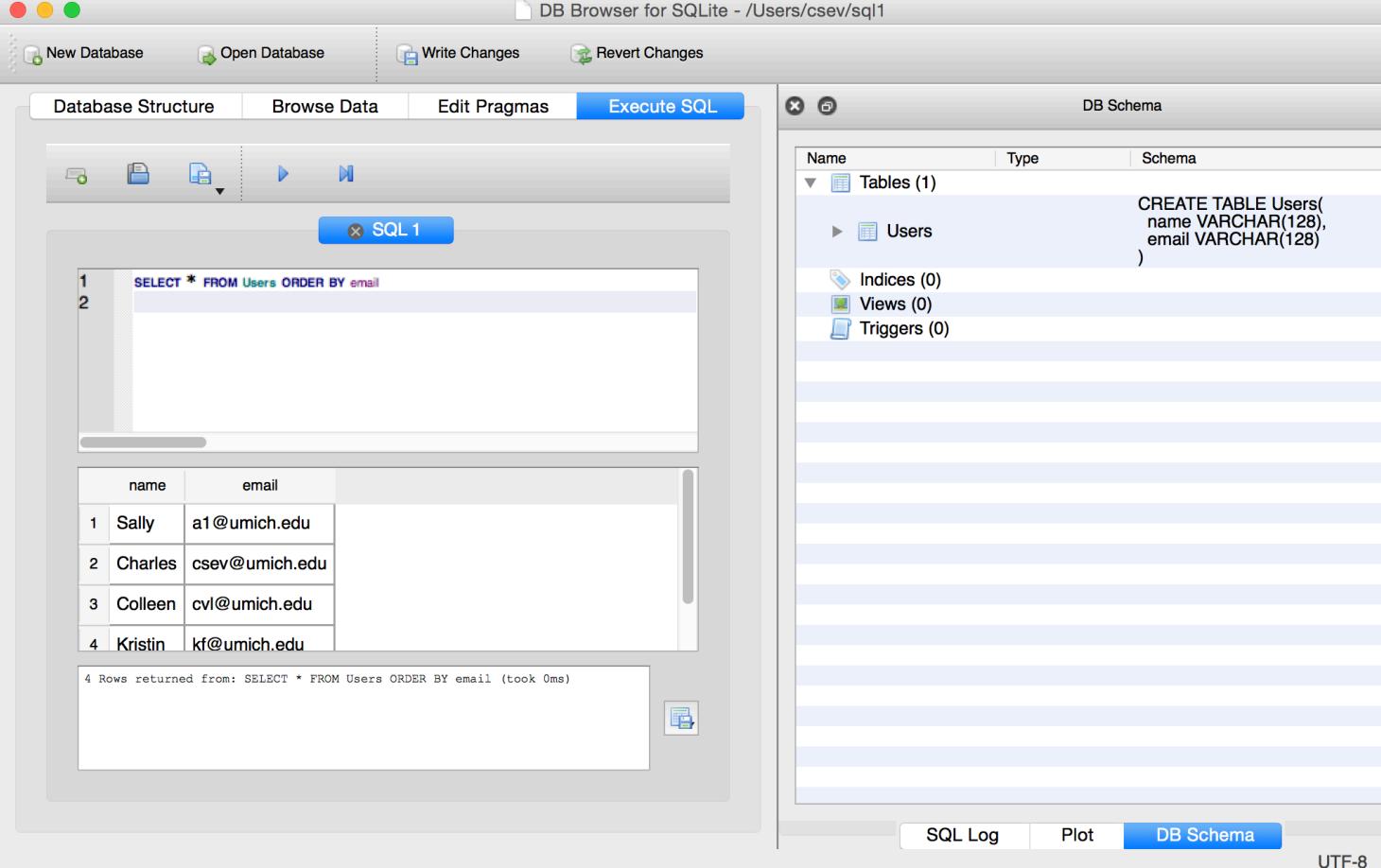
4 Rows returned from: SELECT * FROM Users ORDER BY email (took 0ms)

DB Schema

Name	Type	Schema
Tables (1)		
Users		CREATE TABLE Users(name VARCHAR(128), email VARCHAR(128))
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)

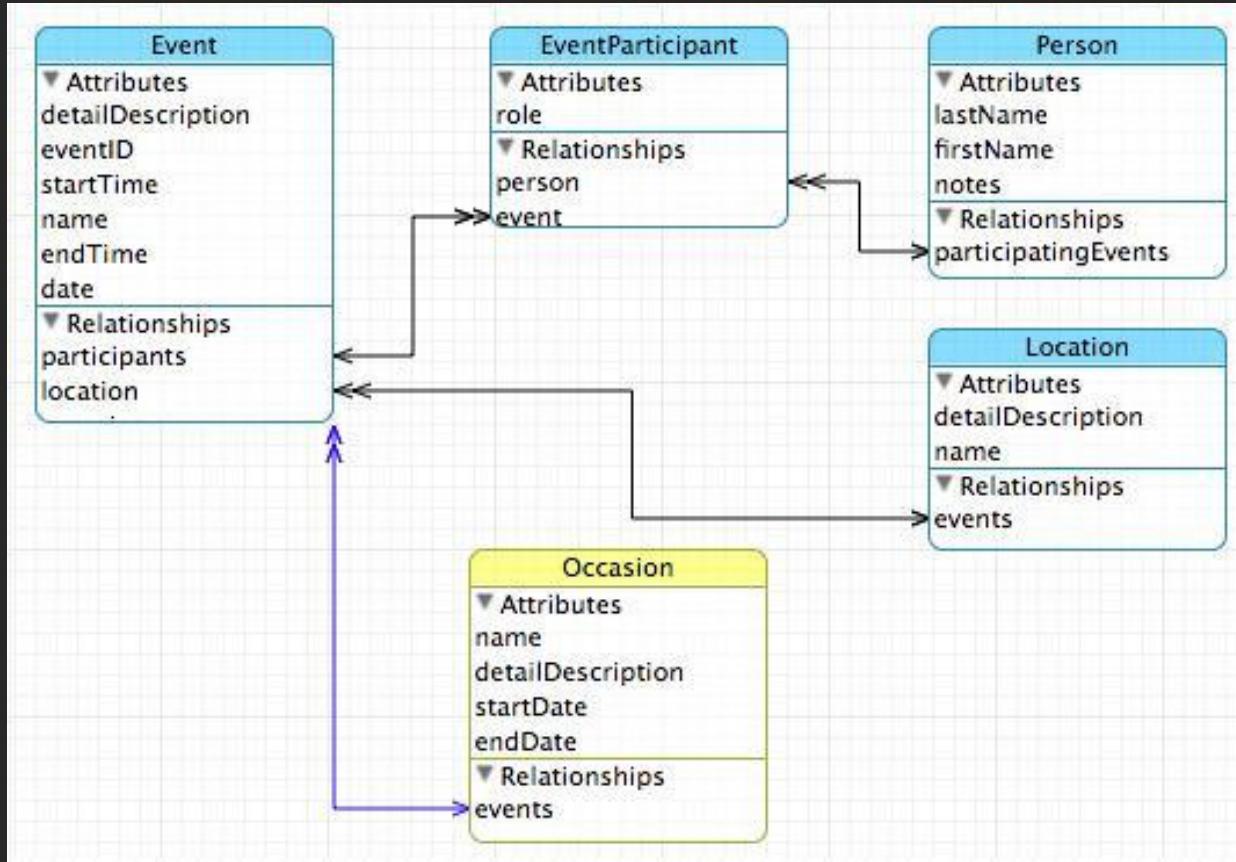
- Tables pretty much look like big fast programmable spreadsheets with rows, columns, and commands
- The power comes when we have more than one table and we can exploit the relationships between the tables

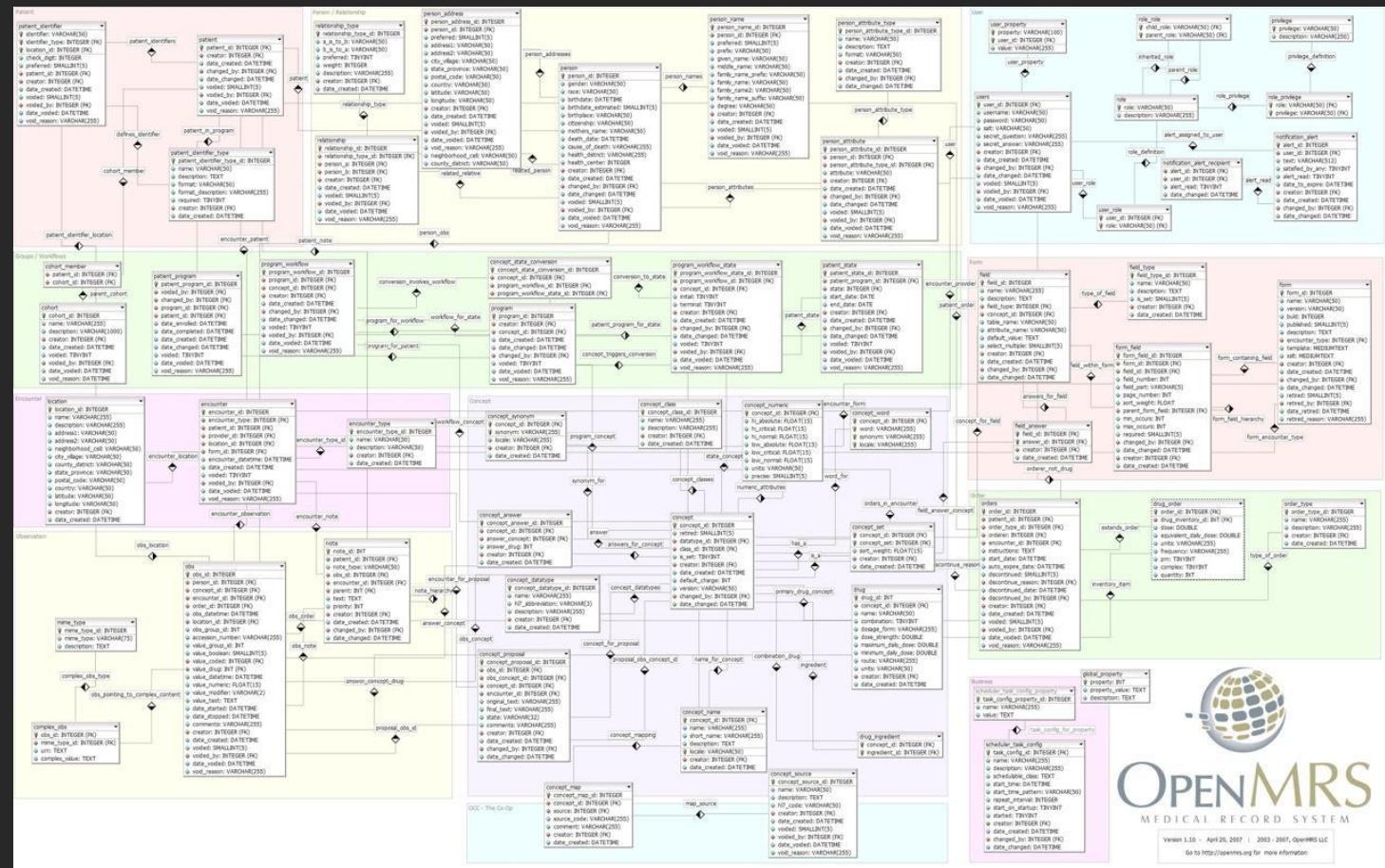
Complex Data Models and Relationships

http://en.wikipedia.org/wiki/Relational_model

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 26, 2007 | 2003 - 2007, OpenMRS LLC
Go to <http://openmrs.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	

<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
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<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

Track

Album

Artist

Genre

Rating

Len

Count

Artist

belongs-to

Album

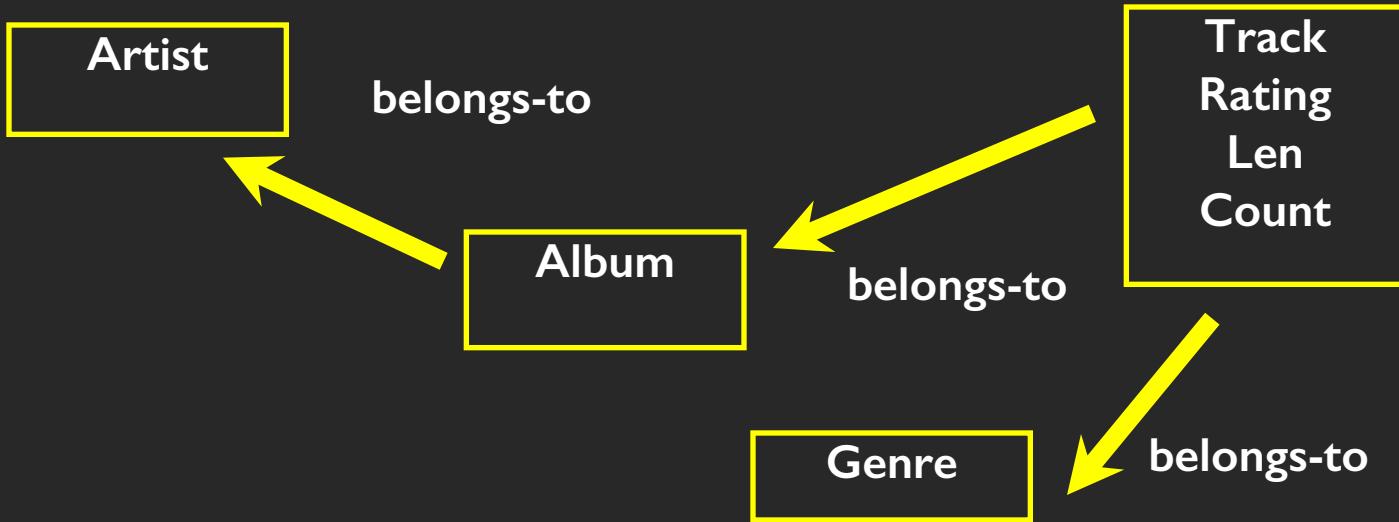
belongs-to

Track
Rating
Len
Count

Genre

belongs-to

<input checked="" type="checkbox"/> Hells Bells	5:13	AC/DC	Who Made Who	Rock		61
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<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

<input checked="" type="checkbox"/>	Hells Bells	5:13	AC/DC	Who Made Who	Rock	★★★★★
<input checked="" type="checkbox"/>	Shake Your Foundations	3:54	AC/DC	Who Made Who	Rock	★★★★★
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<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	2:20	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

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



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

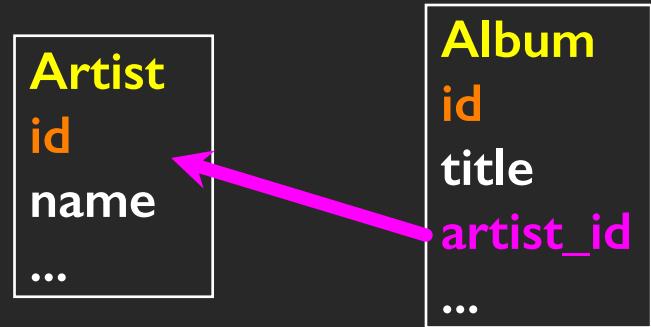
Best practices

- 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
```

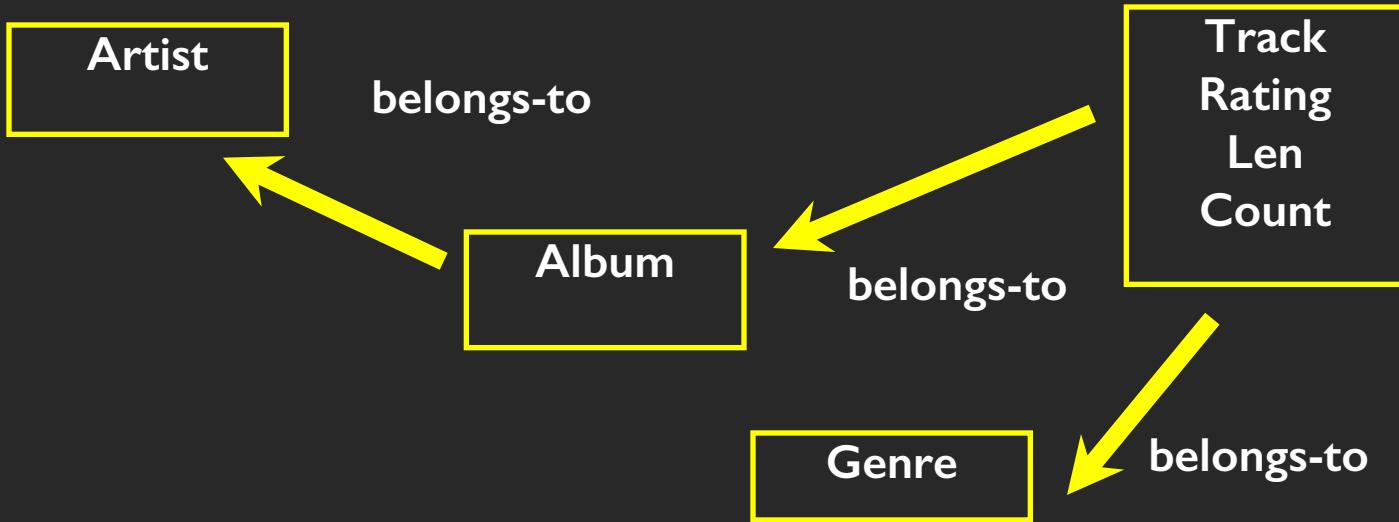
Foreign Keys

- 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

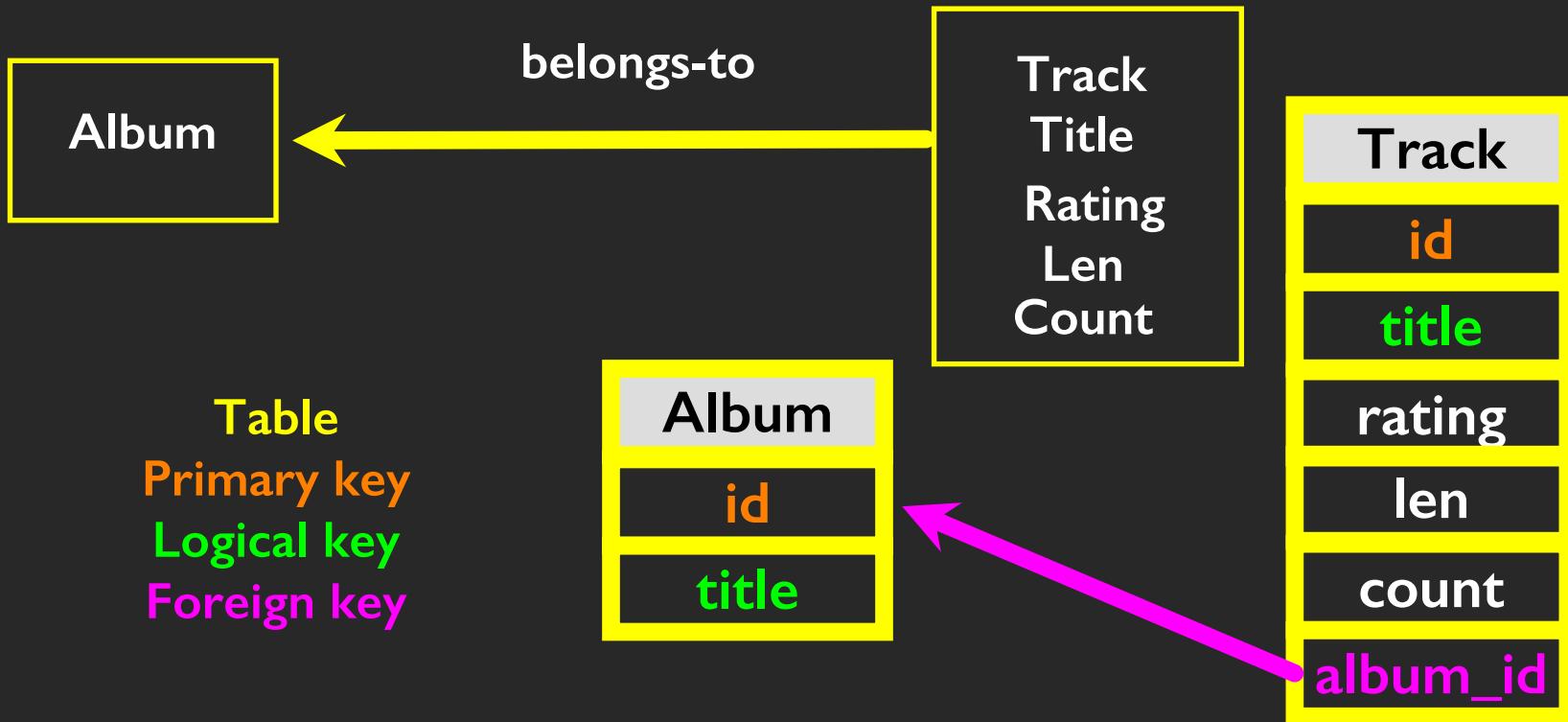


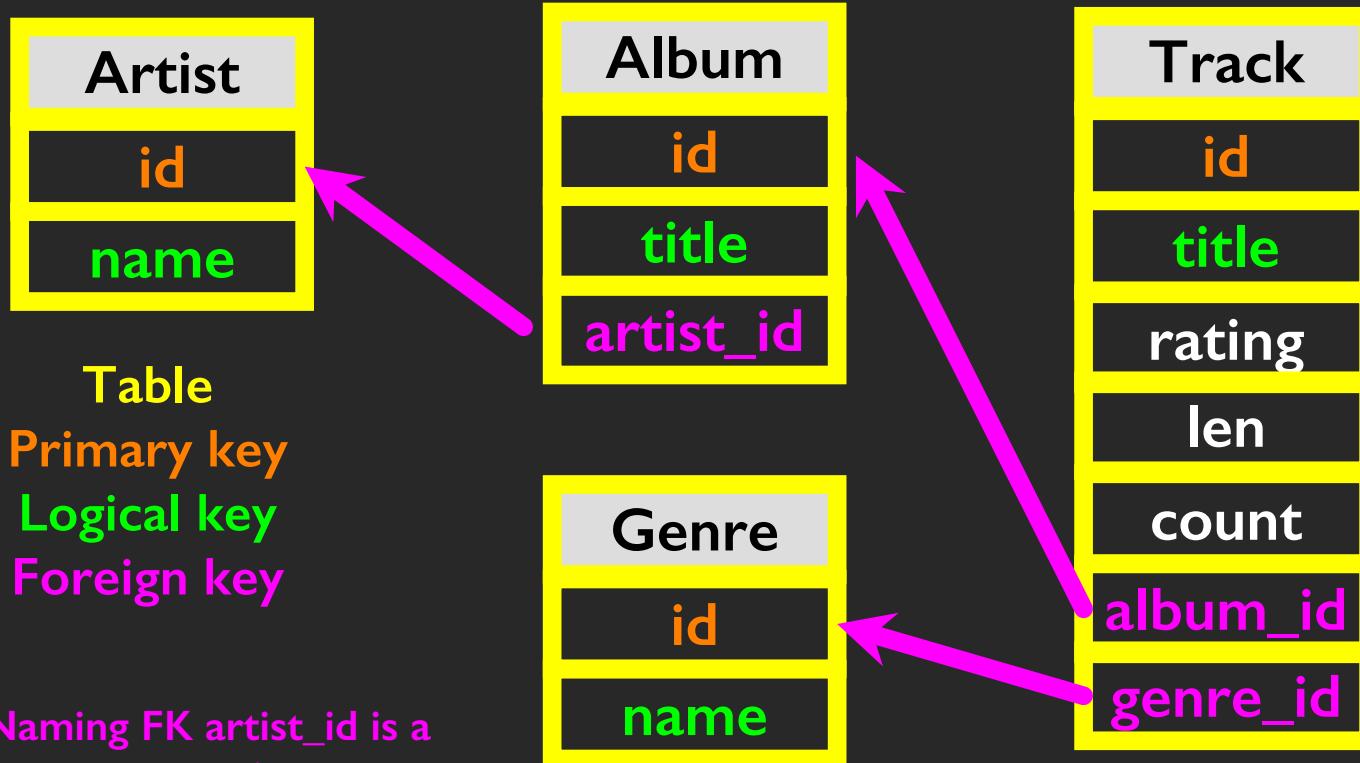


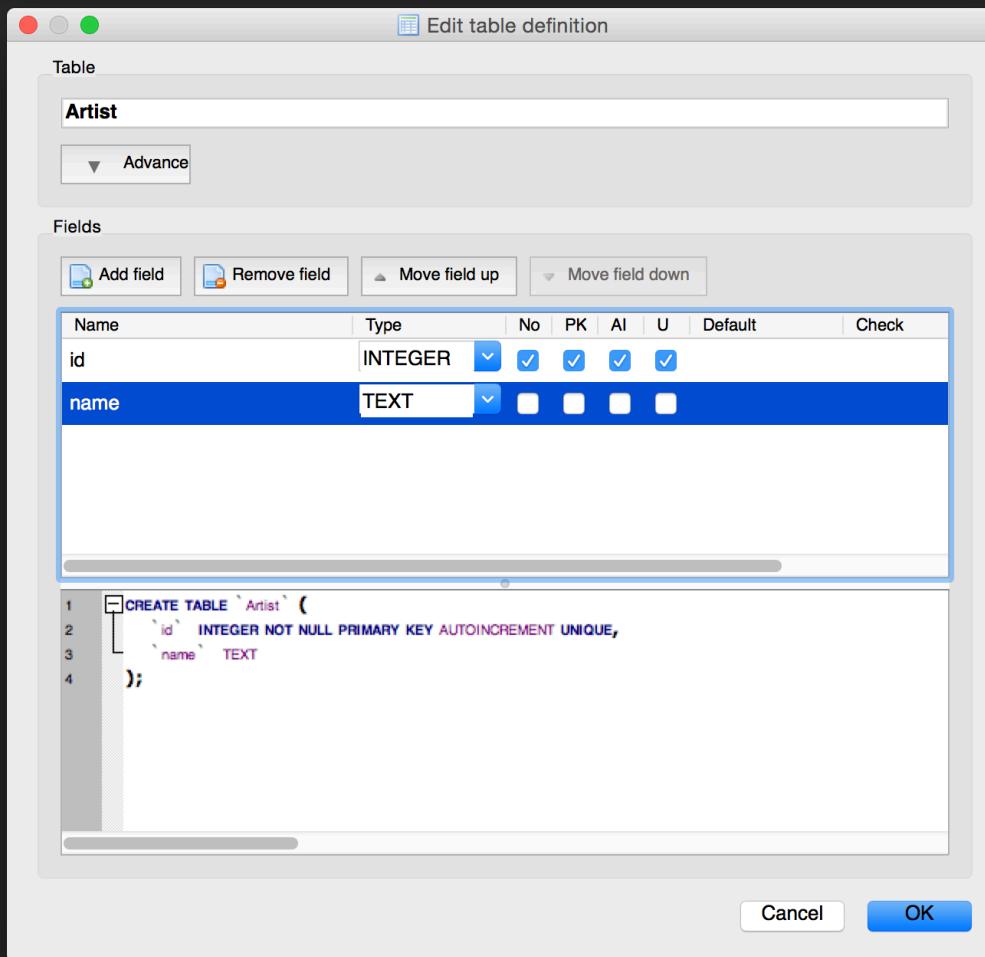
Relationship Building (in tables)

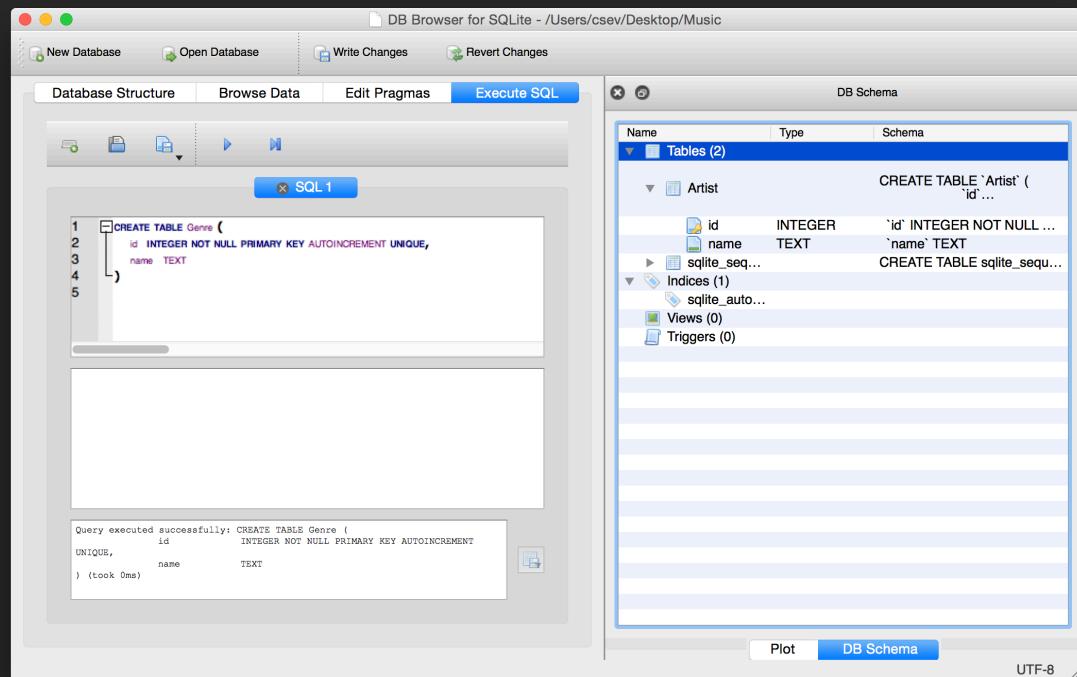


<input checked="" type="checkbox"/> Hells Bells	5:13	AC/DC	Who Made Who	Rock	★★★★★	61
<input checked="" type="checkbox"/> Shake Your Foundations	3:54	AC/DC	Who Made Who	Rock	★★★★★	70
<input checked="" type="checkbox"/> Chase the Ace	3:01	AC/DC	Who Made Who	Rock		56
<input checked="" type="checkbox"/> 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









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

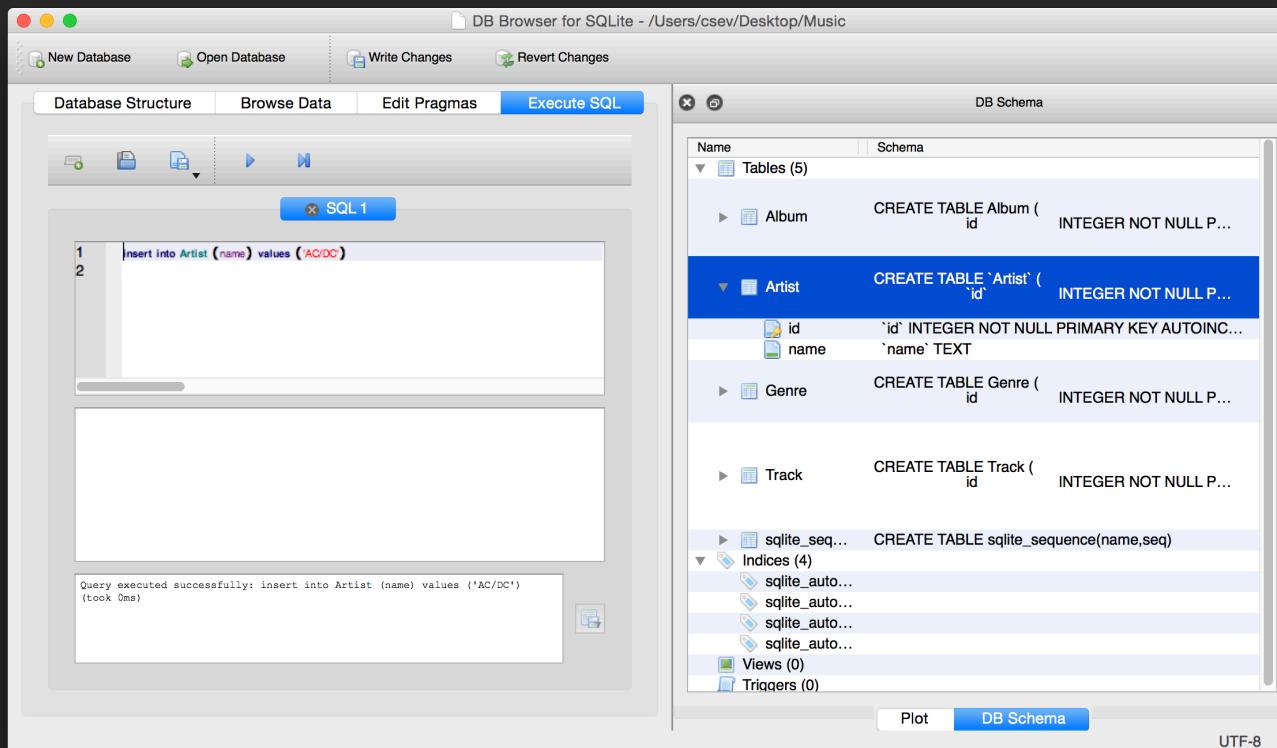
Create Table Modify Table Delete Table

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, `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>
Indices (4)	
sqlite_sequence	<pre>CREATE TABLE sqlite_sequence(name,seq)</pre>
sqlite_autoindex_Album_1	
sqlite_autoindex_Track_1	

Plot DB Schema



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

The screenshot shows two instances of DB Browser for SQLite. The left instance has a SQL tab containing the query `insert into Artist (name) values ('AC/DC')`. The right instance shows the 'Browse Data' tab for the 'Artist' table, which contains two rows:

	id	name
1	1	Led Zepplin
2	2	AC/DC

A yellow arrow points from the right instance towards the left one. The bottom of the left instance shows the message: "Query executed successfully: insert into Artist (name) values ('AC/DC') (took 0ms)".

The right instance also displays the database schema in a separate window titled '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)	

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

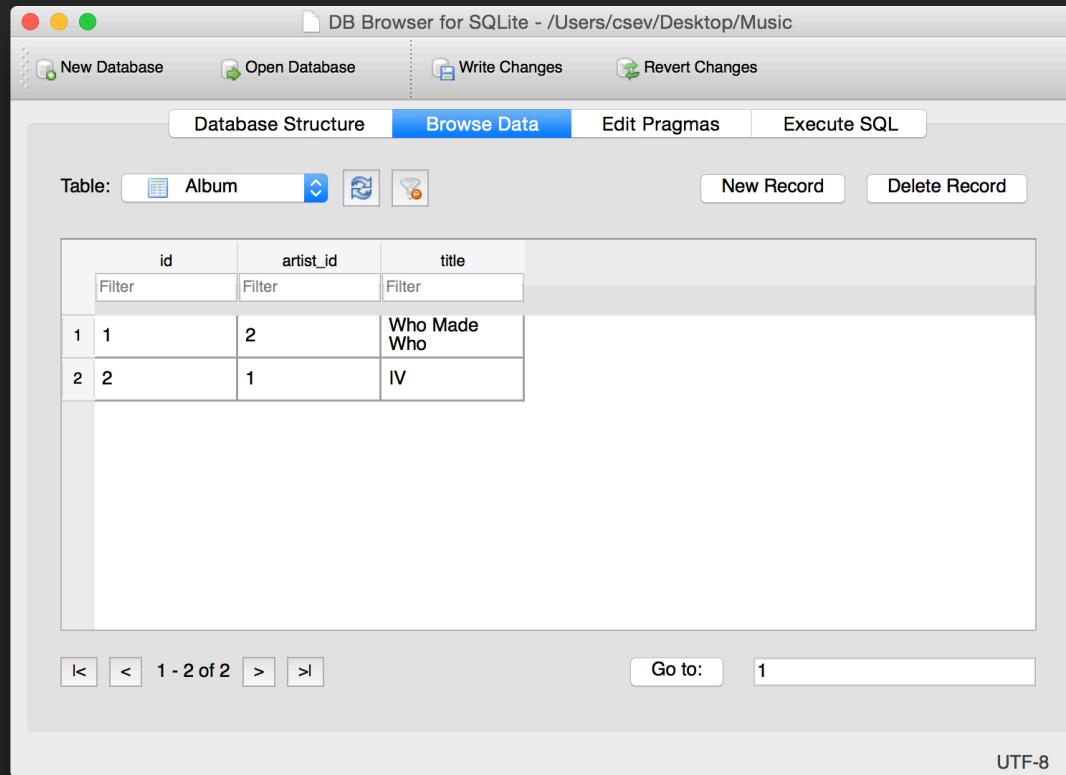
The screenshot shows the DB Browser for SQLite interface. The left pane displays the 'Genre' table with two rows: id 1 (Rock) and id 2 (Metal). The right pane shows the 'DB Schema' with the following tables and their CREATE statements:

- Album: CREATE TABLE Album (id INTEGER NOT NULL PRIMARY KEY)
- Artist: CREATE TABLE `Artist` (id INTEGER NOT NULL PRIMARY KEY)
- Genre: CREATE TABLE Genre (id INTEGER NOT NULL PRIMARY KEY)
- Track: CREATE TABLE Track (id INTEGER NOT NULL PRIMARY KEY)

Indices (4) are also listed: sqlite_sequence, sqlite_autoindex1, sqlite_autoindex2, sqlite_autoindex3, and sqlite_autoindex4.

At the bottom, there are buttons for Plot and DB Schema, and the encoding is set to UTF-8.

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



```
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
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!

Track						
id	title	album_id	genre_id	len	rating	count
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

Album

Album		
id	artist_id	title
1	2	Who Made Who
2	1	IV

Artist

Artist	
id	name
1	Led Zeppelin
2	AC/DC

Genre	
id	name
1	Rock
2	Metal



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**

Album		Artist	
		t	
id	title	id	name
1	Who Made Who	1	Led Zepplin
2	IV	2	AC/DC

Album		Artist	
		t	
id	title	id	name
1	Who Made Who	1	Led Zepplin
2	IV	2	AC/DC

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

id	artist_id	title
1	2	Who Made Who
2	1	IV

id	name
1	Led Zepplin
2	AC/DC

	title	artist_id	id	name
1	Who Made Who	2	2	AC/DC
2	IV	1	1	Led Zepplin

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

	title	name
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
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
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

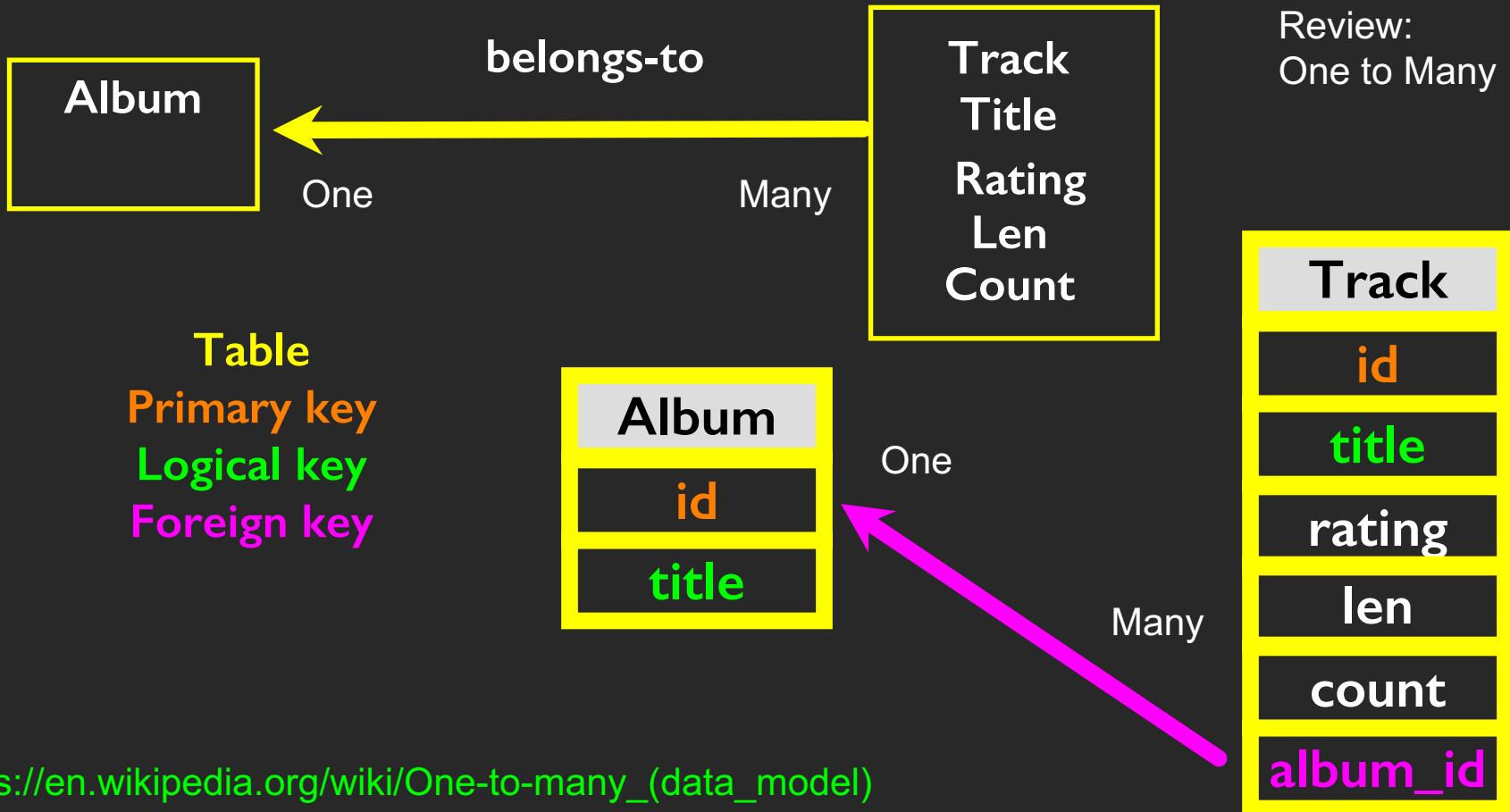
How the tables
are linked

<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))



id	name
1	Rock
2	Metal

One



One

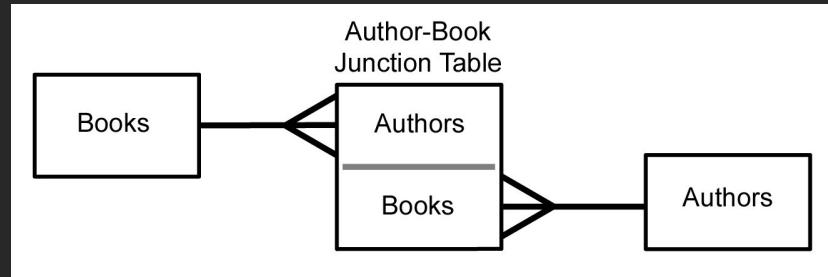
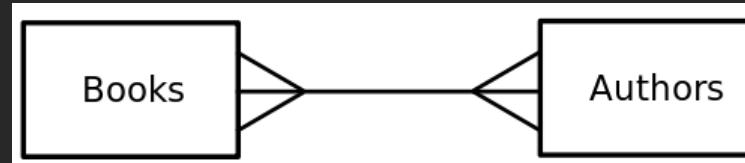
Many

Many

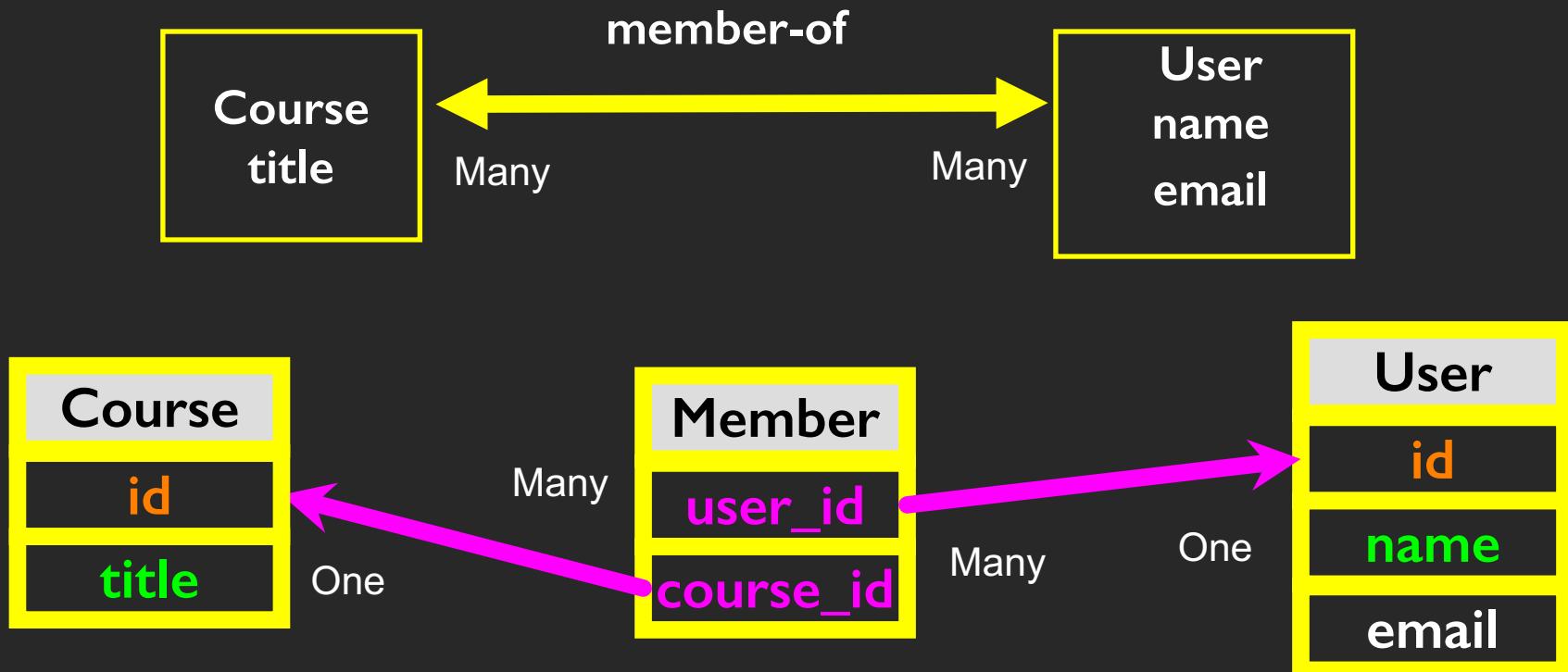
id	title	album_id	genre_id	len	rating	count
1	Black Dog	2	1	297	5	0
2	Stairway	2	1	482	5	0
3	About to Rock	1	2	313	5	0
4	Who Made Who	1	2	207	5	0

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 (id INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT UNIQUE, title TEXT)
Member		CREATE TABLE Member (user_id INTEGER, course_id INTEGER, PRIMARY KEY (user_id, course_id))
User		CREATE TABLE User (id INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT UNIQUE, name TEXT, email TEXT)
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

Filter Filter

< < 1 - 3 of 3 > >|

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: User

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

Filter Filter Filter

New Record Delete Record

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

UTF-8

Insert Memberships

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

id	title
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

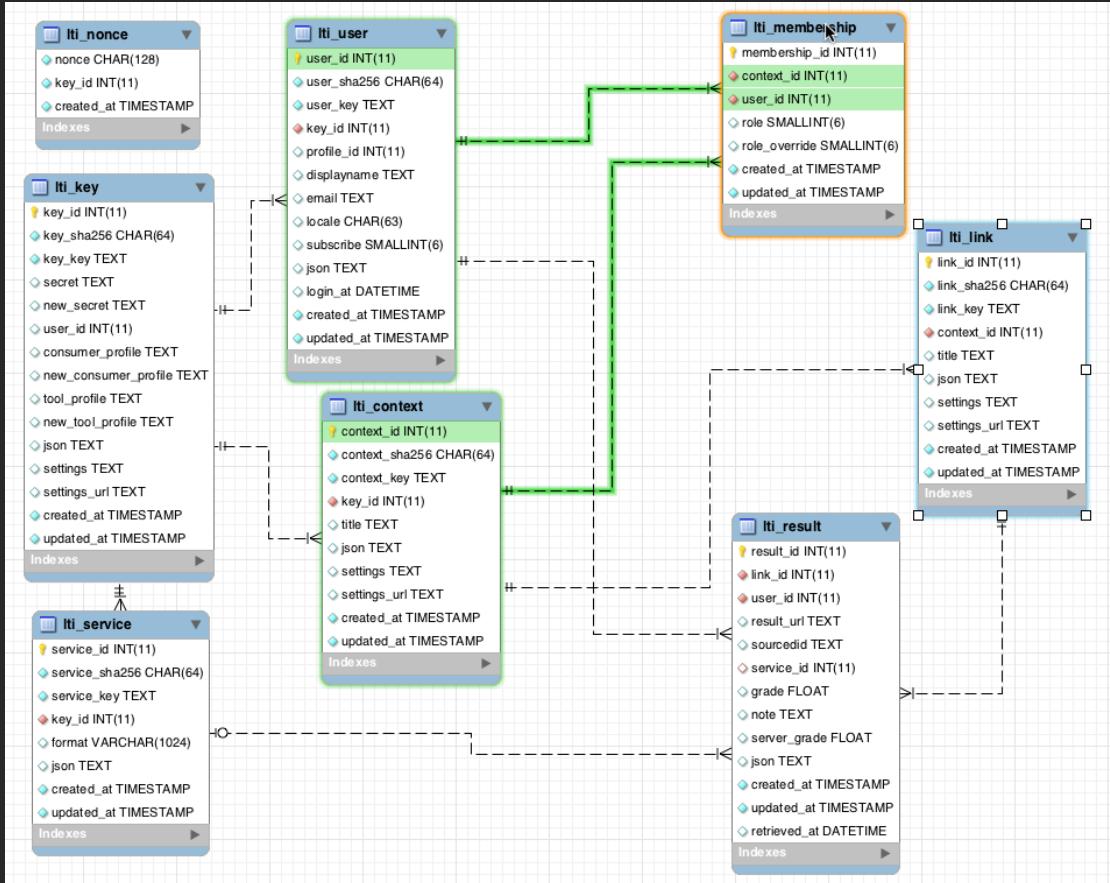
id	name	email
Filter	Filter	Filter
1	Jane	jane@tsugi.org
2	Ed	ed@tsugi.org
3	Sue	sue@tsugi.org

user_id	course_id	role
Filter	Filter	Filter
1	1	1
2	1	0
3	1	0
1	2	0
2	2	1
2	3	1
3	3	0

id	title
Filter	Filter
1	Python
2	SQL
3	PHP

	name	role	title
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