

Relational Databases and SQLite

Charles Severance

Python for Informatics: Exploring Information
www.pythonlearn.com



SQLite Browser

DB Browser for SQLite

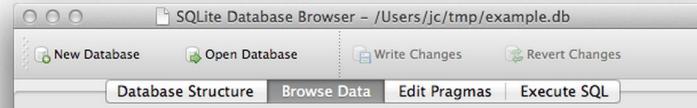
The Official home of the DB Browser for
SQLite

[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.v3.

// 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", "Help". The toolbar contains icons for "New Database", "Open Database", "Write Changes", and "Revert Changes". The bottom navigation bar has 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/>

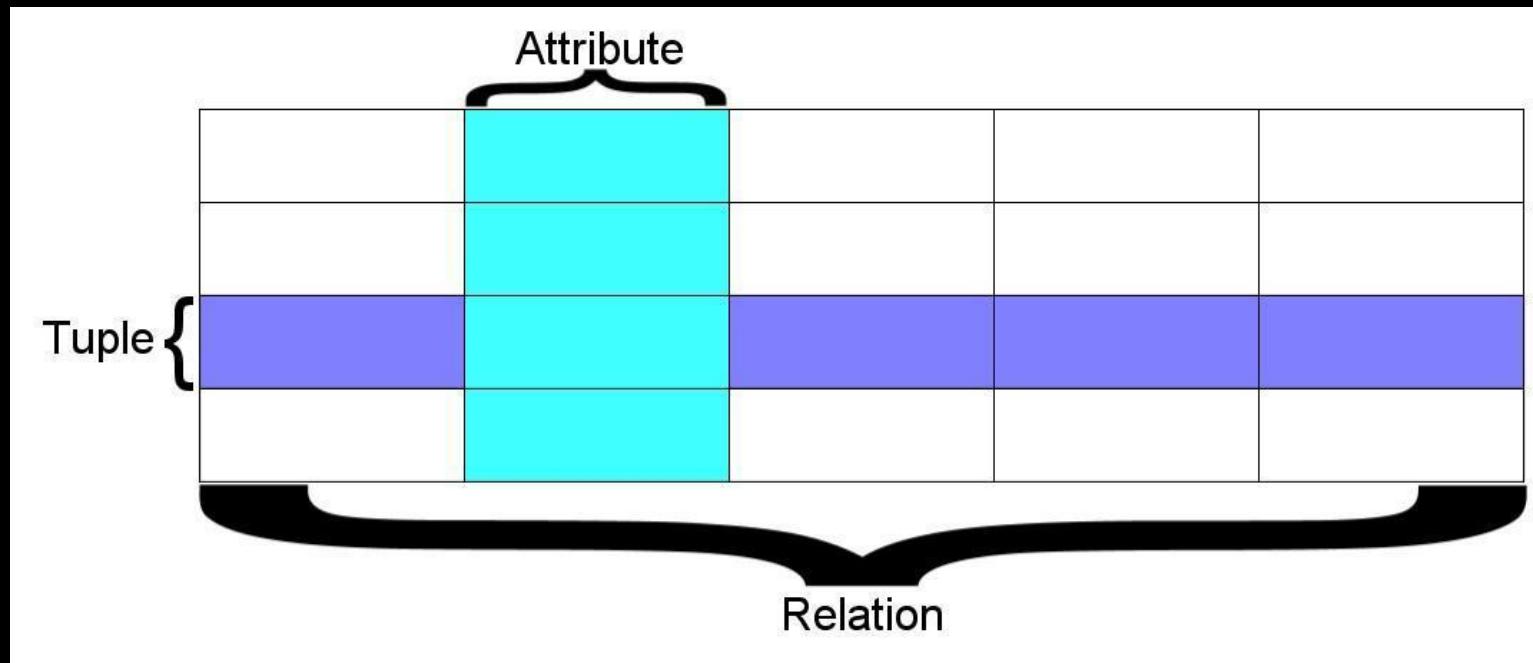
Relational Databases

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

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)

SI502 - 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

2

3

4

5

6

7

8

Tracks Albums Artists Genres +

Columns / Attributes

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

Tables / Relations

SQL

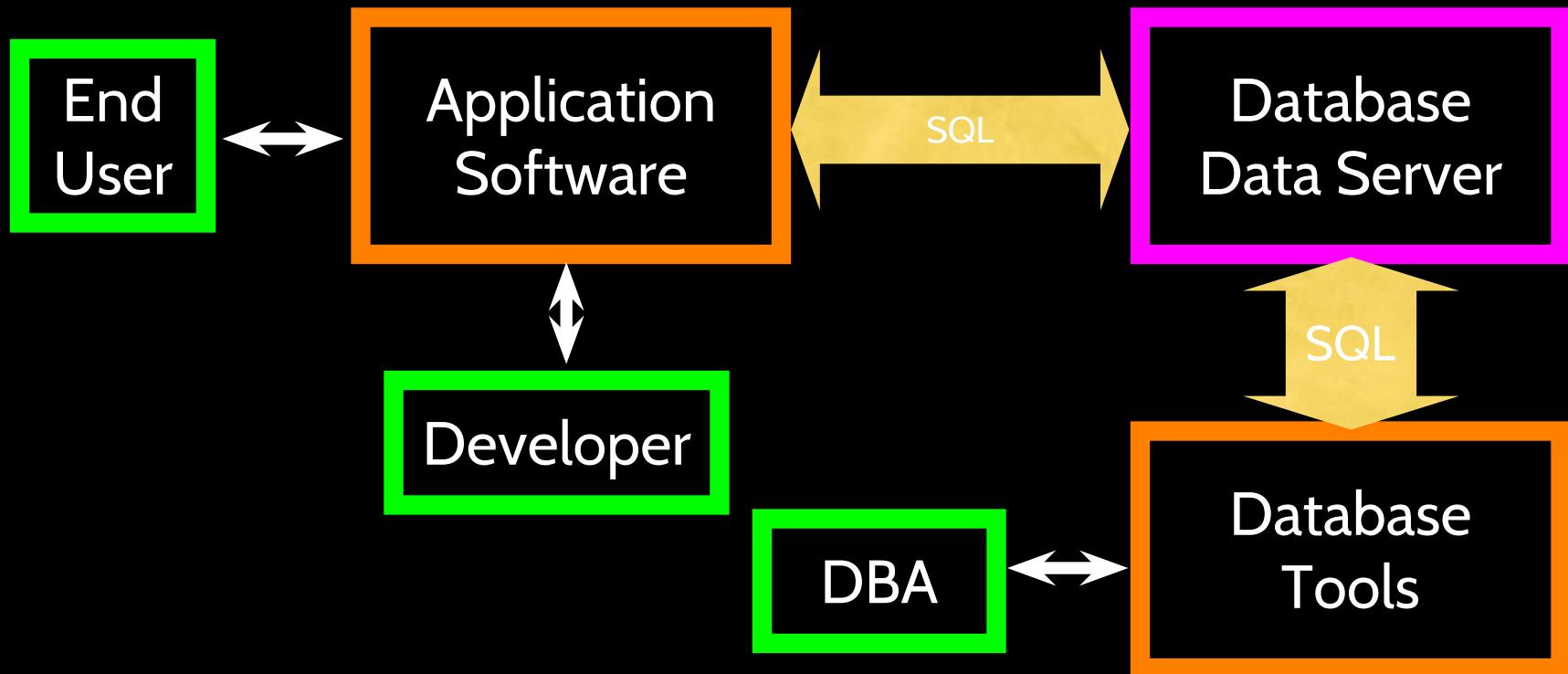
- **Structured Query Language** is the language we use to issue commands to the database
 - Create a table
 - Retrieve some data
 - Insert data
 - Delete data

<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

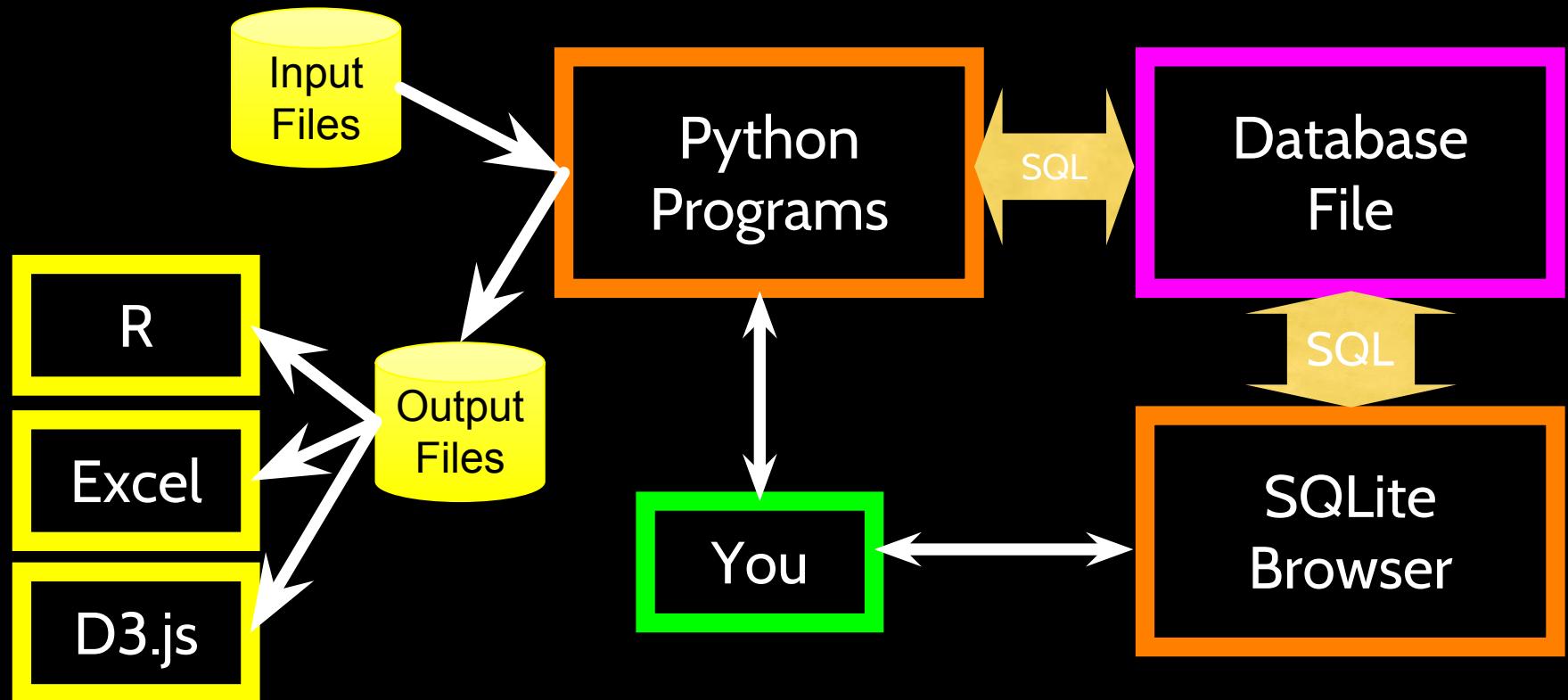


Database Administrator

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, Postgres, ...

SQLite is in lots of software...

symbian

 python™



skype



Microsoft®

McAfee®




Adobe



 **php**

TOSHIBA

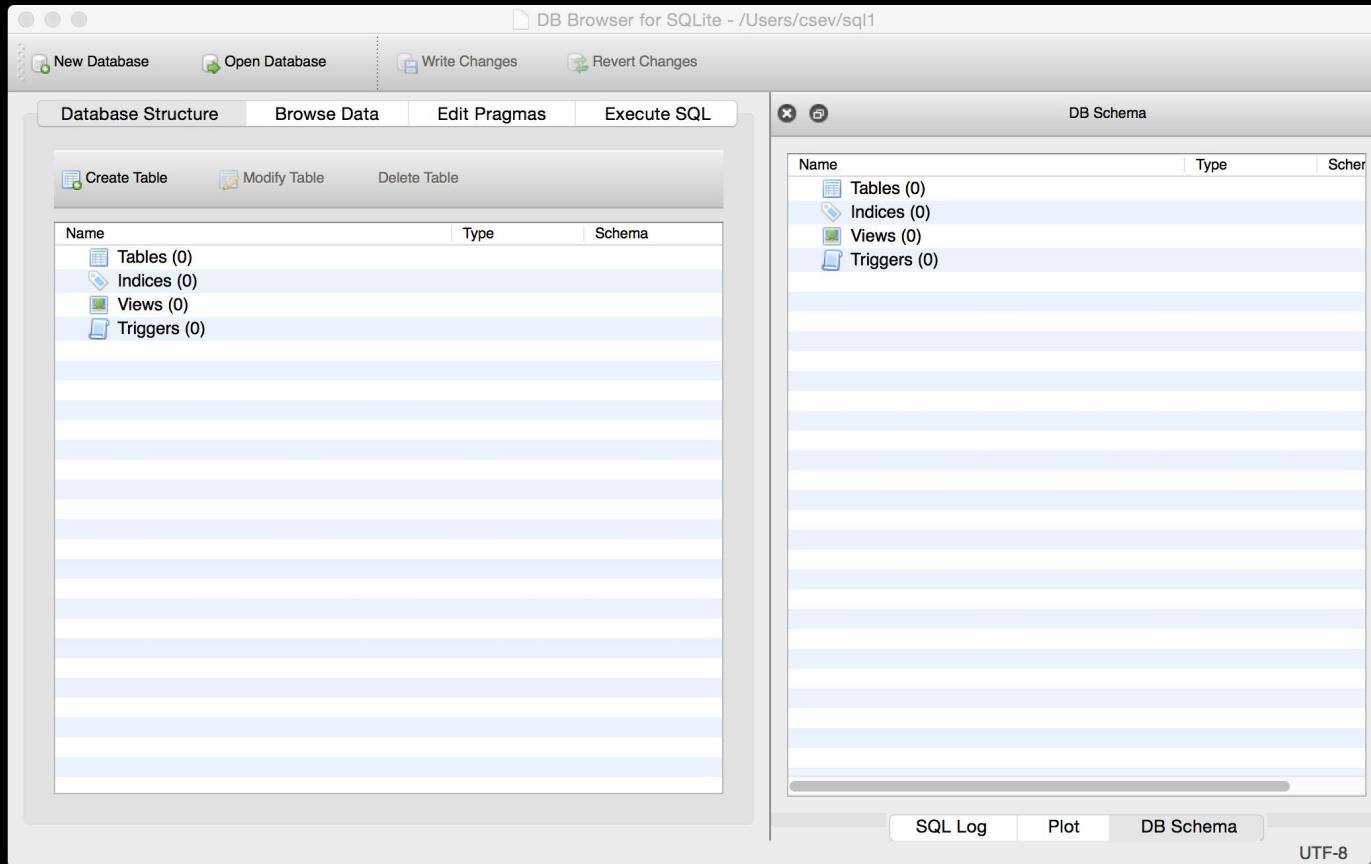
 **Sun**
microsystems

Google

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

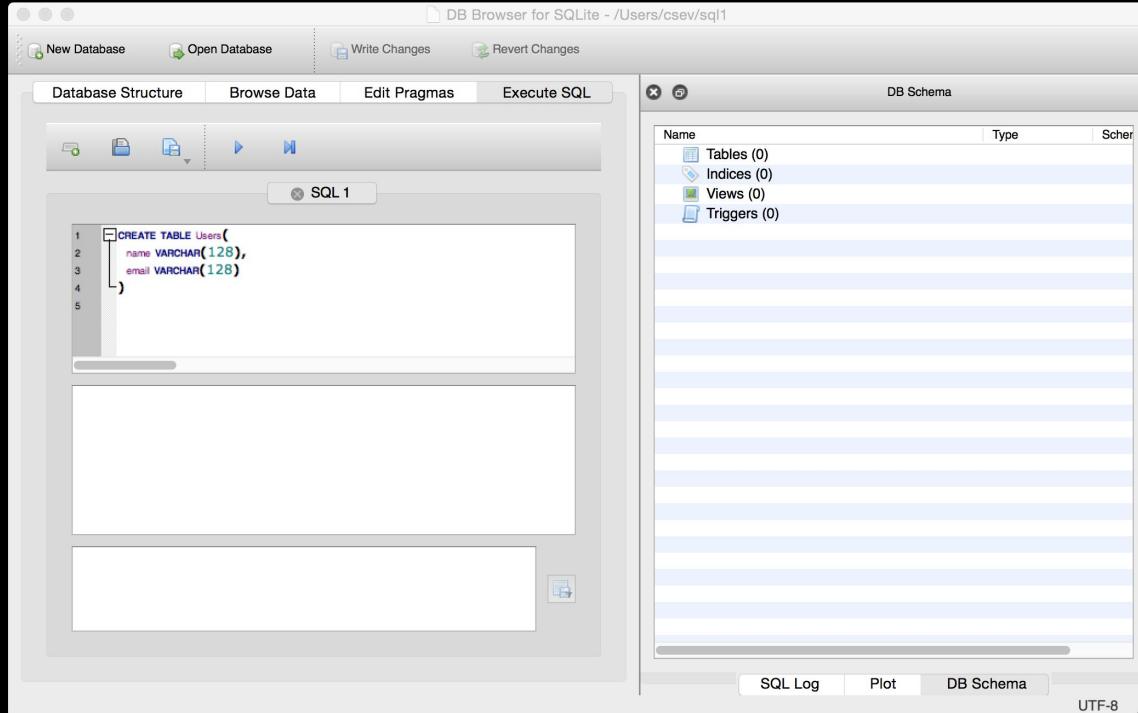
SQLite Browser

- 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/>
- 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(name VARCHAR(128), email VARCHAR(128))
Indices (0)		
Views (0)		
Triggers (0)		

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

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

The screenshot shows the DB Browser for SQLite application interface. The main window displays a table named 'Users' with four rows. The columns are 'name' and 'email'. The rows contain data for Chuck, Colleen, Ted, and Sally. The schema panel on the right shows the CREATE TABLE statement for the 'Users' table. A large text overlay 'Our table with four rows' is centered in the bottom half of the screen.

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')
```

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

Database Structure

1 2 INSERT INTO Users (name, email) VALUES ('Chuck', 'csev@umich.edu'), ('Colleen', 'cvl@umich.edu'), ('Ted', 'ted@umich.edu'), ('Sally', 'a1@umich.edu'), ('Kristin', 'kf@umich.edu')

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

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
5	Kristin	kf@umich.edu

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

DB Schema

Name Type Schema

Tables (1)

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

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

SQL Log Plot DB Schema

UTF-8

The screenshot shows two instances of DB Browser for SQLite. The left instance has a sidebar with a 'Database Structure' tab, a log area with a successful query execution message, and a main area displaying a table with five rows of user data. A large yellow arrow points from the right side of the left window towards the right window. The right instance has a 'DB Schema' tab open, showing the 'Tables (1)' section with a detailed view of the 'Users' table, including its schema definition: 'CREATE TABLE Users(name VARCHAR(128), email VARCHAR(128))'. Both windows have standard OS X-style window controls at the top.

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'
2
```

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

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 large text area containing an SQL command: "DELETE FROM Users WHERE email='ted@umich.edu'". A message below the command states "Query executed successfully: DELETE FROM Users WHERE email='ted@umich.edu' (took 0ms)". To the right, a "DB Schema" panel displays the database structure with a table named "Users" defined by the schema: "CREATE TABLE Users(name VARCHAR(128), email VARCHAR(128))". The "DB Schema" tab is also selected at the bottom. The overall interface is clean and modern, typical of a Mac OS X application.

DB Browser for SQLite - /Users/csev/sql1

New Database Open Database Write Changes Revert Changes

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 2 DELETE FROM U

name email

Filter Filter

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

Query executed successfully (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 illustrates the relationship between the data and its schema. The yellow arrow serves as a visual cue, pointing from the data view on the left to the schema view on the right, emphasizing how the two are interconnected.

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

DB Browser for SQLite - /Users/csev/sql1

New Database Open Database Write Changes Revert Changes

Database Structure Browse

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
email='csev@umich.edu' (took 0ms)

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

DB Schema

Name Type Schema

Tables (1)
Users
Indices (0)
Views (0)
Triggers (0)

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

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

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)

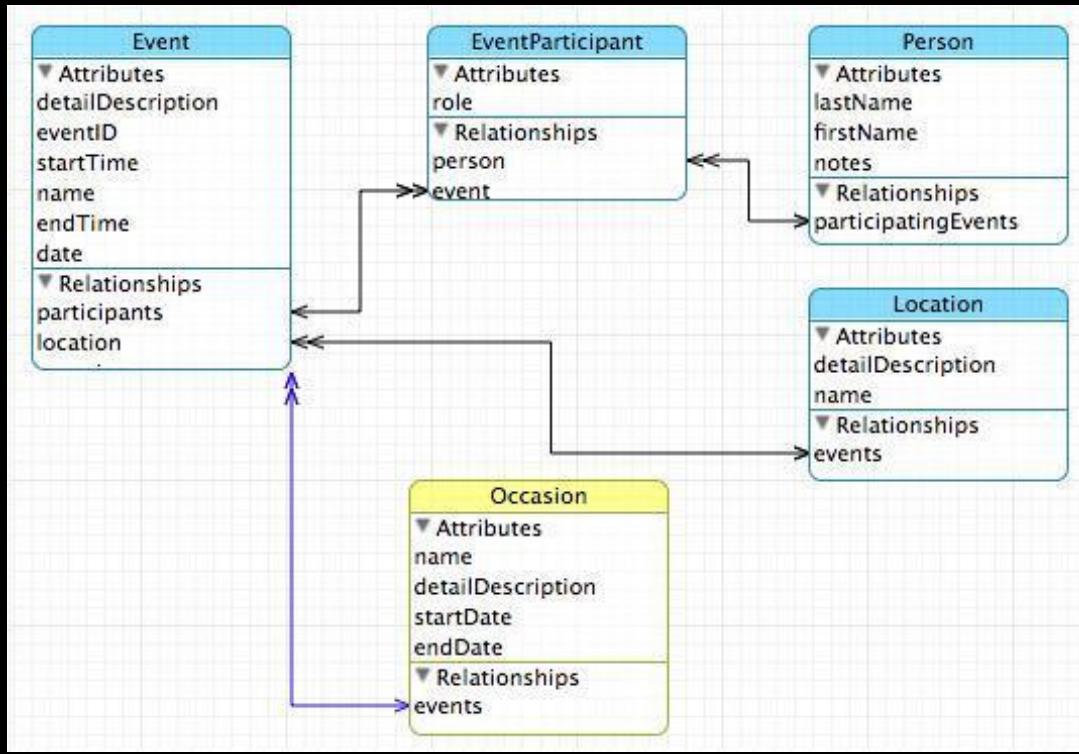
- Tables pretty much look like big fast programmable spreadsheets with rows, columns, and commands
- The power comes when we have more than one table and we can exploit the relationships between the tables

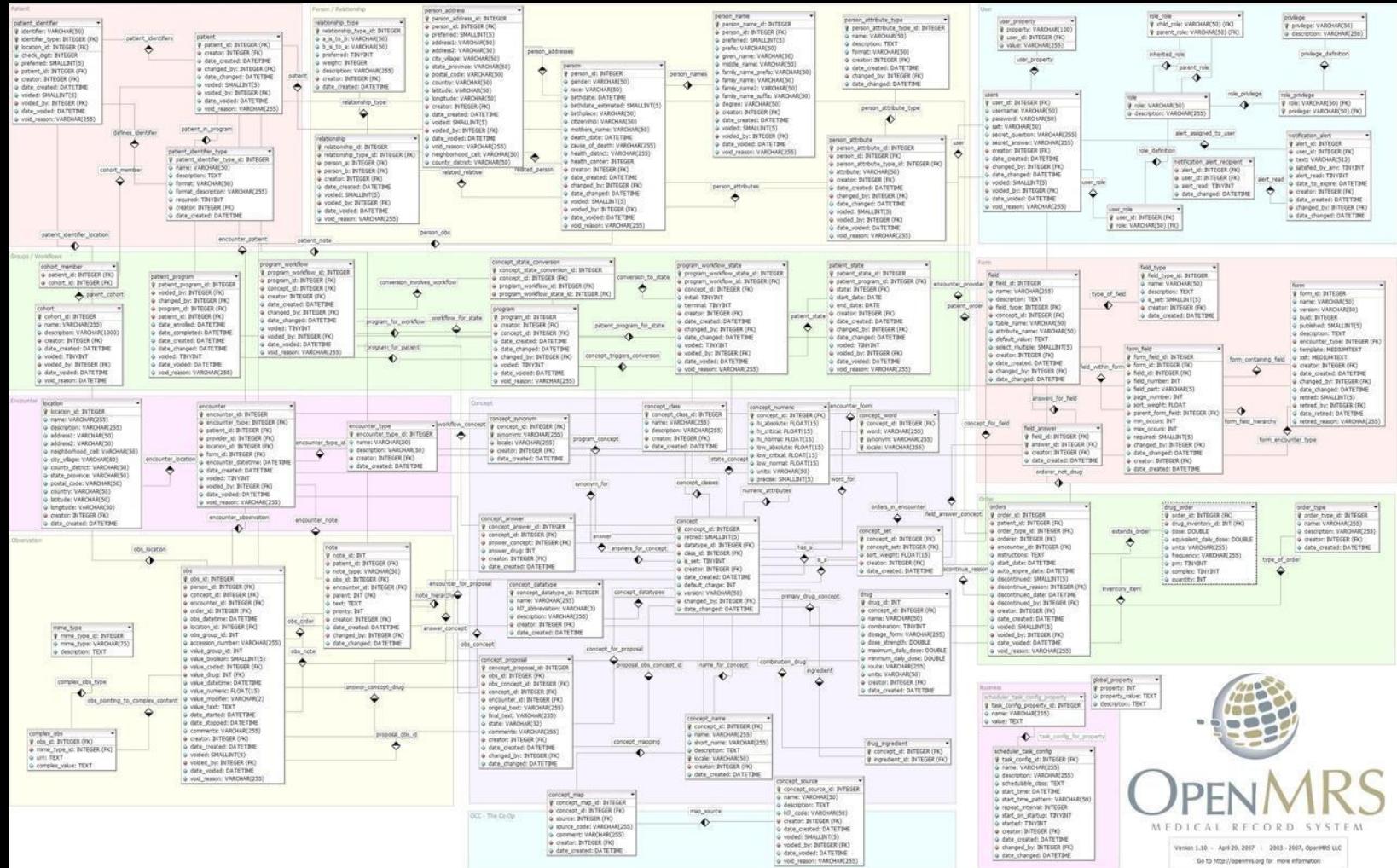
Complex Data Models and Relationships

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 20, 2007 | 2003-2007, OpenMRS User

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
Track	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"/> Tie Me	2:20	America	Greatest Hits	Easy Listen...	★★★★★	22

Track
Album
Artist
Genre
Rating
Len
Count

Artist

belongs-to

Album

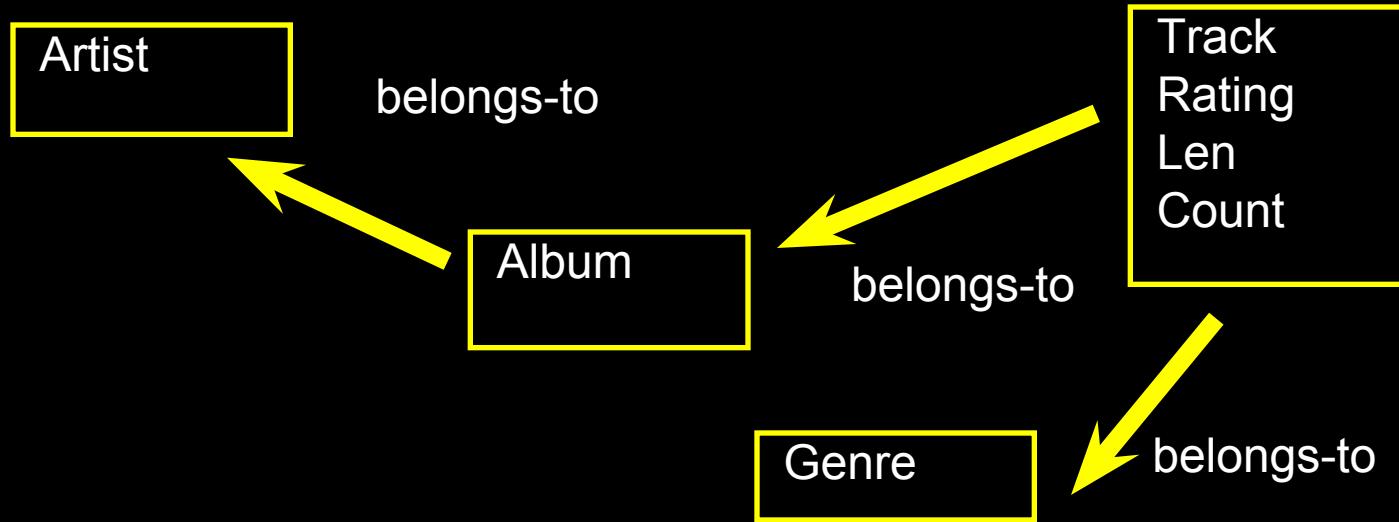
belongs-to

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"/> 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
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<input checked="" type="checkbox"/> Tie Man	2:30	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
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<input checked="" type="checkbox"/> For Those About To Rock (We ...	5:54	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	2:30	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	★★★★★	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 type="checkbox"/> Tie Me	3:20	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

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

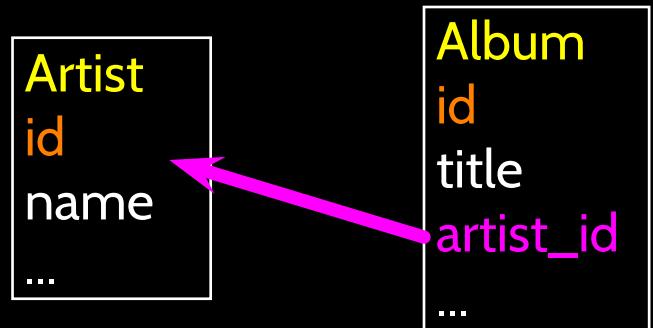
Best practices

- 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

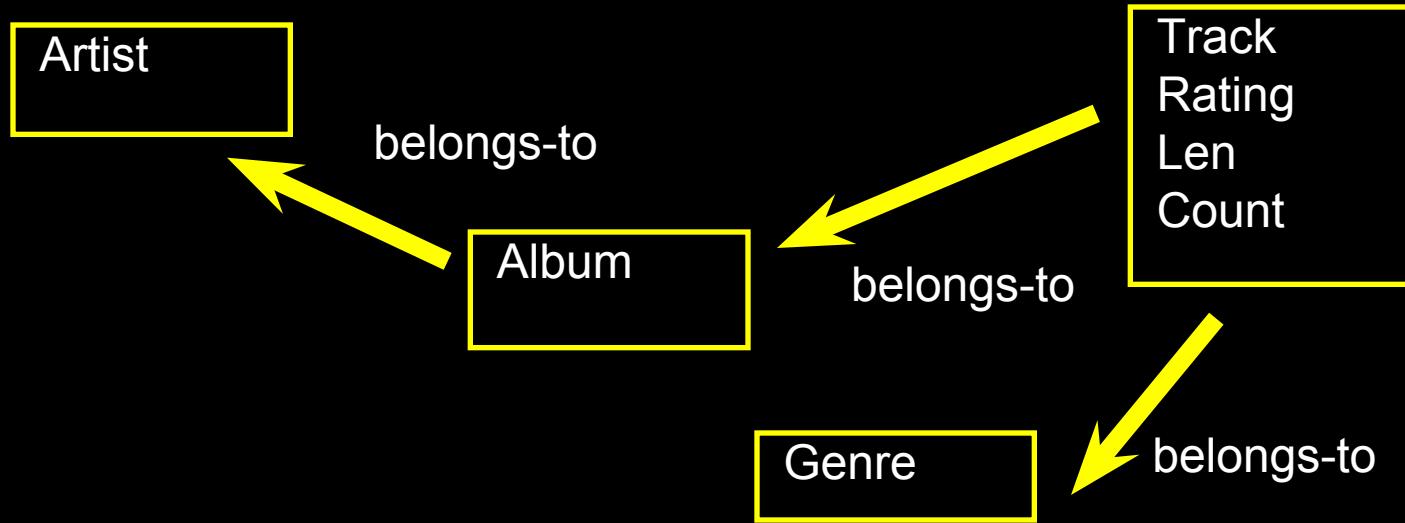
```
User
id
login
password
name
email
created_at
modified_at
login_at
```

Foreign Keys

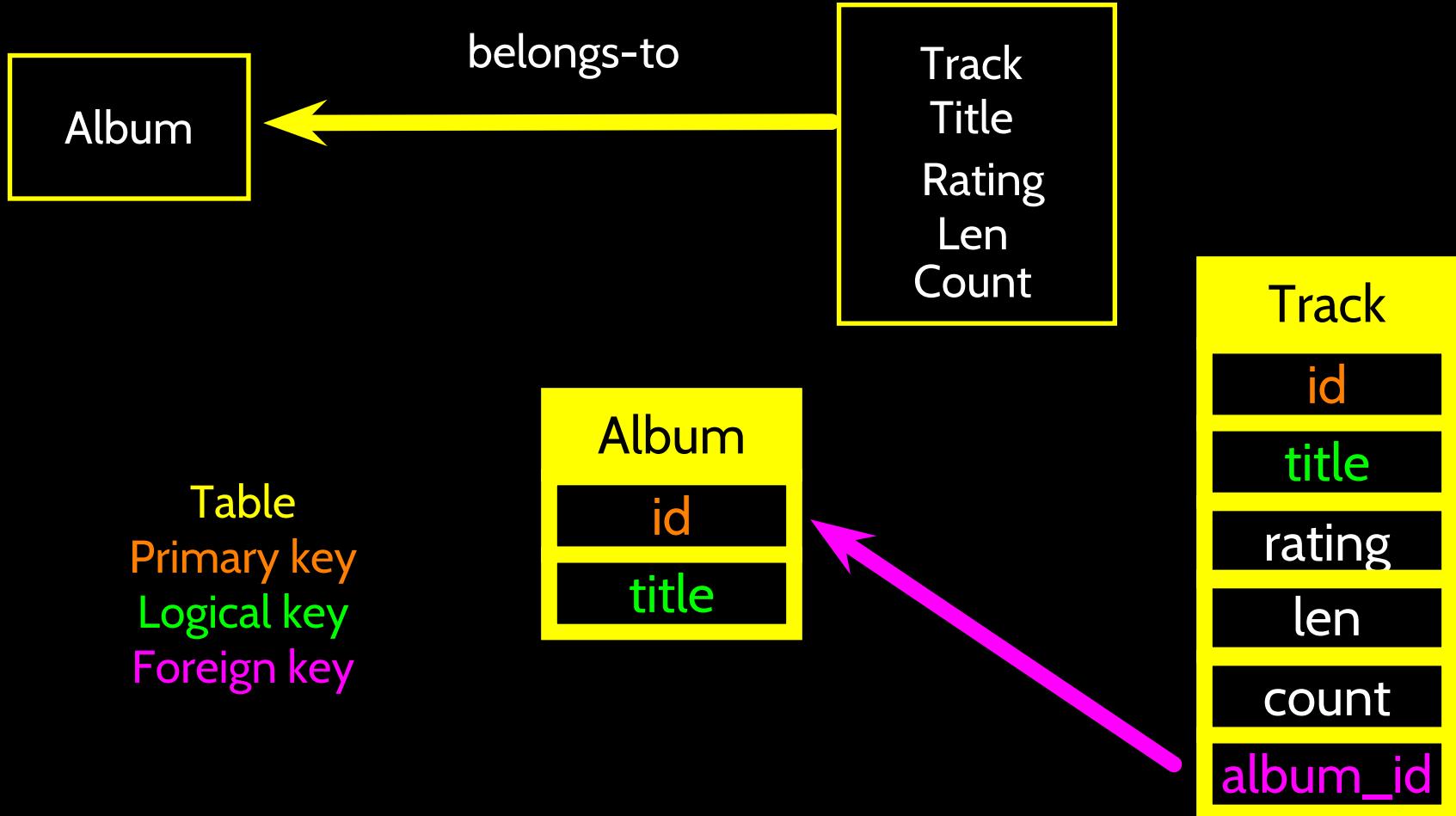
- A **foreign key** is when a table has a column that contains a key which points to the **primary key** of another table.
- When all primary keys are integers, then all foreign keys are integers - this is good - very good

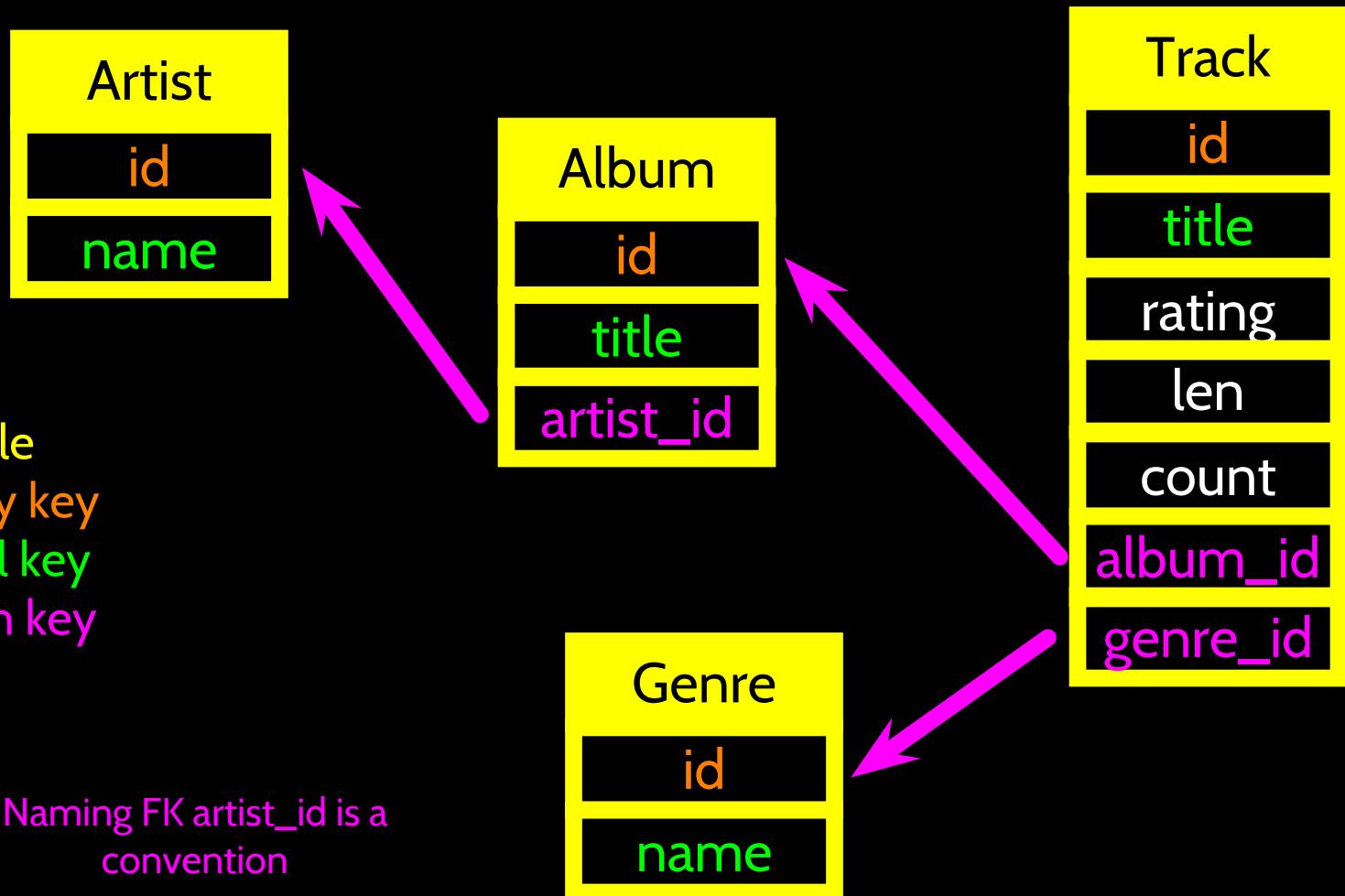


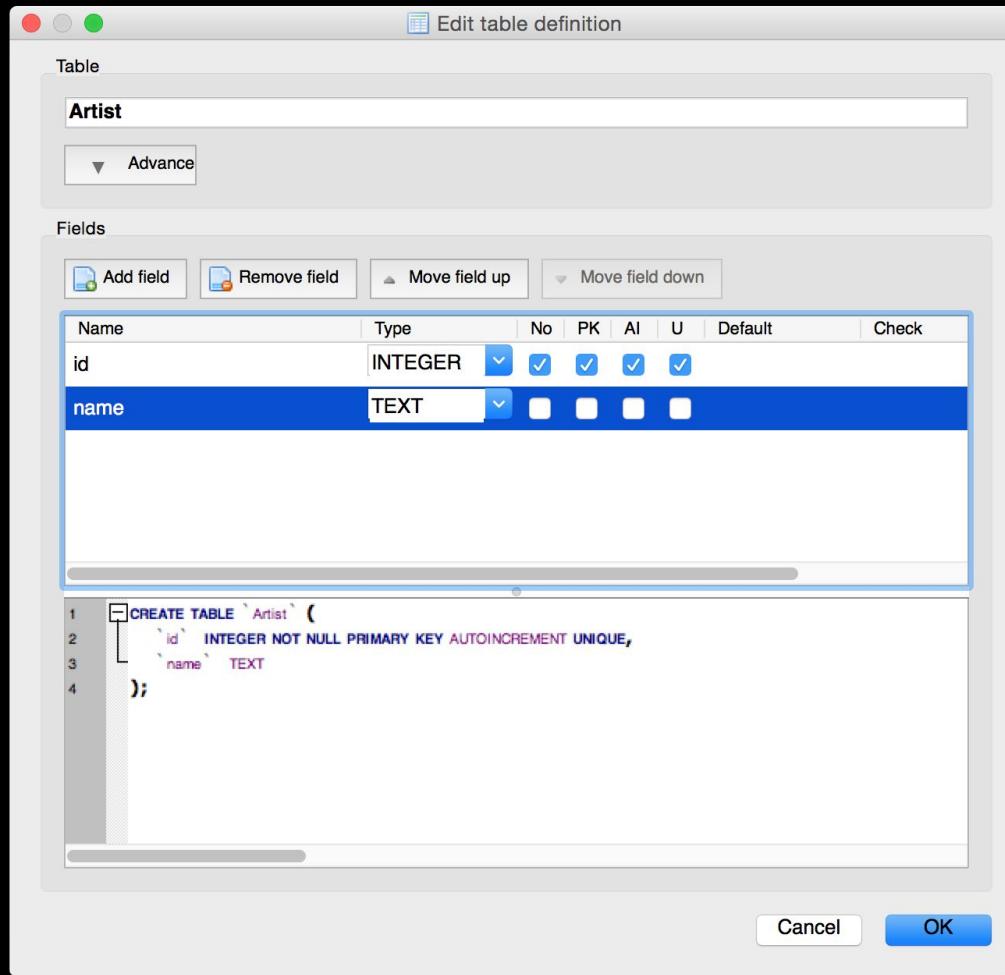
Relationship Building (in tables)



<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	2:30	America	Greatest Hits	Easy Listen...		22







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)

DB Schema

Name	Type	Schema
Tables (2)		
Artist		CREATE TABLE 'Artist' ('id' ...
id	INTEGER	'id' INTEGER NOT NULL ...
name	TEXT	'name' TEXT
sqlite_sequence		CREATE TABLE sqlite_sequ...
Indices (1)		
sqlite_autoindex_1		
Views (0)		
Triggers (0)		

Plot DB Schema

UTF-8

The screenshot shows the DB Browser for SQLite interface. In the top bar, the title is "DB Browser for SQLite - /Users/csev/Desktop/Music". Below the title are menu items: New Database, Open Database, Write Changes, and Revert Changes. The main menu has tabs: Database Structure, Browse Data, Edit Pragmas, and Execute SQL, with Execute SQL being the active tab. On the left, there's a toolbar with icons for New Database, Open Database, Write Changes, and Revert Changes. Below the toolbar is a large text area labeled "SQL 1" containing the SQL code for creating a "Genre" table. The code is: "CREATE TABLE Genre (id INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT UNIQUE, name TEXT)". A message below the code says "Query executed successfully" followed by the table definition and "(took 0ms)". To the right of the SQL area is a "DB Schema" window. It has a tree view under "Tables (2)". Under the "Artist" table, there are two columns: "id" (type INTEGER) and "name" (type TEXT). There is also a "sqlite_sequence" table and an index named "sqlite_autoindex_1". The "DB Schema" tab is selected at the bottom of the window. The status bar at the bottom right shows "UTF-8".

```
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

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 (5)

- Album
 - id INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT UNIQUE
 - artist_id INTEGER
 - title TEXT
- Artist
 - id INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT UNIQUE
 - name TEXT
- Genre
 - id INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT UNIQUE
 - name TEXT
- Track
 - id INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT UNIQUE
 - title TEXT
 - album_id INTEGER
 - genre_id INTEGER
 - len INTEGER
 - rating INTEGER
 - count INTEGER

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

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

CREATE TABLE Genre (
 'id' INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT UNIQUE,
 'name' 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 Schema

Name Schema

Tables (5)

- Album
 - CREATE TABLE "Album" (
 'id' INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT UNIQUE,
 'artist_id' INTEGER,
 'title' TEXT
)
 - id INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT UNIQUE
artist_id INTEGER
title TEXT
- Artist
 - CREATE TABLE `Artist` (
 'id' INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT UNIQUE,
 'name' TEXT
)
 - id INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT UNIQUE
name TEXT
- Genre
 - CREATE TABLE Genre (
 'id' INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT UNIQUE,
 'name' TEXT
)
 - id INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT UNIQUE
name TEXT
- Track
 - 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
)
 - id INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT UNIQUE
title TEXT
album_id INTEGER
genre_id INTEGER
len INTEGER
rating INTEGER
count INTEGER

Indices (4)

- sqlite_sequence CREATE TABLE sqlite_sequence(name,seq)
- sqlite_autoindex_1
- sqlite_autoindex_2
- sqlite_autoindex_3

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 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_autoindex_1
- sqlite_autoindex_2
- sqlite_autoindex_3
- sqlite_autoindex_4

Views (0)

Triggers (0)

Plot DB Schema

UTF-8

```
CREATE TABLE Album (id INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT)
CREATE TABLE `Artist` (`id` INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT, `name` TEXT)
CREATE TABLE Genre (id INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT)
CREATE TABLE Track (id INTEGER NOT NULL PRIMARY KEY AUTOINCREMENT)
CREATE TABLE sqlite_sequence(name,seq)

sqlite_autoindex_1
sqlite_autoindex_2
sqlite_autoindex_3
sqlite_autoindex_4
```

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

The screenshot shows three instances of DB Browser for SQLite running simultaneously on a Mac OS X desktop. The leftmost window displays an SQL query in the 'Execute SQL' tab:

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

The middle window shows the 'Browse Data' tab for the 'Artist' table. It contains the following data:

	id	name
1	1	Led Zepplin
2	2	AC/DC

A yellow arrow points from the right side of the middle window towards the rightmost window.

The rightmost window shows the 'DB Schema' tab, listing the database's schema:

- Tables (5)
 - 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)
 - sqlite_sequence: CREATE TABLE sqlite_sequence(name,seq)
- Indices (4): sqlite_auto_, sqlite_auto_, sqlite_auto_, sqlite_auto_
- Views (0)
- Triggers (0)

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 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

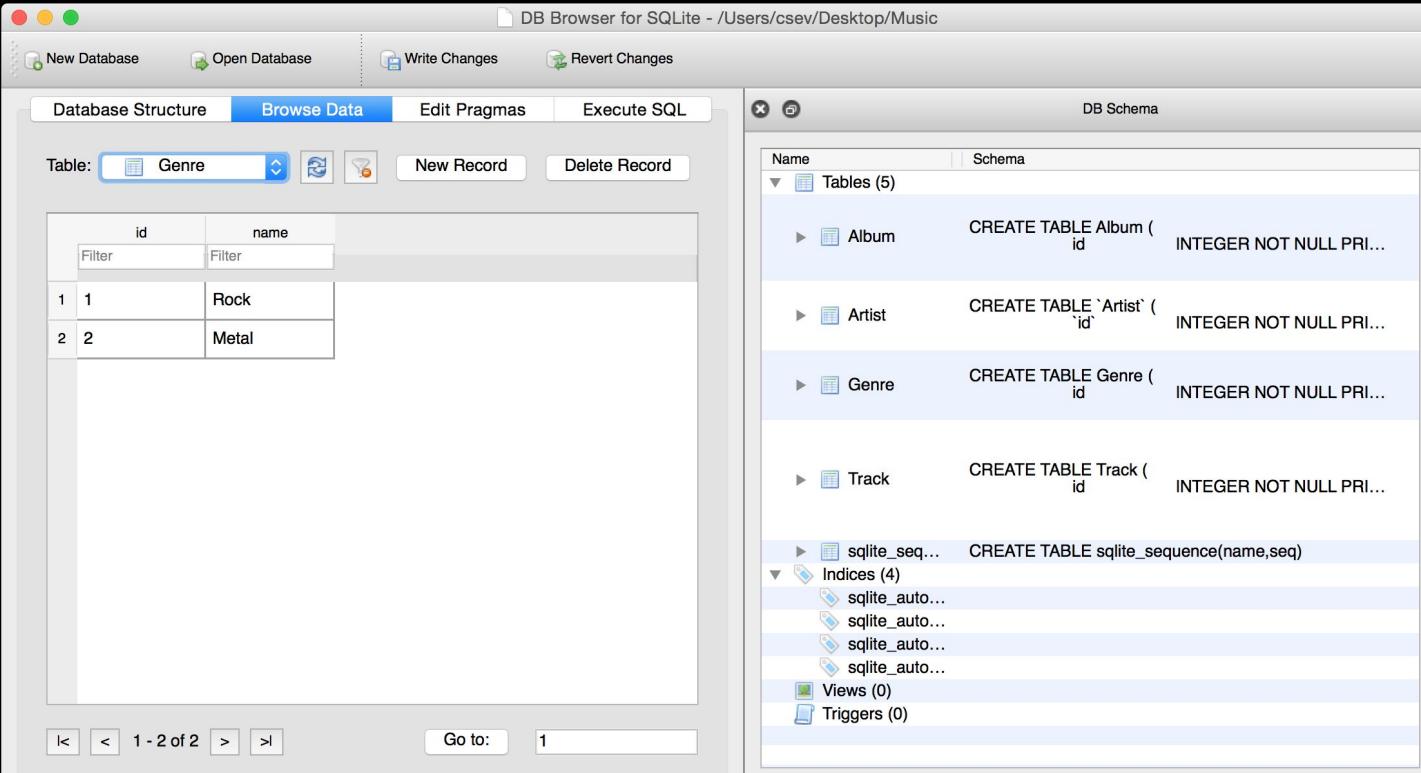
|< < 1 - 2 of 2 > >| Go to: 1

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 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

	<input type="text" value="id"/>	<input type="text" value="artist_id"/>	<input type="text" value="title"/>
	Filter	Filter	Filter
1	1	2	Who Made Who
2	2	1	IV

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

UTF-8

	<input type="text" value="id"/>	<input type="text" value="artist_id"/>	<input type="text" value="title"/>
	Filter	Filter	Filter
1	1	2	Who Made Who
2	2	1	IV

```
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**

id	artist_id	title
1	2	Who Made Who
2	1	IV

Album

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

Artist

id	name
1	Led Zepplin
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	
Filter	Filter	Filter	
1	2	Who Made Who	
2	1	IV	

id	name
Filter	Filter
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	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.

	title	name
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
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

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	2:26	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	5:08	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

Many-To-Many Relationships

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

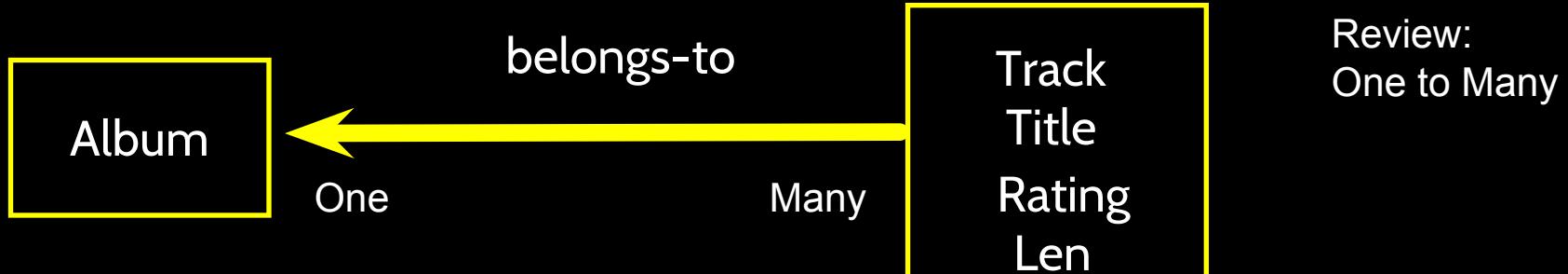
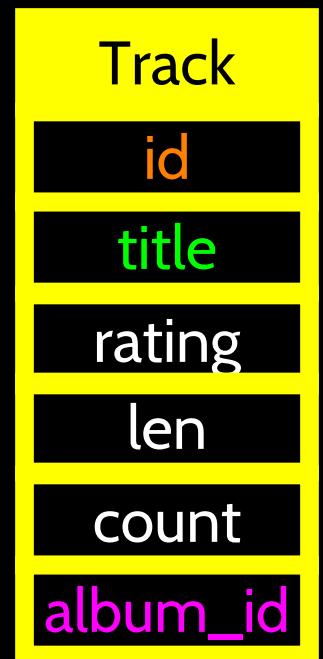


Table
Primary key
Logical key
Foreign key



One
Many





id	name
1	Rock
2	Metal

One

One

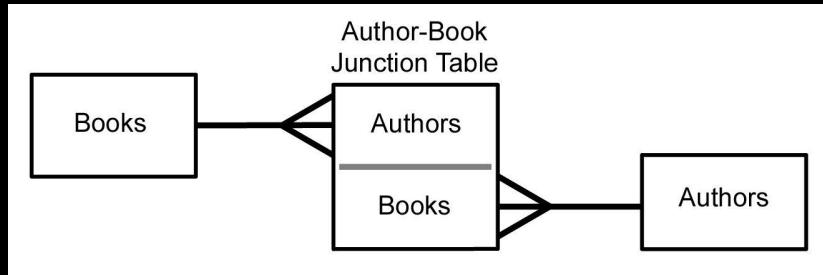
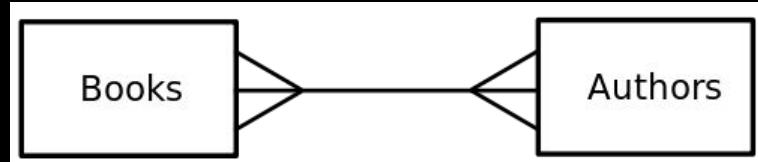
Many

Many

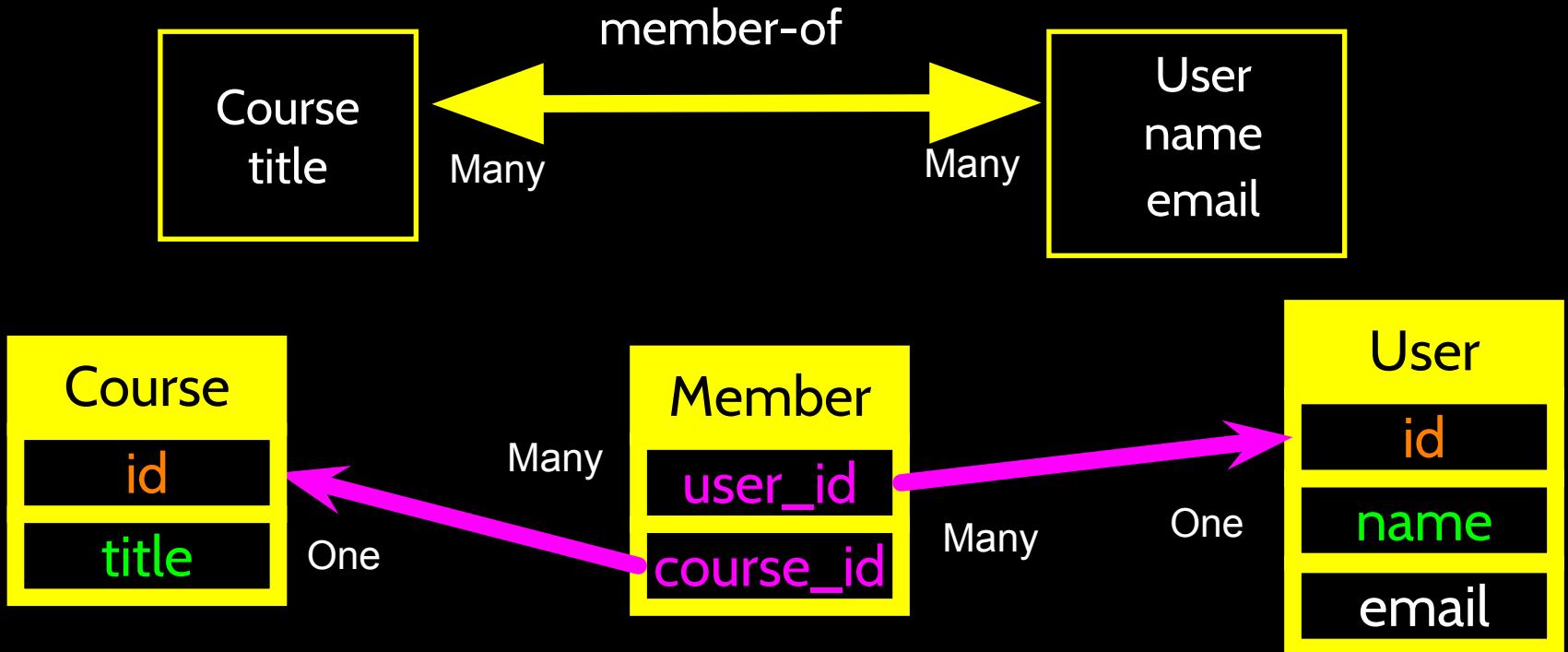
id	title	album_id	genre_id	len	rating	count
1	Black Dog	2	1	297	5	0
2	Stairway	2	1	482	5	0
3	About to Rock	1	2	313	5	0
4	Who Made Who	1	2	207	5	0

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 UNIQUE,
    email   TEXT
)
```

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

```
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 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
	Filter	Filter	Filter
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

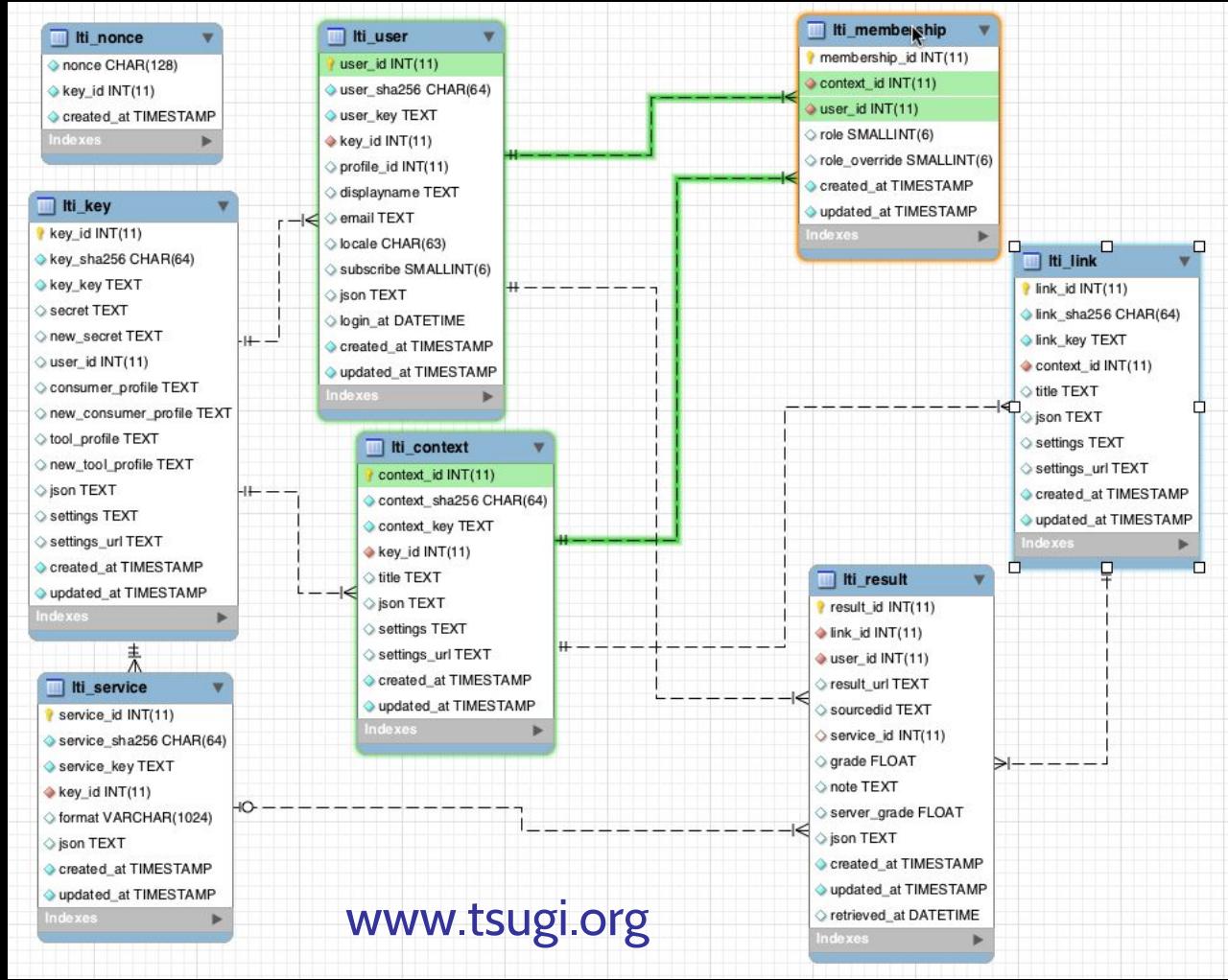
user_id	course_id	role
Filter	Filter	Filter
1	1	1
2	1	0
3	1	0
1	2	0
2	2	1
2	3	1
3	3	0

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 much 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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