Database Programming (Part 1)

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Objectives

- We will cover:
  - **Databases** (**DBs**) and **database management systems** (**DBMSs**)…
  - With a focus on **relational** DBs and DBMSs…
  - With a focus on the **SQLite** DBMS…
  - With a focus on **programming** with SQLite

Agenda

- **Relational DBs and DBMSs**
- SQL and SQLite
- The SQLite command-line client
  - Fundamentals
  - Selecting data
  - Selecting data advanced
  - Changing data
  - Reading & writing

Relational DBs and DBMSs

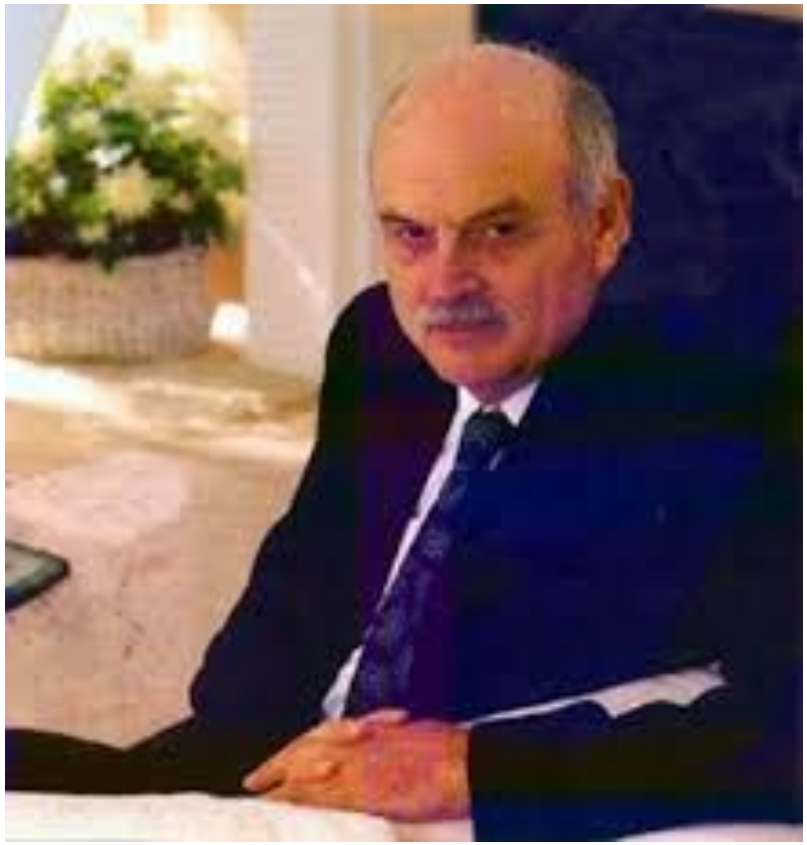
- ***Database*** (***DB***)
  - A structured collection of persistent data
- ***Database management system*** (***DBMS***)
  - Software that maintains DBs
- ***Database administrator*** (***DBA***)
  - A person who administers DBs and DBMSs

Relational DBs and DBMSs

- A good DBMS used by good DBAs can:
  - Reduce redundancy
  - Avoid inconsistencies
  - Facilitate data sharing
  - Enforce standards
  - Apply security restrictions
  - Maintain integrity
  - Balance conflicting requirements
  - Insure safety (backups)

An Introduction to Database Systems, C. J. Date

Relational DBs and DBMSs



Edgar Codd

Relational DBs and DBMSs

Relational DB structure:

Formally	Informally
Relations	Tables
Tuples	Rows
Attributes	Fields

Relational DBs and DBMSs

BOOKS

isbn	title	quantity
123	The Practice of Programming	500
234	The C Programming Language	800
345	Algorithms in C	650

AUTHORS

isbn	author
123	Kernighan
123	Pike
234	Kernighan
234	Ritchie
345	Sedgewick

ORDERS

isbn	custid	quantity
123	222	20
345	222	100
123	111	30

CUSTOMERS

custid	custname	street	zipcode
111	Princeton	114 Nassau St	08540
222	Harvard	1256 Mass Ave	02138
333	MIT	292 Main St	02142

ZIPCODES

zipcode	city	state
08540	Princeton	NJ
02138	Cambridge	MA
02142	Cambridge	MA

Agenda

- Relational DBs and DBMSs
- **SQL and SQLite**
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  - Fundamentals
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  - Reading & writing

SQL and SQLite

SQL

Donald Chamberlin

Raymond Boyce

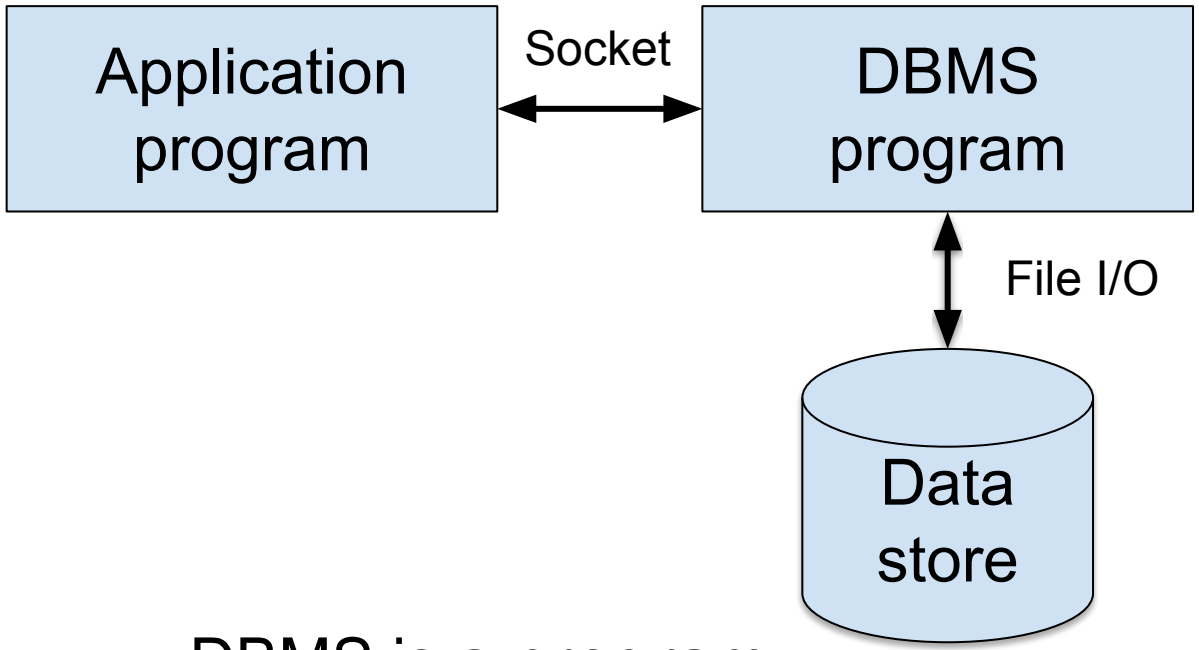
SQL and SQLite

SQLite

D. Richard Hipp

SQL and SQLite

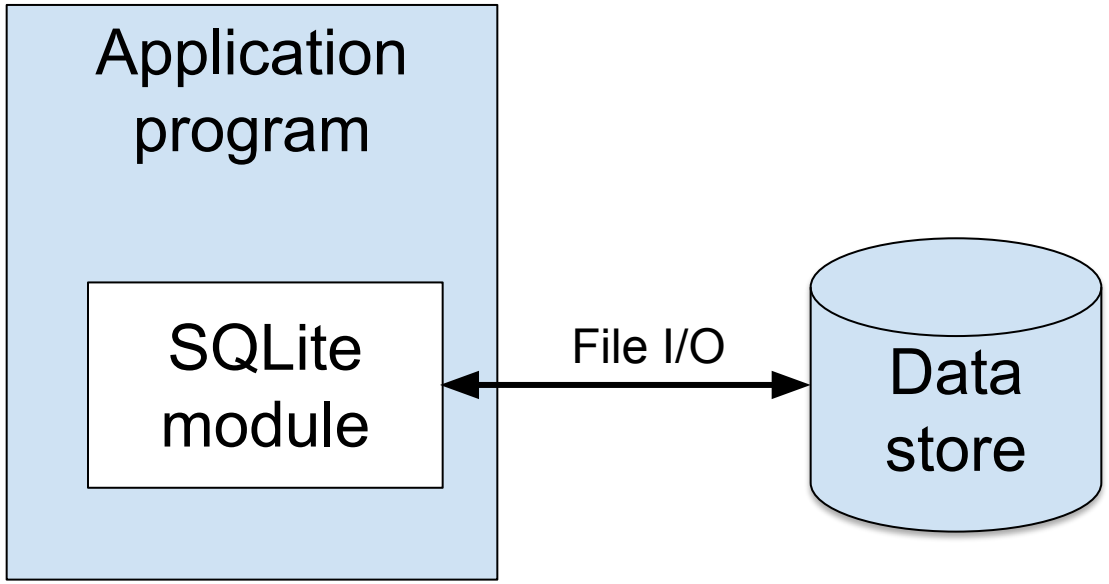
Typical architecture when using a DBMS:



DBMS is a **program**

SQL and SQLite

Typical architecture when using SQLite:



DBMS is a **module**

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- Relational DBs and DBMSs
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- **The SQLite command-line client**
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  - Selecting data advanced
  - Changing data
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SQLite Client

- **Question**: How does one use SQLite?

- **Answer**: In this course:
  - Via the SQLite command-line client
  - Via programs that you compose

SQLite Client

- The `sqlite3` program

```
$ sqlite3 bookstore.sqlite
SQLite version 3.45.1 2024-01-30 16:01:20
Enter ".help" for usage hints.
sqlite>
```

SQLite Client

Standard SQL Statements	SQLite Statements
Do not begin with a period	Begin with a period
Contain keywords are case insensitive	Contain keywords are case sensitive
Must end with a semicolon	Need not end with a semicolon

Agenda

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Agenda

- **Assumptions**
  - The bookstore.sqlite file already exists
  - The bookstore.sqlite file contains the bookstore DB (as previously described)
    - Tables named books, authors, orders, customers, and zipcodes
  - We issued this command:

```
$ sqlite3 bookstore.sqlite
SQLite version 3.45.1 2024-01-30 16:01:20
Enter ".help" for usage hints.
sqlite>
```

SQLite Client: Fundamentals

.help

```
sqlite> .help
.dump ?TABLE? ...      Dump the database in an SQL text format
                         If TABLE specified, only dump tables matching
                         LIKE pattern TABLE.
.help                  Show this message
.output ?FILE?         Send output to FILE or stdout
.quit                  Exit this program
.read FILENAME         Execute SQL in FILENAME
.schema ?PATTERN?      Show the CREATE statements matching PATTERN
                          Add --indent for pretty-printing
.tables ?TABLE?        List names of tables
                         If TABLE specified, only list tables matching
                         LIKE pattern TABLE.
…
sqlite>
```

SQLite Client: Fundamentals

.tables

```
sqlite> .tables
authors    books      customers  orders     zipcodes
sqlite>
```

.schema [*table*]

```
sqlite> .schema
CREATE TABLE books (isbn TEXT, title TEXT, quantity INTEGER);
CREATE TABLE authors (isbn TEXT, author TEXT);
CREATE TABLE customers (custid TEXT, custname TEXT, street TEXT,
zipcode TEXT);
CREATE TABLE zipcodes (zipcode TEXT, city TEXT, state TEXT);
CREATE TABLE orders (isbn TEXT, custid TEXT, quantity INTEGER);
sqlite> .schema books
CREATE TABLE books (isbn TEXT, title TEXT, quantity INTEGER);
sqlite>
```

SQLite Client: Fundamentals

SQLite Data Type	Python Data Type
INTEGER	int
REAL	float
TEXT	str
BLOB	bytes

Python: `None`
SQLite: `NULL`

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SQLite Client: Selecting Data

SELECT *expr*, … FROM *table*, … [WHERE *condition*]
[ORDER BY *column* [ASC | DESC]];

```
sqlite> SELECT * FROM books;
123|The Practice of Programming|500
234|The C Programming Language|800
345|Algorithms in C|650
sqlite> SELECT isbn, title FROM books;
123|The Practice of Programming
234|The C Programming Language
345|Algorithms in C
sqlite> SELECT * FROM books ORDER BY quantity DESC;
234|The C Programming Language|800
345|Algorithms in C|650
123|The Practice of Programming|500
sqlite>
```

Note: The result is a table

SQLite Client: Selecting Data

`WHERE` clauses:

```
sqlite> SELECT * FROM books WHERE quantity=650;
345|Algorithms in C|650
sqlite> SELECT * FROM books WHERE quantity>=650;
234|The C Programming Language|800
345|Algorithms in C|650
sqlite> SELECT * FROM orders WHERE isbn=123 AND custid=222;
123|222|20
sqlite> SELECT * FROM orders WHERE isbn=123 OR custid=222;
123|222|20
345|222|100
123|111|30
sqlite>
```

SQLite Client: Selecting Data

Joining tables:

```
sqlite> SELECT * from books, authors;
123|The Practice of Programming|500|123|Kernighan
123|The Practice of Programming|500|123|Pike
123|The Practice of Programming|500|234|Kernighan
123|The Practice of Programming|500|234|Ritchie
123|The Practice of Programming|500|345|Sedgewick
234|The C Programming Language|800|123|Kernighan
234|The C Programming Language|800|123|Pike
234|The C Programming Language|800|234|Kernighan
234|The C Programming Language|800|234|Ritchie
234|The C Programming Language|800|345|Sedgewick
345|Algorithms in C|650|123|Kernighan
345|Algorithms in C|650|123|Pike
345|Algorithms in C|650|234|Kernighan
345|Algorithms in C|650|234|Ritchie
345|Algorithms in C|650|345|Sedgewick
sqlite>
```

Cartesian product

SQLite Client: Selecting Data

More reasonable joining of tables:

```
sqlite> SELECT * from books, authors WHERE
books.isbn=authors.isbn;
123|The Practice of Programming|500|123|Kernighan
123|The Practice of Programming|500|123|Pike
234|The C Programming Language|800|234|Kernighan
234|The C Programming Language|800|234|Ritchie
345|Algorithms in C|650|345|Sedgewick
sqlite>
```

SQLite Client: Selecting Data

Qualifying fields:

```
sqlite> SELECT title, quantity FROM books,
orders WHERE books.isbn=orders.isbn;
Error: ambiguous column name: quantity
sqlite> SELECT title, orders.quantity FROM
books, orders WHERE books.isbn=orders.isbn;
The Practice of Programming|20
The Practice of Programming|30
Algorithms in C|100
sqlite>
```

SQLite Client: Selecting Data

Joining more than 2 tables:

```
sqlite> SELECT custname, title, orders.quantity
FROM books, customers, orders WHERE
books.isbn=orders.isbn AND
orders.custid=customers.custid;
Harvard|The Practice of Programming|20
Harvard|Algorithms in C|100
Princeton|The Practice of Programming|30
sqlite>
```

SQLite Client: Selecting Data Adv

Joining tables with “missing rows”:

```
sqlite> SELECT * FROM books, orders WHERE
books.isbn=orders.isbn;
123|The Practice of Programming|500|123|111|30
123|The Practice of Programming|500|123|222|20
345|Algorithms in C|650|345|222|100
sqlite>
```

SQLite Client: Selecting Data Adv

Joining tables with “missing rows” (cont.):

```
123|The Practice of Programming|500|123|222|20
123|The Practice of Programming|500|345|222|100
123|The Practice of Programming|500|123|111|30
234|The C Programming Language|800|123|222|20
234|The C Programming Language|800|345|222|100
234|The C Programming Language|800|123|111|30
345|Algorithms in C|650|123|222|20
345|Algorithms in C|650|345|222|100
345|Algorithms in C|650|123|111|30
```

No row for the book with isbn 234 is in result table

Beware (Assignment 1):

In reg.sqlite some courses have no professors

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  - **Selecting data advanced**
  - Changing data
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SQLite Client: Selecting Data Adv

The `LIKE` operator and wildcards:

```
sqlite> SELECT * FROM books WHERE title LIKE 'The%';
123|The Practice of Programming|500
234|The C Programming Language|800
sqlite> SELECT * FROM books WHERE title LIKE '%of%';
123|The Practice of Programming|500
sqlite> SELECT * FROM books WHERE title LIKE 'T_e%';
123|The Practice of Programming|500
234|The C Programming Language|800
sqlite>
```

`%` matches any 0 or more characters

`_` matches any 1 character

SQLite Client: Selecting Data Adv

Case (in)sensitivity:

```
sqlite> SELECT * FROM authors WHERE author="Pike";
123|Pike
sqlite> SELECT * FROM authors WHERE author="pike";
sqlite> SELECT * FROM books WHERE title LIKE 't_e%';
123|The Practice of Programming|500
234|The C Programming Language|800
sqlite> PRAGMA case_sensitive_like=ON;
sqlite> SELECT * FROM books WHERE title LIKE 't_e%';
sqlite>
```

= is case sensitive

`LIKE` is case insensitive by default

Aside: Escape Char

C, Java, and Python define backslash as the ***escape char***

> Within a string literal, the char following the escape char is not a special char

```
"abc\"def"
```

> The second double quote char doesn't delimit the string, but instead is an ordinary char within the string

SQL doesn't define an escape char, but…

SQLite Client: Selecting Data Adv

The `ESCAPE` clause for the `LIKE` operator

```
sqlite> SELECT * FROM books WHERE title LIKE 'The%';
123|The Practice of Programming|500
234|The C Programming Language|800
sqlite> SELECT * FROM books WHERE title LIKE 'The\%' ESCAPE '\';
sqlite>
```

SQLite Client: Selecting Data Adv

Creating indices:

```
CREATE INDEX index ON table (field);
```

```
sqlite> CREATE INDEX books_index ON books (isbn);
sqlite> .schema books
CREATE TABLE books
(isbn TEXT, title TEXT, quantity INTEGER);
CREATE INDEX books_index ON books (isbn);
sqlite>
```

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SQLite Client: Changing Data

UPDATE ***table*** **SET** ***column1=expr1*** **[,** ***column2=expr2*** **…]**
[WHERE ***condition***]

```
sqlite> UPDATE books SET quantity=60 WHERE isbn=123;
sqlite> SELECT * from books;
123|The Practice of Programming|60
234|The C Programming Language|800
345|Algorithms in C|650
sqlite> UPDATE books SET quantity=quantity+1 WHERE isbn=123;
sqlite> SELECT * from books;
123|The Practice of Programming|61
234|The C Programming Language|800
345|Algorithms in C|650
sqlite> UPDATE books SET quantity=500 WHERE isbn=123;
sqlite> SELECT * from books;
123|The Practice of Programming|500
234|The C Programming Language|800
345|Algorithms in C|650
sqlite>
```

SQLite Client: Changing Data

INSERT INTO *table* (*column*, …) VALUES (*expr*, …);

```
sqlite> INSERT INTO books (isbn, title, quantity) VALUES
('456', 'Core Java', 120);
sqlite> SELECT * from books;
123|The Practice of Programming|500
234|The C Programming Language|800
345|Algorithms in C|650
456|Core Java|120
sqlite>
```

SQLite Client: Changing Data

DELETE FROM *table* [WHERE *condition*];

```
sqlite> DELETE FROM books WHERE isbn=456;
sqlite> SELECT * FROM books;
123|The Practice of Programming|500
234|The C Programming Language|800
345|Algorithms in C|650
sqlite> DELETE FROM books;
sqlite> SELECT * FROM books;
sqlite>
```

SQLite Client: Changing Data

DROP TABLE [IF EXISTS] ***table***

```
sqlite> DROP TABLE books;
sqlite> .tables
authors    customers  orders     zipcodes
sqlite>
```

SQLite Client: Changing Data

CREATE TABLE [IF NOT EXISTS] ***table***
(*column datatype*, …);

```
sqlite> CREATE TABLE books (isbn TEXT, title TEXT,
quantity INTEGER);
sqlite> INSERT INTO books (isbn, title, quantity)
VALUES ('123','The Practice of Programming',500);
sqlite> INSERT INTO books (isbn, title, quantity)
VALUES ('234','The C Programming Language',800);
sqlite> INSERT INTO books (isbn, title, quantity)
VALUES ('345','Algorithms in C',650);
sqlite> SELECT * FROM books;
123|The Practice of Programming|500
234|The C Programming Language|800
345|Algorithms in C|650
sqlite>
```

SQLite Client: Changing Data

ALTER TABLE ***table specification*** **[,** ***specification*****]** **…;**

```
sqlite> ALTER TABLE books ADD COLUMN price INTEGER;
sqlite> .schema books
CREATE TABLE books
(isbn TEXT, title TEXT, quantity INTEGER, price INTEGER);
sqlite> SELECT * FROM books;
123|The Practice of Programming|500|
234|The C Programming Language|800|
345|Algorithms in C|650|
sqlite>
```

SQLite Client: Changing Data

```
sqlite> ALTER TABLE books DELETE COLUMN price;
Error: near "DELETE": syntax error
```

```
sqlite> ALTER TABLE books RENAME TO books2;
sqlite> CREATE TABLE books (isbn TEXT, title TEXT, quantity
INTEGER);
sqlite> INSERT INTO books (isbn, title, quantity) SELECT isbn,
title, quantity from books2;
sqlite> DROP TABLE books2;
sqlite> .schema books
CREATE TABLE books
(isbn TEXT, title TEXT, quantity INTEGER);
sqlite>
```

SQLite Client: Changing Data

`.quit`

```
sqlite> .quit
$
```

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- Relational DBs and DBMSs
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  - Changing data
  - **Reading & writing**

SQLite Client: Reading & Writing

To read SQL statements from a text file:

```
$ cat bookstore.sql
CREATE TABLE books
(isbn TEXT, title TEXT, quantity INTEGER);

INSERT INTO books (isbn, title, quantity)
   VALUES ('123','The Practice of Programming',500);
INSERT INTO books (isbn, title, quantity)
   VALUES ('234','The C Programming Language',800);
INSERT INTO books (isbn, title, quantity)
   VALUES ('345','Algorithms in C',650);

CREATE TABLE authors (isbn TEXT, author TEXT);
…
$
```

SQLite Client: Reading & Writing

To read SQL statements from a text file (cont.):

```
$ sqlite3 bookstore.sqlite
sqlite> .read bookstore.sql
sqlite> .quit
$
```

SQLite Client: Reading & Writing

To write SQL statements to a text file:

```
$ sqlite3 bookstore.sqlite
sqlite> .output bookstorebackup.sql
sqlite> .dump
sqlite> .quit
$
```

SQLite Client: Reading & Writing

Resulting file:

```
$ cat bookstorebackup.sql
…
CREATE TABLE books (isbn TEXT, title TEXT, quantity INTEGER);
INSERT INTO books VALUES('123','The Practice of Programming',500);
INSERT INTO books VALUES('234','The C Programming Language',800);
INSERT INTO books VALUES('345','Algorithms in C',650);
CREATE TABLE authors (isbn TEXT, author TEXT);
…
$
```

SQLite Client: Reading & Writing

- **Question**: How does one use SQLite?
- **Answer**: In this course:
  - Via the SQLite command-line client
  - Via programs that you compose…

Summary

- We have covered:
  - Relational DBs and DBMSs
  - SQL and SQLite
  - The SQLite command-line client
- See also:
  - **Appendix 1**: Fancy SQL Joins

Appendix 1:
Fancy SQL Joins

Fancy SQL Joins

Recall:

```
sqlite> SELECT * FROM books;
123|The Practice of Programming|500
234|The C Programming Language|800
345|Algorithms in C|650
sqlite>
```

```
sqlite> SELECT * FROM orders;
123|222|20
345|222|100
123|111|30
sqlite>
```

```
sqlite> SELECT * FROM books, orders;
123|The Practice of Programming|500|123|222|20
123|The Practice of Programming|500|345|222|100
123|The Practice of Programming|500|123|111|30
234|The C Programming Language|800|123|222|20
234|The C Programming Language|800|345|222|100
234|The C Programming Language|800|123|111|30
345|Algorithms in C|650|123|222|20
345|Algorithms in C|650|345|222|100
345|Algorithms in C|650|123|111|30
sqlite>
```

Cartesian product

Fancy SQL Joins

Ordinary SQL join

```
sqlite> SELECT * FROM books, orders WHERE
books.isbn=orders.isbn;
123|The Practice of Programming|500|123|111|30
123|The Practice of Programming|500|123|222|20
345|Algorithms in C|650|345|222|100
sqlite>
```

Conceptually, to compute result table:

- Compute Cartesian product of `books` and `orders`
- Retain only those rows in which `books.isbn = orders.isbn`

Fancy SQL Joins

Inner join

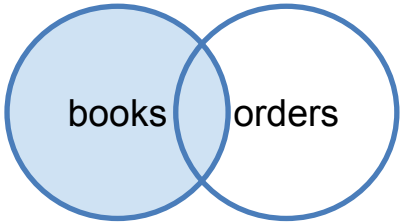
```
sqlite> SELECT * FROM books INNER JOIN orders
ON books.isbn=orders.isbn;
123|The Practice of Programming|500|123|111|30
123|The Practice of Programming|500|123|222|20
345|Algorithms in C|650|345|222|100
sqlite>
```

Same as ordinary join

Note: No row for book with `isbn` 234 is present

Fancy SQL Joins

Left outer join




```
sqlite> SELECT * FROM books LEFT OUTER JOIN
orders ON books.isbn=orders.isbn;
123|The Practice of Programming|500|123|111|30
123|The Practice of Programming|500|123|222|20
234|The C Programming Language|800|||
345|Algorithms in C|650|345|222|100
sqlite>
```

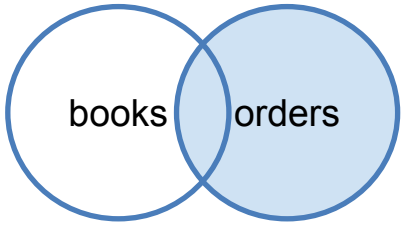
Conceptually, to compute result table:

- Compute inner join
- Add each `book` row that is missing, padded with `NULL` fields

Fancy SQL Joins

Right outer join

```
SELECT * from books
   RIGHT OUTER JOIN orders
   ON books.isbn = orders.isbn;
```



Conceptually, to compute result table:

- Compute inner join
- Add each `orders` row that is missing, padded with `NULL` fields

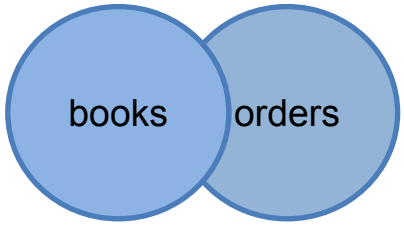
Not supported by SQLite

But could use left outer join with tables switched!

Fancy SQL Joins

Full outer join

```
SELECT * from books
    FULL OUTER JOIN orders
    ON books.isbn = orders.isbn;
```



Conceptually, to compute result table:

- Compute inner join
- Add each `book` row that is missing, padded with NULL fields
- Add each `orders` row that is missing, padded with NULL fields

Not supported by SQLite

Fancy SQL Joins

- Note:
  - COS 333 *assignments* do not require outer joins
  - Your COS 333 *project* probably will not require outer joins
  - But understanding outer joins may help you to better understand inner joins