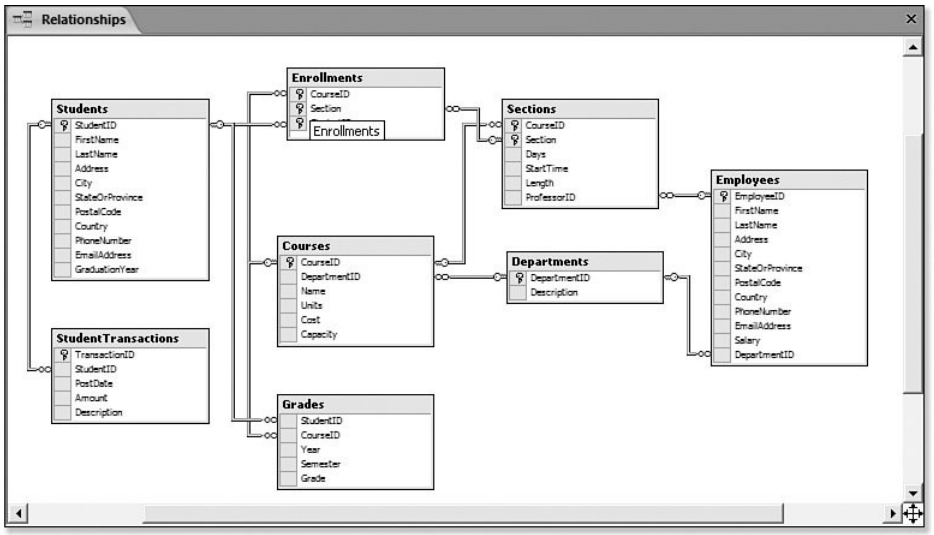
What is a database?

- **relational database**: A method of structuring data as **tables** associated to each other by shared attributes.
- a table **row** corresponds to a unit of data called a record; a **column** corresponds to an attribute of that record

- relational databases typically use Structured Query Language (**SQL**) to define, manage, and search data



Why use a database?

- **powerful**: can search, filter, combine data from many sources
- **fast**: can search/filter a database very quickly compared to a file
- **big**: scale well up to very large data sizes
- **safe**: built-in mechanisms for failure recovery (transactions)
- **multi-user**: concurrency features let many users view/edit data at same time
- **abstract**: layer of abstraction between stored data and app(s)
- **common syntax**: database programs use same SQL commands

Some database software

- **Oracle**
- Microsoft
  - **SQL Server** (powerful)
  - **Access** (simple)

- **PostgreSQL**
  - powerful/complex free open-source database system
- **SQLite**
  - transportable, lightweight free open-source database system
- **MySQL**
  - simple free open-source database system
  - many servers run "LAMP" (Linux, Apache, MySQL, and PHP)
  - Wikipedia is run on PHP and MySQL

Example database: school

id	name	email
123	Bart	bart@fox.com
456	Milhouse	milhouse@fox.com
888	Lisa	lisa@fox.com
404	Ralph	ralph@fox.com

students

id	name
1234	Krabappel
5678	Hoover
9012	Stepp

teachers

id	name	teacher_id
10001	Computer Science 142	1234
10002	Computer Science 143	5678
10003	Computer Science 190M	9012
10004	Informatics 100	1234

courses

student_id	course_id	grade
123	10001	B-
123	10002	C
456	10001	B+
888	10002	A+
888	10003	A+
404	10004	D+

grades

Example database: world

code	name	continent	independence_year	population	gnp	head_of_state	...
AFG	Afghanistan	Asia	1919	22720000	5976.0	Mohammad Omar	...
NLD	Netherlands	Europe	1581	15864000	371362.0	Beatrix	...
...	...	...	...	...	...	...	...

countries (Other columns: region, surface_area, life_expectancy, gnp_old, local_name, government_form, capital, code2)

id	name	country_code	district	population
3793	New York	USA	New York	8008278
1	Los Angeles	USA	California	3694820
...	...	...	...	...

cities

country_code	language	official	percentage
AFG	Pashto	T	52.4
NLD	Dutch	T	95.6
...	...	...	...

languages

Example database: imdb

id	first_name	last_name	gender
433259	William	Shatner	M
797926	Britney	Spears	F
831289	Sigourney	Weaver	F
...			

actors

id	name	year	rank
112290	Fight Club	1999	8.5
209658	Meet the Parents	2000	7
210511	Memento	2000	8.7
...			

movies

actor_id	movie_id	role
433259	313398	Capt. James T. Kirk
433259	407323	Sgt. T.J. Hooker
797926	342189	Herself
...		

roles

movie_id	genre
209658	Comedy
313398	Action
313398	Sci-Fi
...	

movies_genres

id	first_name	last_name
24758	David	Fincher
66965	Jay	Roach
72723	William	Shatner
...		

directors

director_id	movie_id
24758	112290
66965	209658
72723	313398
...	

movies_directors

SQL (link)

```
SELECT name FROM cities WHERE id = 17;
INSERT INTO countries VALUES ('SLD', 'ENG', 'T', 100.0);
```

- **Structured Query Language** (SQL): a language for searching and updating a database
  - a standard syntax that is used by all database software *(with minor incompatibilities)*
  - generally case-insensitive

- a **declarative language**: describes what data you are seeking, not exactly how to find it

The SELECT statement

```
SELECT column(s) FROM table WHERE condition;

SELECT name, population FROM cities
                        WHERE country_code = "FSM";
```

- searches a database and returns a set of results
  - column name(s) after SELECT filter which parts of rows are returned
  - table and column names are **case-sensitive**
  - `SELECT DISTINCT` removes any duplicates
  - `SELECT *` keeps all columns
- WHERE clause filters out rows based on columns' data values
  - in large databases, WHERE clause is critical to reduce result set size

WHERE clauses

```
SELECT name, gnp FROM countries WHERE gnp > 2000000;

SELECT * FROM cities WHERE code = 'USA'
                       AND population >= 2000000;

SELECT code, name, population FROM countries
WHERE  name LIKE 'United%';
```

- WHERE clause can use the following operators:

  =, >, >=, <, <=

  <> : not equal (some systems support !=)

  BETWEEN ***min*** AND ***max***

  LIKE ***pattern*** *(put % on ends to search for prefix/suffix/substring)*

  IN (***value***, ***value***, ..., ***value***)

  condition1 AND ***condition2*** ; ***condition1*** OR ***condition2***

ORDER BY, LIMIT

```
SELECT code, name, population FROM countries
WHERE name LIKE 'United%' ORDER BY population;

SELECT * FROM countries ORDER BY population DESC, gnp;

SELECT name FROM cities WHERE name LIKE 'K%' LIMIT 5;
```

- ORDER BY sorts in ascending (default) or descending order
  - can specify multiple orderings in decreasing order of significance

- LIMIT gets first N results of the query
  - useful as a sanity check to make sure query doesn't return 10^7 rows

Related tables

id	name	email
123	Bart	bart@fox.com
456	Milhouse	milhouse@fox.com
888	Lisa	lisa@fox.com
404	Ralph	ralph@fox.com

students

id	name	teacher_id
10001	Computer Science 142	1234
10002	Computer Science 143	**5678**
10003	Computer Science 190M	**9012**
10004	Informatics 100	1234

courses

student_id	course_id	grade
123	10001	B-
123	10002	C
456	10001	B+
888	**10002**	A+
888	**10003**	A+
404	10004	D+

grades

id	name
1234	Krabappel
5678	Hoover
9012	Stepp

teachers

- **primary key**: column guaranteed to be unique for each row (ID)
- **normalizing**: splitting tables to improve structure / redundancy

JOIN

```
SELECT column(s) FROM table1 name1
                 JOIN table2 name2 ON condition(s)
                 ...
                 JOIN tableN nameN ON condition(s)
                 WHERE condition;
```

```
SELECT name, course_id, grade
FROM students s
JOIN grades g ON s.id = g.student_id
WHERE s.name = 'Bart';
```

- JOIN combines related records from two or more tables
  - ON clause specifies which records from each table are matched
  - rows are often linked by their key columns ('id')
  - joins can be tricky to understand; out of scope of this course

Create/delete a database; CRUD

```
CREATE DATABASE name;
DROP DATABASE name;

CREATE DATABASE warcraft;
```

- Must first create a database and add one or more tables to it.

- Most apps/sites do four general tasks with data in a database:
  - **C**reate new rows
  - **R**ead existing data
  - **U**pdate / modify values in existing rows
  - **D**elete rows

Creating tables

```
CREATE TABLE IF NOT EXISTS name (
  columnName type constraints,
  ...
  columnName type constraints
);
DROP TABLE name;

CREATE TABLE students (
  id INTEGER,
  name VARCHAR(20),
  email VARCHAR(32),
  password VARCHAR(16)
);
```

BOOLEAN	either TRUE or FALSE
INTEGER	32-bit integer
DOUBLE	real number
VARCHAR(***length***)	string up to given length
ENUM(***val***, ..., ***val***)	a fixed set of values
DATE, TIME, DATETIME	timestamps (common value: NOW())
BLOB	binary data

- all columns' names and types must be listed *(see table above)*

Table column constraints

```
CREATE TABLE students (
  id INTEGER UNSIGNED NOT NULL PRIMARY KEY AUTO_INCREMENT,
  name VARCHAR(20) NOT NULL,
  email VARCHAR(32),
  password VARCHAR(16) NOT NULL DEFAULT "12345"
);
```

- NOT NULL: empty value not allowed in any row for that column
- PRIMARY KEY / UNIQUE: no two rows can have the same value
- DEFAULT ***value***: if no value is provided, use the given default
- AUTO_INCREMENT: default value is the last row's value plus 1
  - (usually used for ID column)
- UNSIGNED: don't allow negative numbers (INTEGER only)

INSERT and REPLACE

```
INSERT INTO table (columnName, ..., columnName)
VALUES (value, value, ..., value);

REPLACE INTO table (columnName, ..., columnName)
VALUES (value, value, ..., value);


INSERT INTO students (name, email)
VALUES ("Lewis", "lewis@fox.com");

REPLACE INTO students (id, name, value)
VALUES (789, "Martin", "prince@fox.com");
```

- some columns have default or automatic values (such as IDs)
- omitting them from the INSERT statement uses the defaults
- REPLACE is like INSERT but modifies an existing row

UPDATE

```
UPDATE table
SET column1 = value1,
    ...,
    columnN = valueN
WHERE condition;

UPDATE students
SET email = "lisasimpson@gmail.com"
WHERE id = 888;
```

- modifies an existing row(s) in a table
- Be careful! If you omit WHERE clause, it modifies ALL rows

DELETE

```
DELETE FROM table
WHERE condition;

DELETE FROM students
WHERE id = 888;
```

- removes existing row(s) in a table
- can be used with other syntax like LIMIT, LIKE, ORDER BY, etc.
- Be careful! If you omit WHERE clause, it deletes ALL rows

Modifying existing tables

```
ALTER TABLE name RENAME TO newName;

ALTER TABLE name
ADD COLUMN columnName type constraints;

ALTER TABLE name DROP COLUMN columnName;

ALTER TABLE name
CHANGE COLUMN oldColumnName newColumnName type constraints;
```

- SQL has many commands for modifying existing data
  - the above is not a complete reference

Android SQLiteDatabase (link)

```
SQLiteDatabase db = openOrCreateDatabase(
        "name", MODE_PRIVATE, null);
db.execSQL("SQL query");
```

- methods:
  - *db.*beginTransaction(), *db.*endTransaction()
  - *db.*delete("***table***", "***whereClause***", ***args***)
  - *db.*deleteDatabase(***file***)
  - *db.*insert("***table***", null, ***values***)
  - *db.*query(...)
  - *db.*rawQuery("***SQL query***", ***args***)
  - *db.*replace("***table***", null, ***values***)
  - *db.*update("***table***", ***values***, "***whereClause***", ***args***)

ContentValues (link)

```
ContentValues cvalues = new ContentValues();
cvalues.put("columnName1", value1);
cvalues.put("columnName2", value2);
...
db.insert("tableName", null, cvalues);
```

- `ContentValues` can be optionally used as a level of abstraction for statements like INSERT, UPDATE, REPLACE
  - meant to allow you to use cleaner Java syntax rather than raw SQL syntax for some common operations. Contrast the above with:

```
db.execSQL("INSERT INTO tableName ("
    + columnName1 + ", " + columnName2
    + ") VALUES (" + value1 + ", " + value2 + ")");
```

Cursor (link)

```
Cursor cursor = db.rawQuery("SELECT * FROM students");
cursor.moveToFirst();
do {
    int id = cursor.getInt(cursor.getColumnIndex("id"));
    String email = cursor.getString(
                        cursor.getColumnIndex("email"));
    ...
} while (cursor.moveToNext());
cursor.close();
```

- Cursor lets you iterate through row results one at a time
  - getBlob(*index*), getColumnCount(), getColumnIndex(name), getColumnName(*index*), getCount(), getDouble(*index*), getFloat(*index*), getInt(*index*), getLong(*index*), getString(*index*), moveToPrevious(), ...

Dictionary app exercise

- Write an app that lets the user look up words in a dictionary.
  - The dictionary should be created as a SQLite **database**.
  - When the user types in a word, if that exact word exists in the dictionary, show its definition.
  - If the exact word does not exist in the dictionary, list all words of which the user's text is a substring.