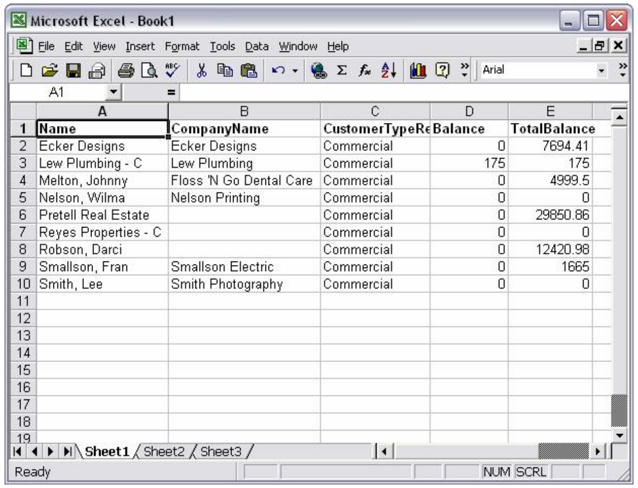
CS 193A

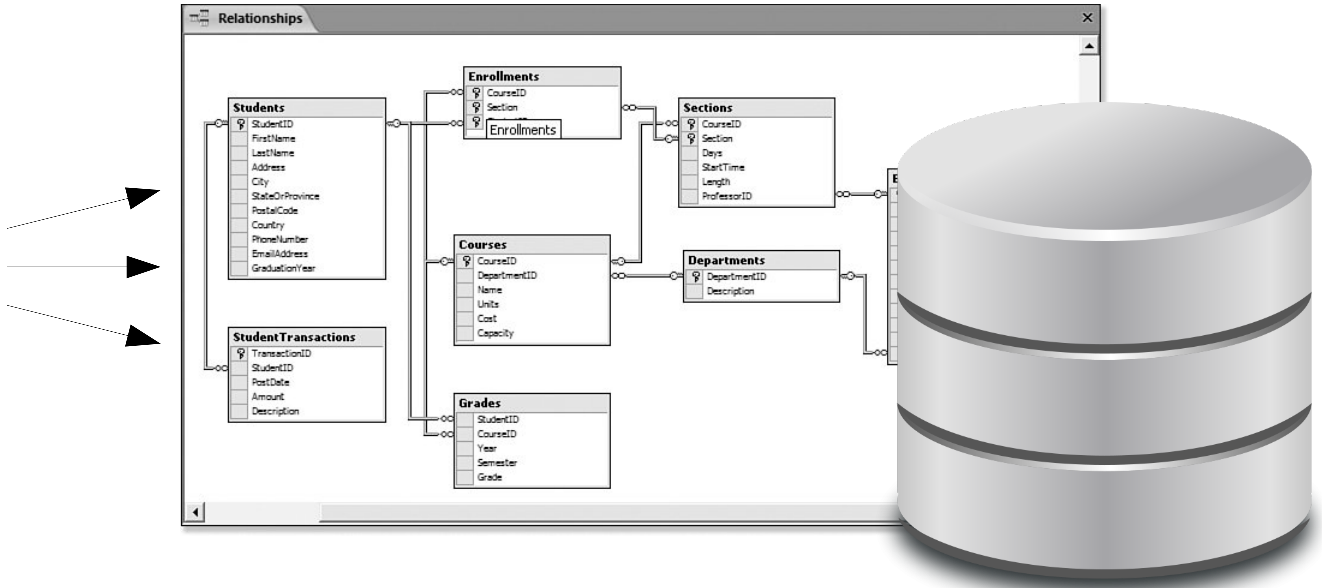
Local Databases and SQL

What is a database?

- **relational database**: Data structured into associated **tables**.
  - think of an Excel worksheet as a table
  - a database is a collection of one or more tables, along with support for efficient operations
    - common operations: "CRUD" (<u>c</u>reate, <u>r</u>ead, <u>u</u>pdate, <u>d</u>elete); fast search
  - a table **row** corresponds to a unit of data called a record; a **column** corresponds to an attribute of that record



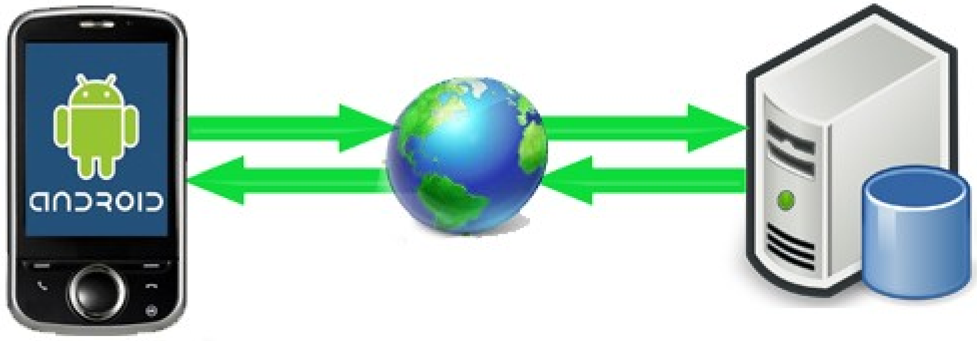
	A	B	C	D	E
1	Name	CompanyName	CustomerTypeRe	Balance	TotalBalance
2	Ecker Designs	Ecker Designs	Commercial	0	7694.41
3	Lew Plumbing - C	Lew Plumbing	Commercial	175	175
4	Melton, Johnny	Floss 'N Go Dental Care	Commercial	0	4999.5
5	Nelson, Wilma	Nelson Printing	Commercial	0	0
6	Pretell Real Estate		Commercial	0	29850.86
7	Reyes Properties - C		Commercial	0	0
8	Robson, Darci		Commercial	0	12420.98
9	Smallson, Fran	Smallson Electric	Commercial	0	1665
10	Smith, Lee	Smith Photography	Commercial	0	0
11					
12					
13					
14					
15					
16					
17					
18					
19					



Where is the data?

- A database can be located in many places.
  - within your Android device (a "local database")
  - on a remote web server
  - spread throughout many remote servers ("in the cloud")
  - ...

- Today we will learn to create and use **local databases**.



Talking to a database

- **SQL** (Structured Query Language): relational databases typically use SQL to define, manage, and search data
  - a declarative language syntax that can be used in many situations

```
SELECT name
FROM   countries
WHERE  population > 20000000;
```

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

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)

Example database: simpsons

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

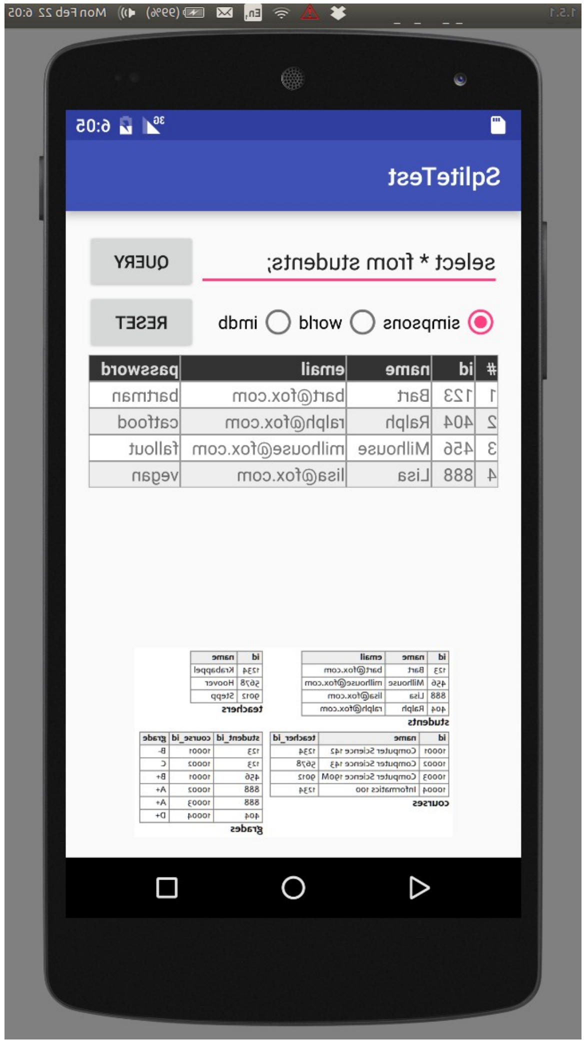
The SELECT statement

```
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

SqliteTest Android app

- instructor-provided **SqliteTest** app lets you type SQL queries and see the results instantly on the emulator
  - contains all databases in this lecture (simpsons, world, imdb)
  - good for testing queries before putting them into actual app Java code



SqliteTest

select * from students;

QUERY

[✓ simpsons] world imdb

RESET

#	id	name	email	password
1	123	Bart	bart@fox.com	bartman
2	404	Ralph	ralph@fox.com	catfood
3	456	Milhouse	milhouse@fox.com	fallout
4	888	Lisa	lisa@fox.com	vegan

students

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

teachers

id	name
1234	Krabappel
5678	Hoover
9012	Stepp

courses

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

grades

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

Android SQLiteDatabase (link)

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

- The `openOrCreateDatabase` method either creates a new empty database with that name or opens an existing one
  - once opened, you can use methods to execute SQL commands:
    - `rawQuery` - if your query **returns** results (e.g. SELECT)
    - `execSQL` - if your query does not return results (e.g. INSERT, DELETE)
  - If query has invalid SQL, throws an `SqliteException`
  - SQLite databases get saved to /data/data/*packageName*/databases/
    - (but you should never need to manipulate them as files directly)

SQLiteDatabase methods (link)

Method	Description

`db.beginTransaction();`
`db.endTransaction();`
	methods for "transactions", which are a series of SQL commands that can be run as a group

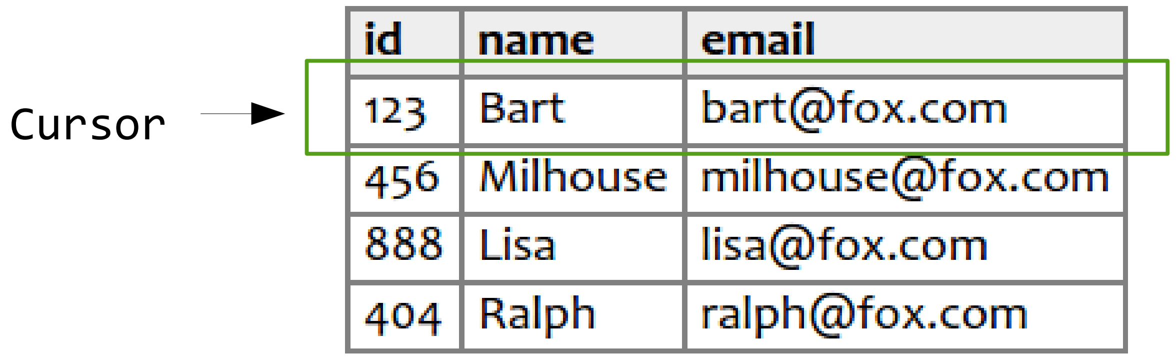
`db.delete("table", "whereClause", args);`	delete rows from a table
`db.deleteDatabase(file);`	delete an entire database *(be careful)*
`db.execSQL("query");`	run a query that doesn't return any results (e.g. insert, delete, update, etc.)
`db.insert("table", null, values);`	insert rows into a database table
`db.query(...);`	(we suggest rawQuery instead)
`db.rawQuery("SQL query", args)`	perform the given SQL `SELECT` query and return a **Cursor** to view the results
`db.replace("table", null, values);`	replace rows in a database table
`db.update("table", values, "whereClause", args);`	update existing rows in a database table

Concept of a Cursor

- The Android SQLite API returns an object called a *Cursor* that allows you to iterate through the results of a SELECT query.
  - Similar to the concept of an *iterator*

- Like a pointer positioned to a given row from the set of results.
  - You can move the cursor forward to the next result row.
  - You can ask the cursor for values of columns of its "current" row.

```
SELECT id, email FROM students;
```

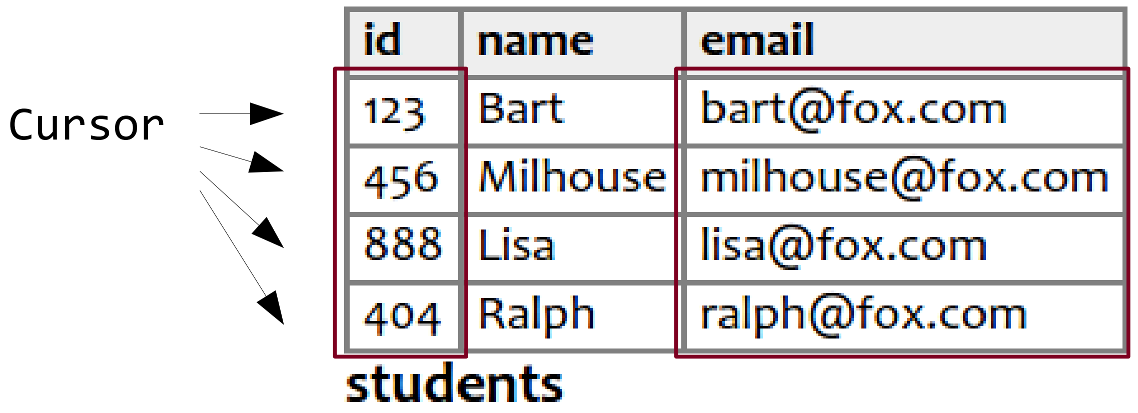


id	name	email
123	Bart	bart@fox.com
456	Milhouse	milhouse@fox.com
888	Lisa	lisa@fox.com
404	Ralph	ralph@fox.com

students

Cursor example (link)

```
// Cursor iterates through row results one at a time
Cursor cr = db.rawQuery(
            "SELECT id, email FROM students", null);
if (cr.moveToFirst()) {
  do {
    int id = cr.getInt(cr.getColumnIndex("id"));
    String email = cr.getString(cr.getColumnIndex("email"));
    ...
  } while (cr.moveToNext());
  cr.close();
}
```



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

Cursor methods (link)

Method	Description
`c.close();`	call this when done with the cursor
`c.getColumnIndex("name")`	index of a column based on its name
`c.getColumnName(index)`	name of column based on its index
`c.getCount()`	number of rows in result

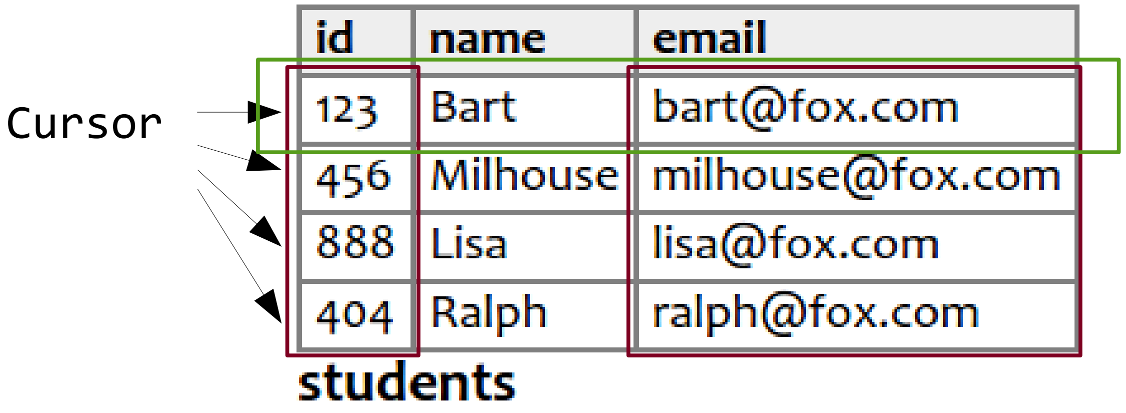
`c.getDouble(index), c.getBlob(index),`
`c.getFloat(index),  c.getInt(index),`
`c.getLong(index),   c.getString(index)`
	get data from a column

`c.isBeforeFirst()`
`c.isFirst()`
`c.isLast()`
	ask about cursor's position

`c.moveToFirst();`
`c.moveToLast();`
`c.moveToNext();`
`c.moveToPosition(index);`
	tell cursor to move to a given position
	(each returns boolean indicating success)

Library: SimpleDatabase, rows

```
// SimpleRow object has same methods as Cursor and more
String query = "SELECT id, email FROM students";
for (SimpleRow row :
        SimpleDatabase.with(this).query("simpsons", query)) {
    int id = row.get("id");
    String email = row.get("email");
    ...
}
```



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

students

SimpleDatabase methods

Method	Description
`deleteDatabase("`***`name`***`");`	remove a database

`executeSqlFile(`***`db, id`***`);`
`executeSqlFile("`***`filename`***`");`
	open and run SQL queries from a file

`exists("`***`name`***`")`	returns true if db exists w/ given name
`getDatabaseNames()`	return array of all dbs in this app
`getTableNames(`***`db`***`)`	return array of all tables' names in given db
`open("`***`name`***`")`	opens db with given name, or creates if does not exist

`query(`***`db`***`, "`***`SQL query`***`")`
`query("`***`name`***`", "`***`SQL query`***`")`
	performs SQL query on given database and returns SimpleCursor of rows

`setLogging(`***`bool`***`)`	turn on/off log statements on each query
`with(`***`context`***`)`	static method to get a SimpleDatabase instance (pass your activity to this method)

Importing a .sql file

- A .sql file contains a sequence of SQL commands.
  - Common format for exporting an entire database and its contents.
  - Used to save a backup or restore db to another server.

- To import a .sql file into an Android app:
  - Put the .sql file into your app's res/raw folder
  - Open it with a Scanner
  - Read lines until you find a semicolon
  - Run the string you read as a query using execSQL
  - Repeat
  - ...

Import .sql example

```
// read example.sql into database named "example"
SQLiteDatabase db = context.openOrCreateDatabase("example");
Scanner scan = new Scanner(getResources()
                      .openRawResource(R.raw.example));
String query = "";
while (scan.hasNextLine()) {    // build and execute queries
    query += scan.nextLine() + "\n";
    if (query.trim().endsWith(";")) {
        db.execSQL(query);
        query = "";
    }
}
```

```
// or just use Stanford library method
SimpleDatabase.with(this)
    .executeSqlFile(db, R.raw.example);
SimpleDatabase.with(this)
    .executeSqlFile("filename");   // creates db named 'filename'
```

More about 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

INSERT and REPLACE

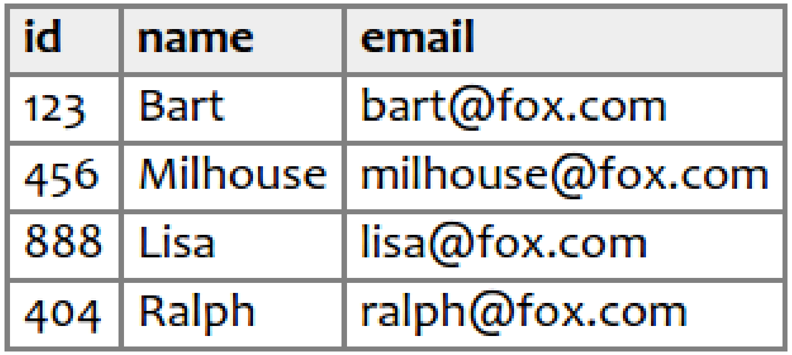
```
INSERT INTO table (columnName, ..., columnName)
VALUES (value, value, ..., value);

REPLACE INTO table (columnName, ..., columnName)
VALUES (value, value, ..., value) WHERE columnName = value;
```

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

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

- columns can 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

Insert with SQLiteDatabase

```java
// use execSQL instead of rawQuery, because no results
String query = "INSERT INTO students (name, email) "
             + "VALUES ('Lewis', 'lewis@fox.com')";
db.execSQL(query);

String query2 = "REPLACE INTO students (id, name, email) "
              + "VALUES (789, 'Martin', 'prince@fox.com')"
              + "WHERE ID = 789";
db.execSQL(query2);
```



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

students

ContentValues (link)

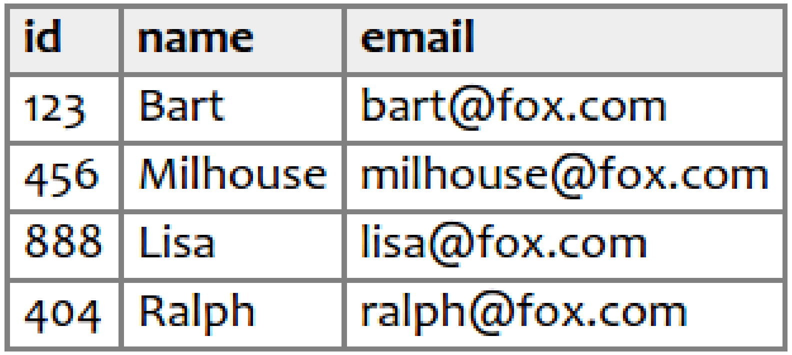
```
// alternative syntax using insert method
String name = "Lewis";
String email = "lewis@fox.com";

~~db.execSQL("INSERT INTO students (name, email) "~~
~~      + "VALUES ('" + name + "', '" + email + "')");~~

// use ContentValues to store values to put in row
ContentValues cvalues = new ContentValues();
cvalues.put("name",  name);
cvalues.put("email", email);
db.insert("students", null, cvalues);
```

- ContentValues can be optionally used as a level of abstraction for statements like INSERT, UPDATE, REPLACE
  - meant to provide cleaner Java syntax rather than raw SQL syntax

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



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

students

Update with SQLiteDatabase

```
// an update statement using execSQL
String query = "UPDATE students "
             + "SET email = 'lisasimpson@gmail.com' "
             + "WHERE id = 888";
db.execSQL(query);

// alternative syntax using ContentValues
ContentValues cvalues = new ContentValues();
cvalues.put("email", "lisasimpson@gmail.com");
db.update("students", cvalues, "id = 888", null);
```

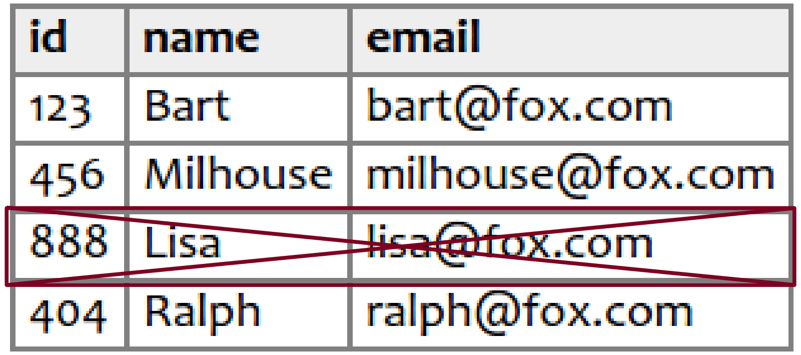
id	name	email
123	Bart	bart@fox.com
456	Milhouse	milhouse@fox.com
888	Lisa	lisa@fox.com
404	Ralph	ralph@fox.com

students

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

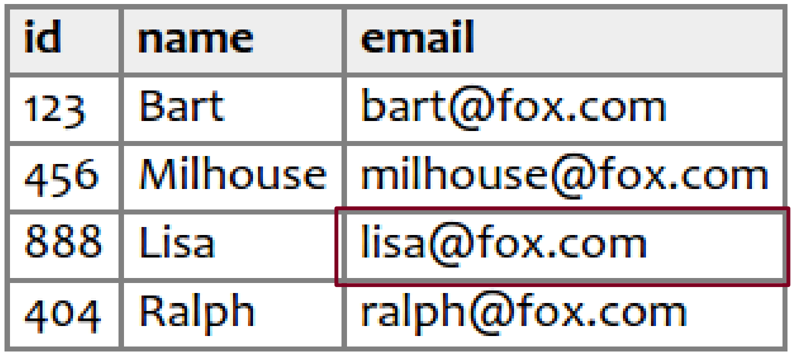


id	name	email
123	Bart	bart@fox.com
456	Milhouse	milhouse@fox.com
~~888~~	~~Lisa~~	~~lisa@fox.com~~
404	Ralph	ralph@fox.com

students

Delete with SQLiteDatabase

```
// an update statement using execSQL
String query = "DELETE FROM students "
             + "WHERE id = 888";
db.execSQL(query);

// alternative syntax using delete method
db.delete("students", "id = 888", null);
```

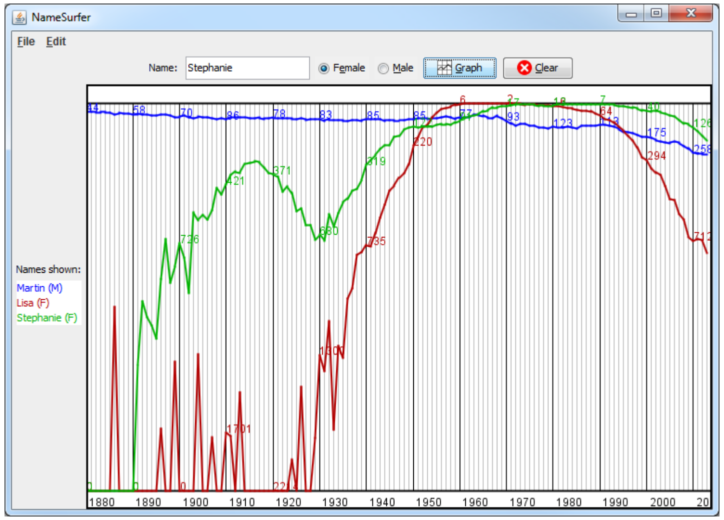


id	name	email
123	Bart	bart@fox.com
456	Milhouse	milhouse@fox.com
888	Lisa	lisa@fox.com
404	Ralph	ralph@fox.com

students

Exercise: Baby Name Surfer

- Write an Android app with a subset of functionality similar to the "Name Surfer" assignment from CS 106A.
  - Prompt the user for a name and sex.
  - Search the **ranks** table for that name/sex.
  - Display the rankings visually in the app.
  - There is also a **meanings** table that stores meanings of baby names.
    - Search it for the meaning of the name typed by the user and display that meaning.



Name: Stephanie [✓ Female] Male

name	sex	year	rank
Aaron	M	1880	133
Aaron	M	1890	148
Zelda	F	2000	3979

ranks

name	meaning
Martin	Derived from Martis
Zelda	Yiddish, English Eith

meanings

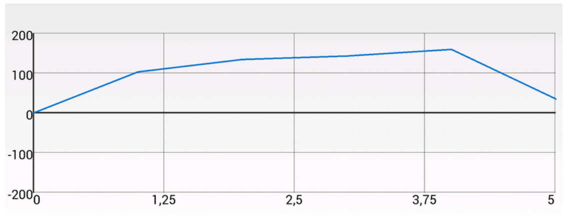
Suggested library: GraphView

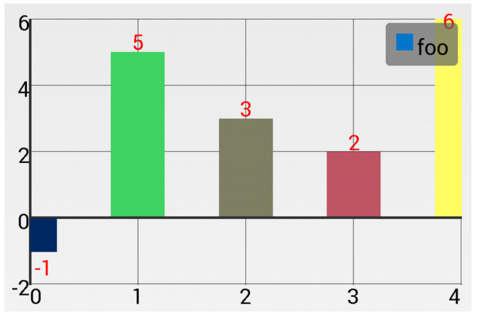
- GraphView library information can be found at:
  - http://www.android-graphview.org/
  - add it to your build.gradle:

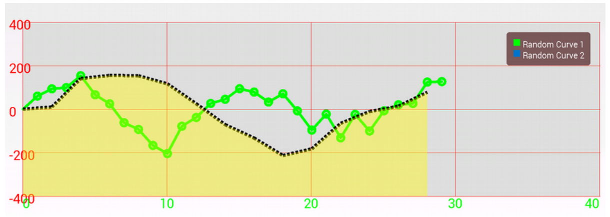
```
dependencies {
    ...
    compile 'com.jjoe64:graphview:4.2.1'
}
```

  - create a graph in your activity XML

```
<com.jjoe64.graphview.GraphView
    android:layout_width="width"
    android:layout_height="height"
    android:id="@+id/id" />
```







Line Graphs in GraphView

- talk to a graph in Java:

```
GraphView graph = (GraphView) findViewById(R.id.id);
graph.setTitle("title");

// set X bounds; Y is the same idea
graph.getViewport().setXAxisBoundsManual(true);
graph.getViewport().setMinX(minX);
graph.getViewport().setMaxX(maxX);
...
```

- add a line to the graph:

```
LineGraphSeries<DataPoint> series = new LineGraphSeries<>();
DataPoint point = new DataPoint(x, y);
series.appendData(point, false, maxPoints);
...
graph.addSeries(series);
```

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)
);
```

INTEGER	32-bit integer
REAL or DOUBLE	real number
VARCHAR(*length*)	string up to given length
BLOB	binary data

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

Table column constraints

```
CREATE TABLE students (
  id INTEGER NOT NULL PRIMARY KEY,
  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

Create with SQLiteDatabase

```
// a create table statement using execSQL
String query = "CREATE TABLE students ( "
             + "  id INTEGER PRIMARY KEY, "
             + "  name VARCHAR(20) NOT NULL, "
             + "  email VARCHAR(32) NOT NULL, "
             + "  password VARCHAR(16) NOT NULL "
             + ")";
db.execSQL(query);
```

id	name	email	password

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

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