# STATS 507
# Data Analysis using Python

Lecture 15: Databases with SQL

# Last lecture: HTML, XML and JSON

Each provided a different (though similar) way of storing data

Key motivation of JSON (and, sort of, HTML and XML): self-description

But we saw that JSON could get quite unwieldy quite quickly…

# Example of a more complicated JSON object

```
complex_json_string="""{
    "id": "0001",
    "type": "donut",
    "name": "Cake",
    "ppu": 0.55,
    "batters":
        {
            "batter":
                [
                    { "id": "1001", "type": "Regular" },
                    { "id": "1002", "type": "Chocolate" },
                    { "id": "1003", "type": "Blueberry" },
                    { "id": "1004", "type": "Devil's Food" }
                ]
        },
    "topping":
        [
            { "id": "5001", "type": "None" },
            { "id": "5002", "type": "Glazed" },
            { "id": "5005", "type": "Sugar" },
            { "id": "5007", "type": "Powdered Sugar" },
            { "id": "5006", "type": "Chocolate with Sprinkles" },
            { "id": "5003", "type": "Chocolate" },
            { "id": "5004", "type": "Maple" }
        ]
}"""
```

What if I have hundreds of different kinds of cakes or donuts? The nestedness of JSON objects makes them a little complicated. Generally, JSON is good for delivering (small amounts of) data, but for storing and manipulating large, complicated collections of data, there are better tools, namely databases.

**Note:** there are also security and software engineering reasons to prefer databases over JSON for storing data, but that's beyond the scope of our course.

# Why use a database?

Database software hides the problem of actually handling data

- As we'll see in a few slides, this is a complicated thing to do!
- Indexing, journaling, archiving handled automatically

Allow fast, concurrent (i.e., multiple users) access to data

- ACID transactions (more on this in a few slides)

Access over the web

- DBs can be run, e.g., on a server

Again, JSON/XML/HTML/etc good for delivering data, DBs good for storing

# Databases (DBs)

Information, organized so as to make retrieval fast and efficient

**Examples:** Census information, product inventory, library catalogue

This course: **relational databases**

https://en.wikipedia.org/wiki/Relational_database

So-named because they capture relations between entities

In existence since the 1970s, and still the dominant model in use today

Outside the scope of this course: other models (e.g., object-oriented)

https://en.wikipedia.org/wiki/Database_model

Textbook: *Database System Concepts* by Silberschatz, Korth and Sudarshan.

# Relational DBs: pros and cons

**Pros:**

Natural for the vast majority of applications

Numerous tools for managing and querying

**Cons:**

Not well-suited to some data (e.g., networks, unstructured text)

Fixed schema (i.e., hard to add columns)

Expensive to maintain when data gets large (e.g., many TBs of data)

# Fundamental unit of relational DBs: the record

Each entity in a DB has a corresponding **record**

- Features of a record are stored in **fields**
- Records with same “types” of fields collected into **tables**
- Each record is a row, each field is a column

| ID | Name | UG University | Field | Birth Year | Age at Death |
|---|---|---|---|---|---|
| 101010 | Claude Shannon | University of Michigan | Electrical Engineering | 1916 | 84 |
| 314159 | Albert Einstein | ETH Zurich | Physics | 1879 | 76 |
| 21451 | Ronald Fisher | University of Cambridge | Statistics | 1890 | 72 |

Table with six fields and three records.

# Fields can contain different data types

| ID | Name | UG University | Field | Birth Year | Age at Death |
|---|---|---|---|---|---|
| 101010 | Claude Shannon | University of Michigan | Electrical Engineering | 1916 | 84 |
| 314159 | Albert Einstein | ETH Zurich | Physics | 1879 | 76 |
| 21451 | Ronald Fisher | University of Cambridge | Statistics | 1890 | 72 |

Unsigned int, String, String, String, Unsigned int, Unsigned int

Of course, can also contain floats, signed ints, etc. Some DB software allows categorical types (e.g., letter grades).

# By convention, each record has a **primary key**

| ID | Name | UG University | Field | Birth Year | Age at Death |
|---|---|---|---|---|---|
| 101010 | Claude Shannon | University of Michigan | Electrical Engineering | 1916 | 84 |
| 314159 | Albert Einstein | ETH Zurich | Physics | 1879 | 76 |
| 21451 | Ronald Fisher | University of Cambridge | Statistics | 1890 | 72 |

Primary key used to uniquely identify the entity associated to a record, and facilitates joining information across tables.

| ID | PhD Year | PhD University | Thesis Title |
|---|---|---|---|
| 101010 | 1940 | MIT | An Algebra for Theoretical Genetics |
| 314159 | 1905 | University of Zurich | A New Determination of Molecular Dimensions |
| 21451 | | | |

# ACID: Atomicity, Consistency, Isolation, Durability

**Atomicity:** to outside observer, every transaction (i.e., changing the database) should appear to have happened “instantaneously”.

**Consistency:** DB changes should leave the DB in a “valid state” (e.g., changes to one table that affect other tables are propagated before the next transaction)

**Isolation:** concurrent transactions don’t “step on each other’s toes”

**Durability:** changes to DB are permanent once they are committed

**Note:** some RDBMSs achieve faster performance, at cost of one or more of above
**Related:** Brewer’s Theorem https://en.wikipedia.org/wiki/CAP_theorem

# Relational Database Management Systems (RDBMSs)

Program that facilitates interaction with database is called RDBMS

Public/Open-source options:

MySQL, PostgreSQL, **SQLite**

Proprietary:

IBM Db2, Oracle, SAP, SQL Server (Microsoft)

**We'll use SQLite, because it comes built-in to Python. More later.**

# SQL (originally SEQUEL, from IBM)

**S**tructured **Q**uery **L**anguage (**S**tructured **E**nglish **QUE**ry **L**anguage)

Language for interacting with relational databases

- Not the only way to do so, but by far most popular
- Slight variation from platform to platform (“dialects of SQL”)

**Good tutorials/textbooks:**
https://www.w3schools.com/sql/sql_intro.asp
O’Reilly books: *Learning SQL* by Beaulieu
*SQL Pocket Guide* by Gennick
Severance, Chapter 14: http://www.pythonlearn.com/html-270/book015.html

# Examples of database operations

| ID | Name | GPA | Major | Birth Year |
|---|---|---|---|---|
| 101010 | Claude Shannon | 3.1 | Electrical Engineering | 1916 |
| 500100 | Eugene Wigner | 3.2 | Physics | 1902 |
| 314159 | Albert Einstein | 4.0 | Physics | 1879 |
| 214518 | Ronald Fisher | 3.25 | Statistics | 1890 |
| 662607 | Max Planck | 2.9 | Physics | 1858 |
| 271828 | Leonard Euler | 3.9 | Mathematics | 1707 |
| 999999 | Jerzy Neyman | 3.5 | Statistics | 1894 |
| 112358 | Ky Fan | 3.55 | Mathematics | 1914 |

- Find names of all physics majors
- Compute average GPA of students born in the 19th century
- Find all students with GPA > 3.0

SQL allows us to easily specify queries like these (and far more complex ones).

# Common database operations

**Extracting records:** find all rows in a table

**Filtering records:** retain only the records (rows) that match some criterion

**Sorting records:** reorder selected rows according to some field(s)

**Adding/deleting records:** insert new row(s) into a table or remove existing row(s)

**Grouping records:** gather rows according to some field

**Adding/deleting tables:** create new or delete existing tables

**Merging tables:** combine information from multiple tables into one table

# Common database operations

SQL includes keywords for succinctly expressing all of these operations.

**Extracting records:** find all rows in a table

**Filtering records:** retain only the records (rows) that match some criterion

**Sorting records:** reorder selected rows according to some field(s)

**Adding/deleting records:** insert new row(s) into a table or remove existing row(s)

**Grouping records:** gather rows according to some field

**Adding/deleting tables:** create new or delete existing tables

**Merging tables:** combine information from multiple tables into one table

# Retrieving records: SQL `SELECT` Statements

Basic form of a SQL `SELECT` statement:

```
SELECT [column names] FROM [table]
```

**Example:** we have table `t_customers` of customer IDs, names and companies

**Retrieve all customer names:** `SELECT name FROM t_customers`

**Retrieve all company names:** `SELECT company FROM t_customers`

**Note:** by convention (and good practice), one often names tables to be prefixed with “TB_” or “t_”. In our illustrative examples, I won’t always do this for the sake of space and brevity, but I highly recommend it in practice. See https://launchbylunch.com/posts/2014/Feb/16/sql-naming-conventions/ and http://leshazlewood.com/software-engineering/sql-style-guide/ for two people’s (differing) opinions.

## Table `t_students`

| id | name | gpa | major | birth_year | pets | favorite_color |
|---|---|---|---|---|---|---|
| 101010 | Claude Shannon | 3.1 | Electrical Engineering | 1916 | 2 | Blue |
| 314159 | Albert Einstein | 4.0 | Physics | 1879 | 0 | Green |
| 999999 | Jerzy Neyman | 3.5 | Statistics | 1894 | 1 | Red |
| 112358 | Ky Fan | 3.55 | Mathematics | 1914 | 2 | Green |

```
SELECT id, name, birth_year FROM t_students
```

| id | name | birth_year |
|---|---|---|
| 101010 | Claude Shannon | 1916 |
| 314159 | Albert Einstein | 1879 |
| 999999 | Jerzy Neyman | 1894 |
| 112358 | Ky Fan | 1914 |

# Filtering records: SQL `WHERE` Statements

To further filter the records returned by a `SELECT` statement:

```
SELECT [column names] FROM [table] WHERE [filter]
```

**Example:** table `t_inventory` of product IDs, unit cost, and number in stock

**Retrieve IDs for all products with unit cost at least $1:**

```
SELECT id FROM t_inventory WHERE unit_cost>=1
```

**Note:** Possible to do much more complicated filtering, e.g., regexes, set membership, etc. We'll discuss that more in a few slides.

## Table `t_students`

| id | name | gpa | major | birth_year | pets | favorite_color |
|---|---|---|---|---|---|---|
| 101010 | Claude Shannon | 3.1 | Electrical Engineering | 1916 | 2 | Blue |
| 314159 | Albert Einstein | 4.0 | Physics | 1879 | 0 | Green |
| 999999 | Jerzy Neyman | 3.5 | Statistics | 1894 | 1 | Red |
| 112358 | Ky Fan | 3.55 | Mathematics | 1914 | 2 | Green |

```
SELECT id, name FROM t_students WHERE birth_year >1900
```

| id | name |
|---|---|
| 101010 | Claude Shannon |
| 112358 | Ky Fan |

# NULL means Nothing!

**Table `t_thesis`**

| id | phd_year | phd_university | thesis_title |
|---|---|---|---|
| 101010 | 1940 | MIT | An Algebra for Theoretical Genetics |
| 314159 | 1905 | University of Zurich | A New Determination of Molecular Dimensions |
| 214511 | | | |
| 774477 | 1970 | MIT | |

```
SELECT id FROM t_thesis WHERE phd_year IS NULL
```

| id |
|---|
| 21451 |

`NULL` matches the *empty string*, i.e., matches the case where the field was left empty. Note that if the field contains, say, `' '`, then `NULL` will ***not*** match that row!

# Ordering records: SQL `ORDER BY` Statements

To order the records returned by a `SELECT` statement:

```
SELECT [columns] FROM [table] ORDER BY [column] [ASC|DESC]
```

**Example:** table `t_inventory` of product IDs, unit cost, and number in stock

**Retrieve IDs, # in stock, for all products, ordered by descending # in stock:**

```
    SELECT id, number_in_stock FROM t_inventory

    ORDER BY number_in_stock DESC
```

**Note:** most implementations order ascending by default, but best to always specify, for your sanity and that of your colleagues!

## Table `t_students`

| id | name | gpa | major | birth_year | pets | favorite_color |
|---|---|---|---|---|---|---|
| 101010 | Claude Shannon | 3.1 | Electrical Engineering | 1916 | 2 | Blue |
| 314159 | Albert Einstein | 4.0 | Physics | 1879 | 0 | Green |
| 999999 | Jerzy Neyman | 3.5 | Statistics | 1894 | 1 | Red |
| 112358 | Ky Fan | 3.55 | Mathematics | 1914 | 2 | Green |

```
SELECT id, name, gpa FROM t_students ORDER BY gpa DESC
```

| id | name | gpa |
|---|---|---|
| 314159 | Albert Einstein | 4.0 |
| 112358 | Ky Fan | 3.55 |
| 999999 | Jerzy Neyman | 3.5 |
| 101010 | Claude Shannon | 3.1 |

# More filtering: `DISTINCT` Keyword

To remove repeats from a set of returned results:

```
SELECT DISTINCT [columns] FROM [table]
```

**Example:** table `t_student` of student IDs, names, and majors

**Retrieve all the majors:**

```
    SELECT DISTINCT major FROM t_student
```

## Table `t_students`

| id | name | gpa | major | birth_year | pets | favorite_color |
|---|---|---|---|---|---|---|
| 101010 | Claude Shannon | 3.1 | Electrical Engineering | 1916 | 2 | Blue |
| 314159 | Albert Einstein | 4.0 | Physics | 1879 | 0 | Green |
| 999999 | Jerzy Neyman | 3.5 | Statistics | 1894 | 1 | Red |
| 112358 | Ky Fan | 3.55 | Mathematics | 1914 | 2 | Green |

```
SELECT DISTINCT pets FROM t_students ORDER BY pets ASC
```

**Test your understanding:** what should this return?

## Table `t_students`

| id | name | gpa | major | birth_year | pets | favorite_color |
|---|---|---|---|---|---|---|
| 101010 | Claude Shannon | 3.1 | Electrical Engineering | 1916 | 2 | Blue |
| 314159 | Albert Einstein | 4.0 | Physics | 1879 | 0 | Green |
| 999999 | Jerzy Neyman | 3.5 | Statistics | 1894 | 1 | Red |
| 112358 | Ky Fan | 3.55 | Mathematics | 1914 | 2 | Green |

```
SELECT DISTINCT pets FROM t_students ORDER BY pets ASC
```

| pets |
|---|
| 0 |
| 1 |
| 2 |

# More on `WHERE` Statements

`WHERE` keyword supports all the natural comparisons one would want to perform

| (Numberical) Operation | Symbol/keyword |
| --- | --- |
| Equal | = |
| Not equal | <> |
| Less than | < |
| Less than or equal to | <= |
| Greater than | > |
| Greater than or equal to | >= |
| Within a range | BETWEEN … AND ... |

**Examples:**

```
SELECT id from t_student WHERE …

    … gpa>=3.2

    … pets=1

    … gpa BETWEEN 2.9 AND 3.1

    … birth_year > 1900

    … pets <> 0
```

**Caution:** different implementations define `BETWEEN` differently (i.e., inclusive vs exclusive)! Be sure to double check!

# More on `WHERE` Statements

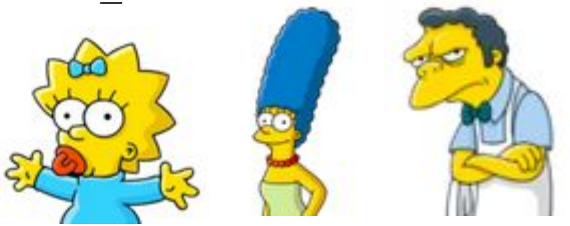
`WHERE` keyword also allows (limited) regex support and set membership

```
SELECT id, major from t_student WHERE major IN (“Mathematics”,”Statistics”)

SELECT id, major from t_student WHERE major NOT IN (“Physics”)
```

Regex-like matching with `LIKE` keyword, wildcards `‘_’` and `‘%’`

```
SELECT id,name from t_simpsons_characters WHERE first_name LIKE “M%”
```



```
SELECT id,name from t_simpsons_characters WHERE first_name LIKE “B_rt”
```

Matches `‘Bart’`, `‘Bert’`, `‘Bort’`...

# Aggregating results: `GROUP BY`

I have a DB of transactions at my internet business, and I want to know how much each customer has spent in total.

| customer_id | customer | order_id | dollar_amount |
|---|---|---|---|
| 101 | Amy | 0023 | 25 |
| 200 | Bob | 0101 | 10 |
| 315 | Cathy | 0222 | 50 |
| 200 | Bob | 0120 | 12 |
| 310 | Bob | 0429 | 100 |
| 315 | Cathy | 0111 | 33 |
| 101 | Amy | 0033 | 25 |
| 315 | Cathy | 0504 | 70 |

```
SELECT customer_id,SUM(dollar_amount)
FROM t_transactions GROUP BY customer_id
```

| customer_id | dollar_amount |
|---|---|
| 101 | 50 |
| 200 | 22 |
| 310 | 100 |
| 315 | 153 |

`GROUP BY field_x` combines the rows with the same value in the field `field_x`

# More about `GROUP BY`

`GROUP BY` supports other operations in addition to `SUM`:

- `COUNT`, `AVG`, `MIN`, `MAX`
- Called **aggregate** functions

Can filter results *after* `GROUP BY` using the `HAVING` keyword

```
SELECT customer_id, SUM(dollar_amount) AS total_dollar FROM t_transactions
GROUP BY customer_id HAVING total_dollar>50
```

| customer_id | dollar_amount |
|---|---|
| 101 | 50 |
| 200 | 22 |
| 310 | 100 |
| 315 | 153 |

| customer_id | total_dollar |
|---|---|
| 310 | 100 |
| 315 | 153 |

# More about `GROUP BY`

`GROUP BY` supports other operations in addition to `SUM`:

- `COUNT, AVG, MIN, MAX`
- Called **aggregate** functions

**Note:** the difference between the `HAVING` keyword and the `WHERE` keyword is that `HAVING` operates *after* applying filters and `GROUP BY`.

Can filter results *after* `GROUP BY` using the `HAVING` keyword

```
SELECT customer_id, SUM(dollar_amount) AS total_dollar FROM t_transactions
GROUP BY customer_id HAVING total_dollar>50
```

The `AS` keyword just lets us give a nicer name to the aggregated field.

| customer_id | dollar_amount |
|---|---|
| 101 | 50 |
| 200 | 22 |
| 310 | 100 |
| 315 | 153 |

| customer_id | total_dollar |
|---|---|
| 310 | 100 |
| 315 | 153 |

# Merging tables: `JOIN`

| ID | Name | GPA | Major | Birth Year |
|---|---|---|---|---|
| 101010 | Claude Shannon | 3.1 | Electrical Engineering | 1916 |
| 314159 | Albert Einstein | 4.0 | Physics | 1879 |
| 999999 | Jerzy Neyman | 3.5 | Statistics | 1894 |
| 112358 | Ky Fan | 3.55 | Mathematics | 1914 |

| ID | #Pets | Favorite Color |
|---|---|---|
| 101010 | 2 | Blue |
| 314159 | 0 | Green |
| 999999 | 1 | Red |
| 112358 | 2 | Green |

**Join tables based on primary key**

| ID | Name | GPA | Major | Birth Year | #Pets | Favorite Color |
|---|---|---|---|---|---|---|
| 101010 | Claude Shannon | 3.1 | Electrical Engineering | 1916 | 2 | Blue |
| 314159 | Albert Einstein | 4.0 | Physics | 1879 | 0 | Green |
| 999999 | Jerzy Neyman | 3.5 | Statistics | 1894 | 1 | Red |
| 112358 | Ky Fan | 3.55 | Mathematics | 1914 | 2 | Green |

# Merging tables: `INNER JOIN`

t_student

| id | name | gpa | major | birth_year |
|---|---|---|---|---|
| 101010 | Claude Shannon | 3.1 | Electrical Engineering | 1916 |
| 314159 | Albert Einstein | 4.0 | Physics | 1879 |
| 999999 | Jerzy Neyman | 3.5 | Statistics | 1894 |
| 112358 | Ky Fan | 3.55 | Mathematics | 1914 |

t_personal

| id | pets | favorite_color |
|---|---|---|
| 101010 | 2 | Blue |
| 314159 | 0 | Green |
| 999999 | 1 | Red |
| 112358 | 2 | Green |

**Join tables based on primary key**

```
SELECT id, name,favorite_color
FROM
t_student INNER JOIN t_personal
ON t_student.id=t_personal.id
```

| id | name | favorite_color |
|---|---|---|
| 101010 | Claude Shannon | Blue |
| 314159 | Albert Einstein | Green |
| 999999 | Jerzy Neyman | Red |
| 112358 | Ky Fan | Green |

# Merging tables: `INNER JOIN`

t_student

| id | name | gpa | major | birth_year |
| --- | --- | --- | --- | --- |
| 101010 | Claude Shannon | 3.1 | Electrical Engineering | 1916 |
| 314159 | Albert Einstein | 4.0 | Physics | 1879 |
| 999999 | Jerzy Neyman | 3.5 | Statistics | 1894 |
| 112358 | Ky Fan | 3.55 | Mathematics | 1914 |

t_personal

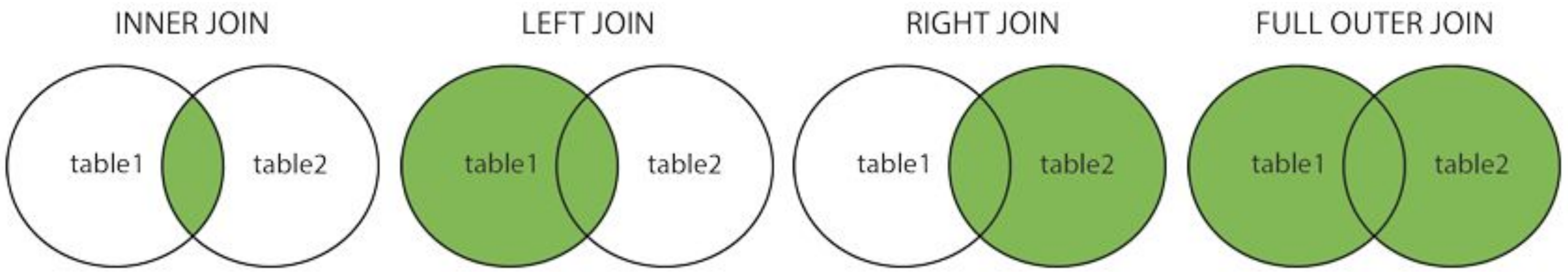
| id | pets | favorite_color |
| --- | --- | --- |
| 101010 | 2 | Blue |
| 314159 | 0 | Green |
| 999999 | 1 | Red |
| 112358 | 2 | Green |

## Join tables based on primary key

```
SELECT id, name,favorite_color
FROM
t_student INNER JOIN t_personal
ON t_student.id=t_personal.id
```

| id | name | favorite_color |
| --- | --- | --- |
| 101010 | Claude Shannon | Blue |
| 314159 | Albert Einstein | Green |
| 999999 | Jerzy Neyman | Red |
| 112358 | Ky Fan | Green |

# Other ways of joining tables: `OUTER JOIN`




`(INNER) JOIN`: Returns records that have matching values in both tables

`LEFT (OUTER) JOIN`: Return all records from the left table, and the matched records from the right table

`RIGHT (OUTER) JOIN`: Return all records from the right table, and the matched records from the left table

`FULL (OUTER) JOIN`: Return all records when there is a match in either left or right table

https://www.w3schools.com/sql/sql_join.asp

# Creating/modifying/deleting rows

Insert a row into a table: `INSERT INTO`

```
INSERT INTO table_name [col1, col2, col3, …]
VALUES value1, value2, value3, …
```

**Note:** if adding values for all columns, you only need to specify the values.

Modify a row in a table: `UPDATE`

```
UPDATE table_name SET col1=value1,col2=value2,
WHERE condition
```

Delete rows from a table: `DELETE`

```
DELETE FROM table_name WHERE condition
```

**Caution:** if `WHERE` clause is left empty, you'll delete/modify the whole table!

# Creating and deleting tables

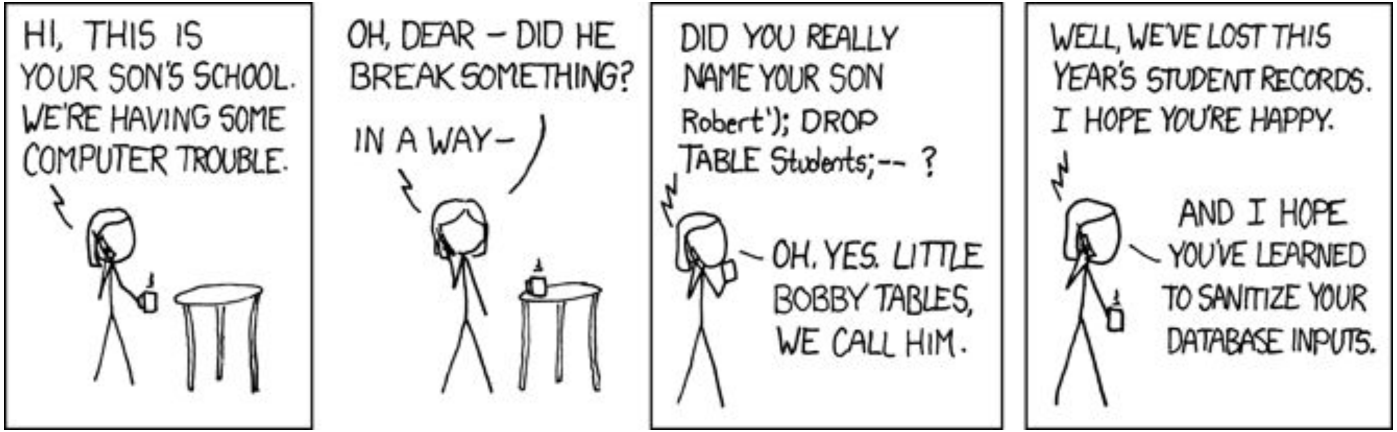
Create a new table: `CREATE TABLE`

```
CREATE TABLE table_name [col1 datatype, col2 datatype, …]
```

Delete a table: `DROP TABLE`

```
DROP TABLE table_name;
```

Be careful when dropping tables!



# Python `sqlite3` package implements SQLlite

`Connection` object represents a database

- `Connection` object can be used to create a `Cursor` object
- `Cursor` facilitates interaction with database

`conn = sqlite3.connect('example.db')`

- establish connection to given DB file (creating it if necessary)
- return `Connection` object

`c = conn.cursor()`

- Creates and returns a `Cursor` object for interacting with DB

`c.execute( [SQL command] )`

- runs the given command; cursor now contains query results

# Python `sqlite3` package

**Important point:** unlike many other RDBMSs, SQLite does not allow multiple connections to the same database at the same time.

So, if you're working in a distributed environment, you'll need something else

e.g., MySQL, Oracle, etc.

# Python `sqlite3` in action

```
import sqlite3
conn = sqlite3.connect('example.db')
c = conn.cursor() # create a cursor object.
c.execute('''CREATE TABLE t_student (id, name, field, birth_year)''')
students = [(101010, 'Claude Shannon', 'Electrical Engineering', 1916),
            (500100, 'Eugene Wigner', 'Physics', 1902),
            (314159, 'Albert Einstein', 'Physics', 1879),
            (214518, 'Ronald Fisher', 'Statistics', 1890),
            (662607, 'Max Planck', 'Physics', 1858),
            (271828, 'Leonard Euler', 'Mathematics', 1707),
            (999999, 'Jerzy Neyman', 'Statistics', 1894),
            (112358, 'Ky Fan', 'Mathematics', 1914)]
c.executemany('INSERT INTO t_student VALUES (?,?,?,?)', students)
conn.commit() # Write the changes back to example.db
for row in c.execute('''SELECT * from t_student'''):
    print row
```

```
(101010, u'Claude Shannon', u'Electrical Engineering', 1916)
(500100, u'Eugene Wigner', u'Physics', 1902)
(314159, u'Albert Einstein', u'Physics', 1879)
(214518, u'Ronald Fisher', u'Statistics', 1890)
(662607, u'Max Planck', u'Physics', 1858)
(271828, u'Leonard Euler', u'Mathematics', 1707)
(999999, u'Jerzy Neyman', u'Statistics', 1894)
(112358, u'Ky Fan', u'Mathematics', 1914)
```

# Python `sqlite3` in action

```
import sqlite3
conn = sqlite3.connect('example.db')
c = conn.cursor() # create a cursor object.
c.execute('''CREATE TABLE t_student (id, name, field, birth_year)''')
students = [(101010, 'Claude Shannon', 'Electrical Engineering', 1916),
            (500100, 'Eugene Wigner', 'Physics', 1902),
            (314159, 'Albert Einstein', 'Physics', 1879),
            (214518, 'Ronald Fisher', 'Statistics', 1890),
            (662607, 'Max Planck', 'Physics', 1858),
            (271828, 'Leonard Euler', 'Mathematics', 1707),
            (999999, 'Jerzy Neyman', 'Statistics', 1894),
            (112358, 'Ky Fan', 'Mathematics', 1914)]
c.executemany('INSERT INTO t_student VALUES (?,?,?,?)', students)
conn.commit() # Write the changes back to example.db
for row in c.execute('''SELECT * from t_student'''):
    print row
```

```
(101010, u'Claude Shannon', u'Electrical Engineering', 1916)
(500100, u'Eugene Wigner', u'Physics', 1902)
(314159, u'Albert Einstein', u'Physics', 1879)
(214518, u'Ronald Fisher', u'Statistics', 1890)
(662607, u'Max Planck', u'Physics', 1858)
(271828, u'Leonard Euler', u'Mathematics', 1707)
(999999, u'Jerzy Neyman', u'Statistics', 1894)
(112358, u'Ky Fan', u'Mathematics', 1914)
```

Create the table. Note that we need not specify a data type for each column. SQLite is flexible about this.

Insert rows in the table.

**Note:** `sqlite3` has special syntax for parameter substitution in strings. Using the built-in Python string substitution is insecure-- vulnerable to SQL injection attack.

Executing a query returns an iterator over query results.

# Python `sqlite3` annotated

```python
import sqlite3
conn = sqlite3.connect('example.db')
```

Establishes a connection to the database stored in `example.db`.

```python
c = conn.cursor()
```

`cursor` object is how we interact with the database. Think of it kind of like the cursor for your mouse. It points to, for example, a table, row or query results in the database.

```python
c.execute('''CREATE TABLE t_student (id, name, field, birth_year)''')
```

`cursor.execute` will run the specified SQL command on the database.

```python
c.executemany('INSERT INTO t_student VALUES (?,?,?,?)', students)
conn.commit() # Write the changes back to example.db
```

`executemany` runs a list of SQL commands.

`commit` writes changes back to the file. WIthout this, the next time you open `example.db`, the table `t_student` will be empty!

```python
conn.close()
```

Close the connection to the database. Think of this like Python file `close`.

# Metainformation: sqlite_master

Special table that holds information about the “real” tables in the database

Two tables, named `t_student` and `t_thesis`

```
import os, sqlite3
os.remove('example.db') #remove old version of the database.
conn = sqlite3.connect('example.db')
c = conn.cursor()
c.execute('''CREATE TABLE t_student (id, name, field, birth_year)''')
c.execute('''CREATE TABLE t_thesis (thesis_id, phd_title phd_year)''')
for r in c.execute('''SELECT * FROM sqlite_master'''):
    print r
```

```
(u'table', u't_student', u't_student', 2, u'CREATE TABLE t_student (id, name, field, birth_year)')
(u'table', u't_thesis', u't_thesis', 3, u'CREATE TABLE t_thesis (thesis_id, phd_title phd_year)')
```

# Retrieving column names in `sqlite3`

```
c.execute('''SELECT * from t_student''')
c.description
```

```
(('id', None, None, None, None, None, None),
 ('name', None, None, None, None, None, None),
 ('field', None, None, None, None, None, None),
 ('birth_year', None, None, None, None, None, None))
```

`description` attribute contains the column names; returned as a list of tuples for agreement with a different Python DB API.

```
[desc[0] for desc in c.description]
```

```
['id', 'name', 'field', 'birth_year']
```

**Note:** this is especially useful in tandem with the `mysql_master` table when exploring a new database, like in your homework!