Introduction to Data, Pandas and SQL

Part B – Pandas and SQL

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Lecture Outline

Part A: Data and Databases

What is data and how can we store it?

Part B: Pandas and SQL

Tools to inspect data

Relational Databases and Tables

- A collection of tables related to each other through common data values.
- Rows represent attributes of something.
- Everything in a column is values of one attributes.
- A cell is expected to be atomic.
- Tables are related to each other if they have columns called keys which represent the same values.

Structured Query Language (SQL)

What if our dataset doesn't fit in RAM?

What if we cannot download the entire dataset on our computer?

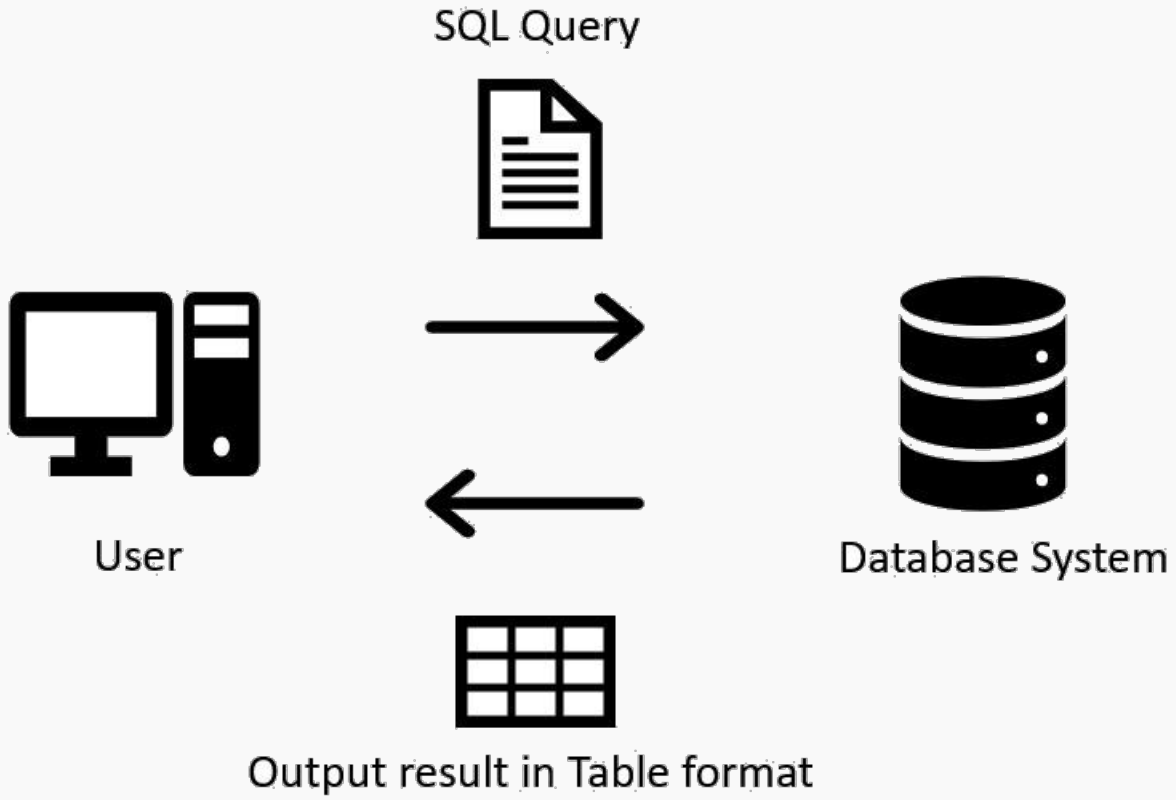
How to pronounce SQL
Credit : u/thefizzynator


SQL

Structured Query Language

SQL is a language that allows us to access and manipulate data stored in relational databases.

With SQL we can create, read, update and delete records stored in these databases.



SQL Queries

Queries are statements used to add, modify, query, or remove data from an SQL database

There are several SQL data statements, most used are:

- SELECT – to retrieve data from the database
- UPDATE – to modify data in the table
- DELETE – to delete data from the table
- INSERT – to add/populate the table in database

SQL Queries

SELECT is used to retrieve data from one or more tables in the database

Syntax of a SELECT statement,

SELECT columns or expressions

FROM tables

WHERE condition

GROUP BY column to group rows

HAVING condition

ORDER BY column to order rows

LIMIT number of rows to be returned

INTO TEMP save results of query in a temporary table

SQL Queries - Example

Consider a SQL table **fortune500** below with information about fortune 500 companies

company_name	country	num_of_employees	revenues_millions	profit_millions	Assets_millions
Walmart	USA	2300000	485873	13643.0	198825
State Grid	China	926067	315199	9571.3	198825
Sinopec Group	China	713288	267518	1257.9	310726
Toyota Motor	Japan	364445	254694	16899.3	437575
...					

What is the SQL Query to display all columns from **fortune500** table?

```
SELECT *
FROM fortune500
```

SQL Queries - Example

Consider a SQL table **fortune500** below with information about fortune 500 companies

company_name	country	num_of_employees	revenues_millions	profit_millions	Assets_millions
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Toyota Motor	Japan	364445	254694	16899.3	437575
...					

What is the SQL Query to display the first 4 rows with only *company_name*, *country* columns from **fortune500** table?

```
SELECT company_name, country
FROM fortune500
LIMIT 4
```

SQL Queries - Example

What is the SQL Query to display the first 4 rows with only *company_name*, *country* columns from **fortune500** table?

```
SELECT company_name, country
FROM fortune500
LIMIT 4
```

What will be the output of the above code?

company_name	country
Walmart	USA
State Grid	China
Sinopec Group	China
Toyota Motor	Japan

SQL Queries - Example

Consider a SQL table **fortune500** below with information about fortune 500 companies

company_name	country	num_of_employees	revenues_millions	profit_millions	Assets_millions
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Toyota Motor	Japan	364445	254694	16899.3	437575
...					

Which companies have more than a million employees?

```
SELECT company_name, country, num_of_employees
FROM fortune500
WHERE num_of_employees > 1000000
```

SQL Queries - Example

Which companies have more than a million employees?

```
SELECT company_name, country, num_of_employees
FROM fortune500
WHERE num_of_employees > 1000000
```

What will be the output of the above code?

company_name	country	num_of_employees
Wallmart	USA	2300000
China National Petroluem	China	1512048

SQL Queries - Example

Consider a SQL table **fortune500** below with information about fortune 500 companies

company_name	country	num_of_employees	revenues_millions	profit_millions	Assets_millions
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Sinopec Group	China	713288	267518	1257.9	310726
Toyota Motor	Japan	364445	254694	16899.3	437575
...					

What is the total revenue of fortune 500 companies in each country? Display only the first 4 rows.

```
SELECT country, SUM(revenues_millions)
FROM fortune500
GROUP BY country
LIMIT 4
```

GROUP BY can be used with an aggregation function like COUNT(), AVG(), SUM(), MIN(), MAX()

SQL Queries - Example

What is the total revenue of fortune 500 companies in each country? Display only the first 4 rows.

```
SELECT country, SUM(revenues_millions) AS total_revenue
FROM fortune500
GROUP BY country
LIMIT 4
```

What will be the output of the above code?

You can use AS to set/rename columns in the output

country	total_revenue
Australia	235821
Belgium	45905
Brazil	364172
Britain	1179837

SQL Queries - Example

What is the total revenue of fortune 500 companies in each country ordered by total revenue?

```
SELECT country, SUM(revenues_millions) AS total_revenue
FROM fortune500
GROUP BY country
ORDER BY total_revenue DESC
```

What will be the output of the above code?

country	total_revenue
USA	8476825
China	6038369
Japan	2711366
Germany	1853535

UPDATE

UPDATE statement is used to modify one or more rows in a table

Syntax of a UPDATE statement,

```
UPDATE    Table

SET       column1 = expression1,
          column2 = expression2

WHERE     condition
```

Data scientists don't usually modify the databases, they usually query data. Therefore, the UPDATE query is not used as much as the SELECT query.

UPDATE

Consider a SQL table **fortune500** below with information about fortune 500 companies

company_name	country	num_of_employees	revenues_millions	profit_millions	Assets_millions
Walmart	USA	2300000	485873	13643.0	198825
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Sinopec Group	China	713288	267518	1257.9	310726
Toyota Motor	Japan	364445	254694	16899.3	437575
...					
IBM	USA	414400	79919	11872.0	117470
...					

Change the name of IBM company in fortune500 table to 'International Business Machines'

```
UPDATE fortune500
SET company_name = 'International Business Machines'
WHERE company_name = 'IBM'
```

UPDATE

Change the name of IBM company in fortune500 table to ’International Business Machines’

```
UPDATE fortune500
SET company_name = 'International Business Machines'
WHERE company_name = 'IBM'
```

What will be the output of the above code?

company_name	country	num_of_employees	revenues_millions	profit_millions	Assets_millions
Wallmart	USA	2300000	485873	13643.0	198825
State Grid	China	926067	315199	9571.3	198825
Sinopec Group	China	713288	267518	1257.9	310726
Toyota Motor	Japan	364445	254694	16899.3	437575
...					
International Business Machines	USA	414400	79919	11872.0	117470
...					

SQLite

How would you run a SQL query in Python?

How would you query a database?

SQLite

SQLite is a software library that provides a relational database management system.

Python implements a standard database API called **DBAPI2**. DB-API2 is a library that lets python connect to a database server. So, SQLite is used to process DB-API2 method calls and query the database.

There is an even higher-level API available called SQLAlchemy.

SQLite

SQLite

```python
import sqlite3

try:
    sqliteConnection = sqlite3.connect('SQLite_Python.db')
    cursor = sqliteConnection.cursor()
    cursor.execute('''SELECT * from EMPLOYEE''')
    result = cursor.fetchall()
    sqliteConnection.commit()
    cursor.close()

except sqlite3.Error as error:
    print("Error while creating a sqlite table", error)

finally:
    if sqliteConnection:
        sqliteConnection.close()
        print("sqlite connection is closed")

```

This opens a connection to the SQLite database file. If database is opened successfully, it returns a connection object.

SQLite

```
1  import sqlite3
2
3  try:
4      sqliteConnection = sqlite3.connect('SQLite_Python.db')
5      cursor = sqliteConnection.cursor()
6      cursor.execute('''SELECT * from EMPLOYEE''')
7      result = cursor.fetchall()
8      sqliteConnection.commit()
9      cursor.close()
10
11 except sqlite3.Error as error:
12     print("Error while creating a sqlite table", error)
13
14 finally:
15     if sqliteConnection:
16         sqliteConnection.close()
17         print("sqlite connection is closed")
18
```

Cursor class is an instance using which you can invoke methods that execute SQLite statements, fetch data from the result sets of the queries.

SQLite

```
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2
3  try:
4      sqliteConnection = sqlite3.connect('SQLite_Python.db')
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6      cursor.execute('''SELECT * from EMPLOYEE''')
7      result = cursor.fetchall()
8      sqliteConnection.commit()
9      cursor.close()
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11 except sqlite3.Error as error:
12     print("Error while creating a sqlite table", error)
13
14 finally:
15     if sqliteConnection:
16         sqliteConnection.close()
17         print("sqlite connection is closed")
18
```

This routine executes an SQL statement.

SQLite

```
1  import sqlite3
2
3  try:
4      sqliteConnection = sqlite3.connect('SQLite_Python.db')
5      cursor = sqliteConnection.cursor()
6      cursor.execute('''SELECT * from EMPLOYEE''')
7      result = cursor.fetchall()
8      sqliteConnection.commit()
9      cursor.close()
10
11 except sqlite3.Error as error:
12     print("Error while creating a sqlite table", error)
13
14 finally:
15     if sqliteConnection:
16         sqliteConnection.close()
17         print("sqlite connection is closed")
18
```

This routine fetches all rows of a query result, returning a list.

SQLite

```
1  import sqlite3
2
3  try:
4      sqliteConnection = sqlite3.connect('SQLite_Python.db')
5      cursor = sqliteConnection.cursor()
6      cursor.execute('''SELECT * from EMPLOYEE''')
7      result = cursor.fetchall()
8      sqliteConnection.commit()
9      cursor.close()
10
11 except sqlite3.Error as error:
12     print("Error while creating a sqlite table", error)
13
14 finally:
15     if sqliteConnection:
16         sqliteConnection.close()
17         print("sqlite connection is closed")
18
```

This method commits the current transaction. If you don't call this method, anything you did since the last call to commit() is not visible from other database connections.

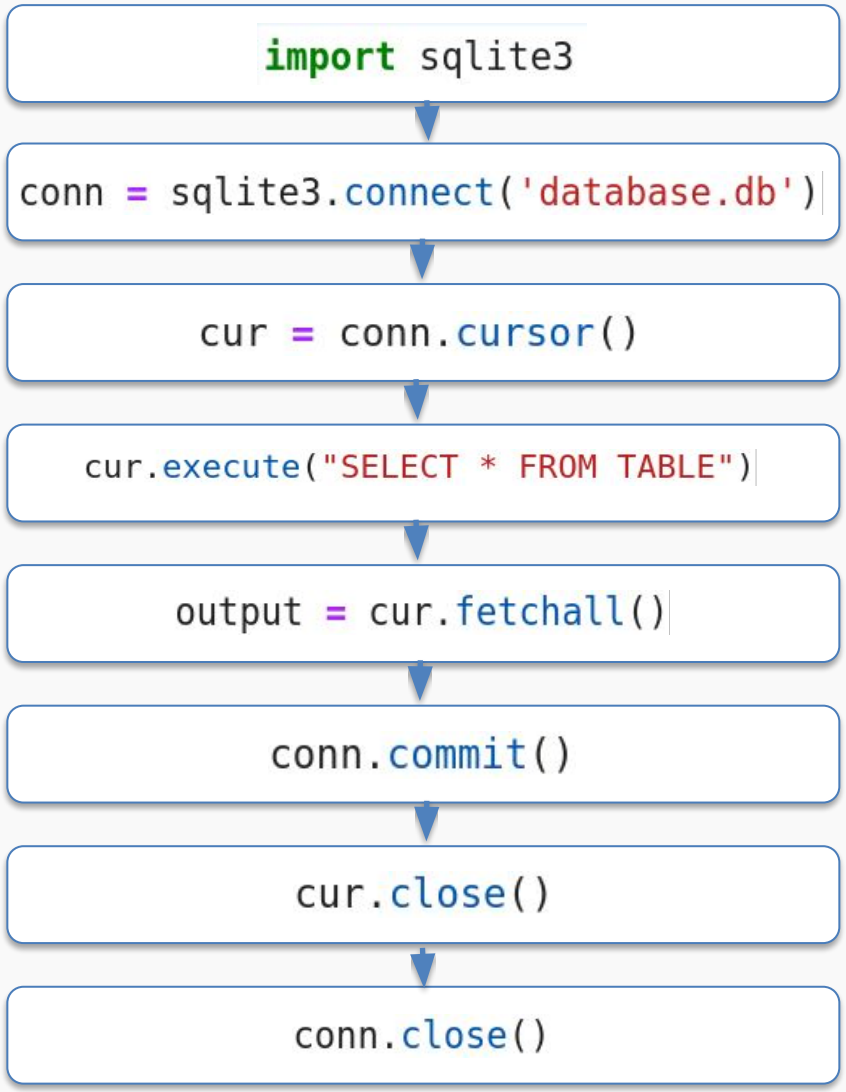
SQLite

```
1  import sqlite3
2
3  try:
4      sqliteConnection = sqlite3.connect('SQLite_Python.db')
5      cursor = sqliteConnection.cursor()
6      cursor.execute('''SELECT * from EMPLOYEE''')
7      result = cursor.fetchall()
8      sqliteConnection.commit()
9      cursor.close()
10
11 except sqlite3.Error as error:
12     print("Error while creating a sqlite table", error)
13
14 finally:
15     if sqliteConnection:
16         sqliteConnection.close()
17         print("sqlite connection is closed")
18
```

Closes the cursor connection.

Closes the database connection.

SQLite


import sqlite3
conn = sqlite3.connect('database.db')
cur = conn.cursor()
cur.execute("SELECT * FROM TABLE")
output = cur.fetchall()
conn.commit()
cur.close()
conn.close()

SQLite and Pandas

SQLite and Pandas

VERBS	PANDAS	SQL
QUERY/SELECTION	query() (and loc[], iloc[])	SELECT WHERE
SORT	sort_values()	ORDER BY
SELECT-DISTINCT	unique(), drop_duplicates()	SELECT DISTINCT COLUMN
ASSIGN	assign	ALTER/UPDATE

SQLite and Pandas

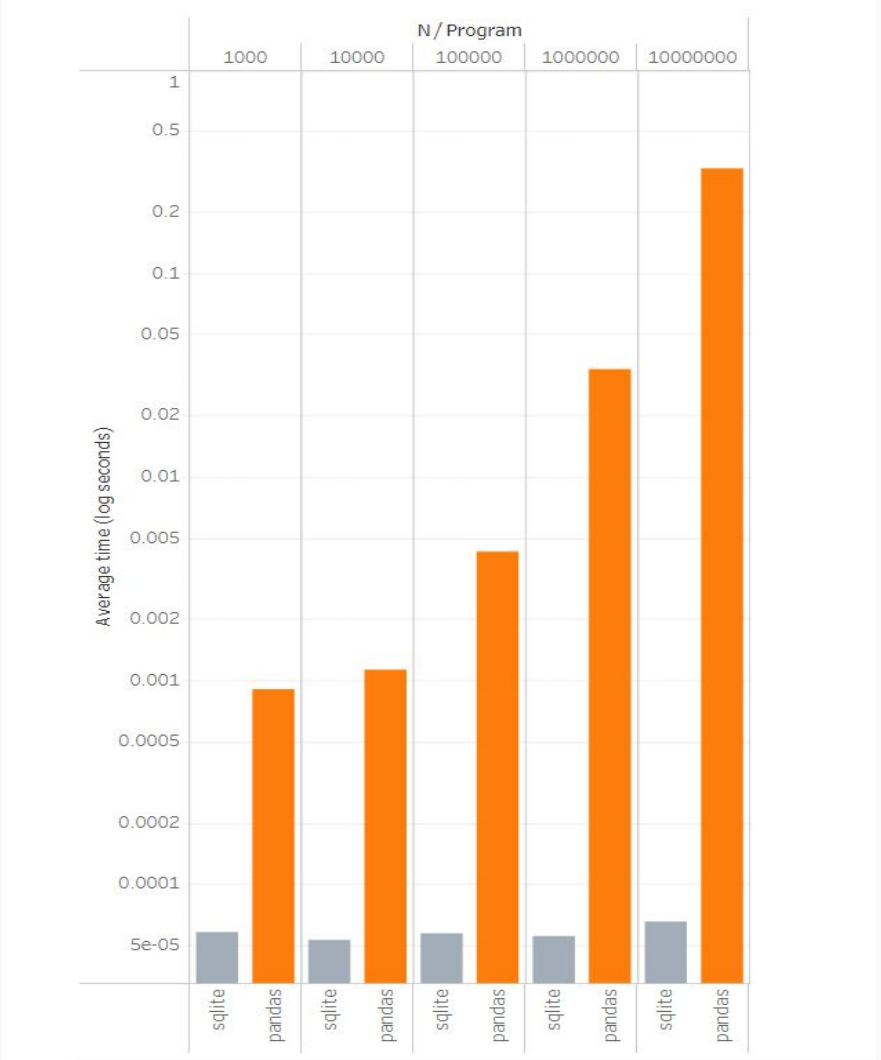
VERBS	PANDAS	SQL
AGGREGATE	describe(), mean(), max()	None, AVG(),MAX()
SAMPLE	sample()	implementation dep, use RAND()
GROUP-AGG	groupby/agg, count, mean	GROUP BY
DELETE	drop/masking	DELETE/WHERE

Structured Query Language

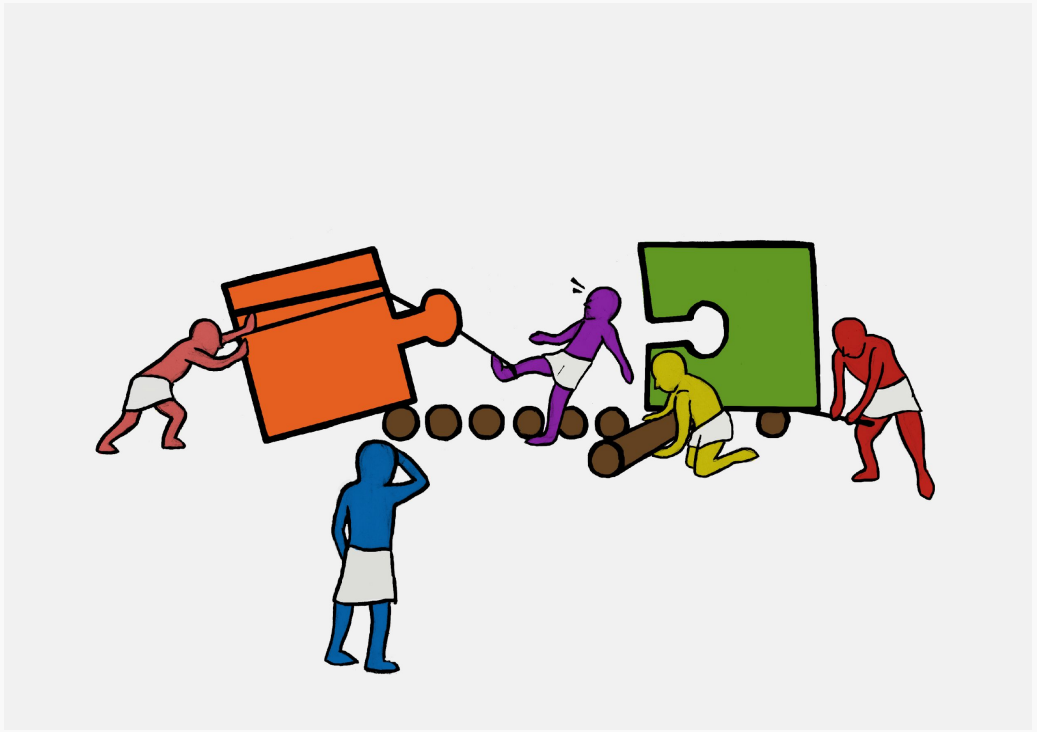
SQL will be faster under the following conditions.

- Dealing With Highly Structured and Relational Data
- The Mathematical Operations Involved Are Kept Simple
- The Need for Transforming Data Into Other Formats Is Not Present

Moreover, relational databases are important for data that doesn't fit into memory.

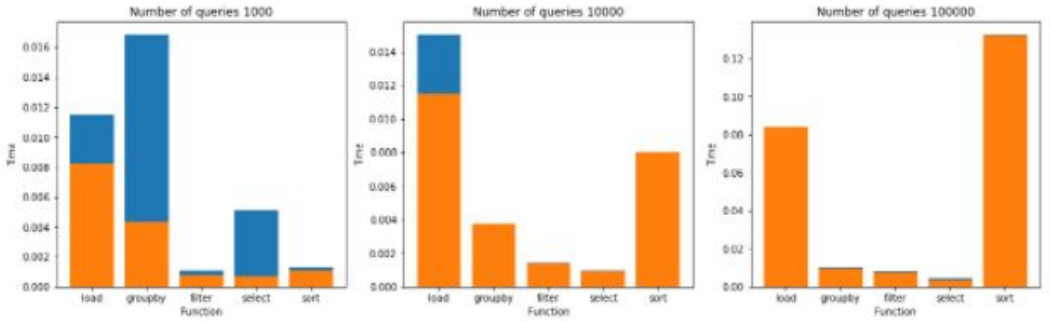


Performance comparison for 'select' queries



Exercise: B.1 - Comparing the performance of Pandas and SQLite

The aim of this exercise is to evaluate the performance of SQLite and Pandas for different functions.



Instructions:

- Write a function to generate a sample dataset of a given size with column names 'Name', 'Department', 'Birthyear' and 'Salary'. Use randomly generated string, character, integer and float data types to generate the CSV.
- Generate 4 different sample datasets with 1000, 10000, 100000 and 1000000 rows each.
- Define a class `PandasQuery` with 5 functions to perform the following queries using Pandas:
  - `load(csv_file, column_names)` - Read in the csv file and create a Pandas DataFrame with appropriate column names
  - `groupby(df)` - Groups the dataset by department and aggregate to find mean of 'DOB' and sum of 'Salary'
  - `filter(df)` - Filter the dataframe to obtain rows that contain Department=='a'
  - `select(df)` - Selects the 'Name' and 'Department' columns of the

Combining Tables

Mutating Joins add new variables to one table by matching rows.

Common types of joins:

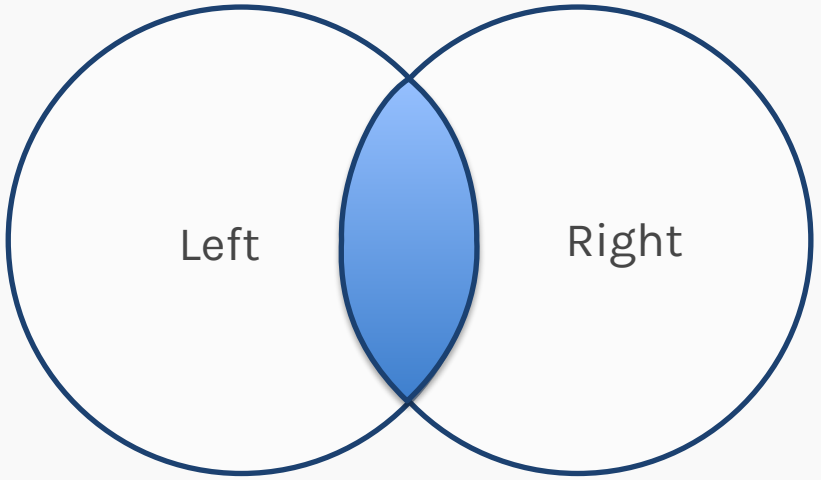
1. Inner Join
2. Left (Outer) Join
3. Right (Outer) Join
4. Full (Outer) Join

Note: SQLite supports Inner Join and Left (Outer) Join

Inner Join

LEFT	key	A	B
0	K0	A0	B0
1	K1	A1	B1
2	K2	A2	B2
3	K3	A3	B3

RIGHT	key	C	D
0	K0	C0	D0
1	K1	C1	D1
2	K1	C2	D2
3	K4	C3	D3



Inner Merge

RESULT	key	A	B	C	D
0	K0	A0	B0	C0	D0
1	K1	A1	B1	C1	D1
2	K1	A1	B1	C2	D2

Pandas

```
pd.merge(left, right, on='key', how='inner')
```

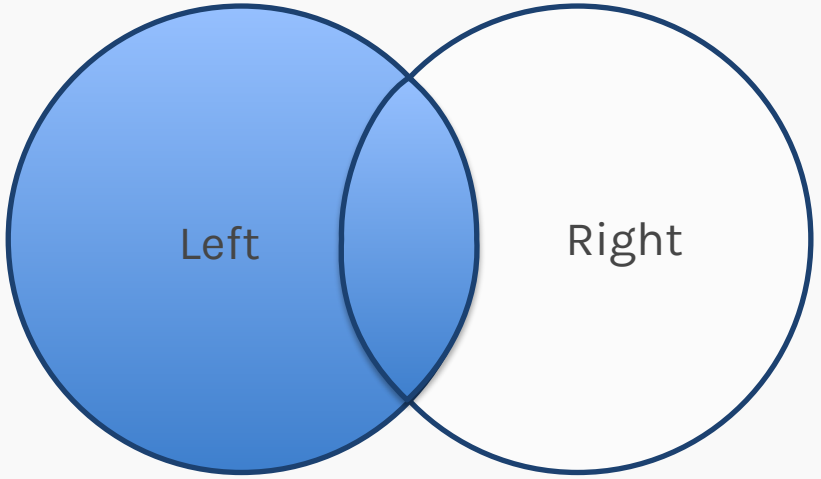
SQL

```
SELECT left.id,left.KEY,left.A,left.B,right.C,right.D FROM left
INNER JOIN right ON left.key = right.key;
```

Left Outer Join

LEFT	key	A	B
0	K0	A0	B0
1	K1	A1	B1
2	K2	A2	B2
3	K3	A3	B3

RIGHT	key	C	D
0	K0	C0	D0
1	K1	C1	D1
2	K1	C2	D2
3	K4	C3	D3



Left Merge

RESULT	key	A	B	C	D
0	K0	A0	B0	C0	D0
1	K1	A1	B1	C1	D1
2	K1	A1	B1	C2	D2
3	K2	A2	B2	NaN	NaN
4	K3	A3	B3	NaN	NaN

Pandas

```
pd.merge(left, right, on='key', how='left')
```

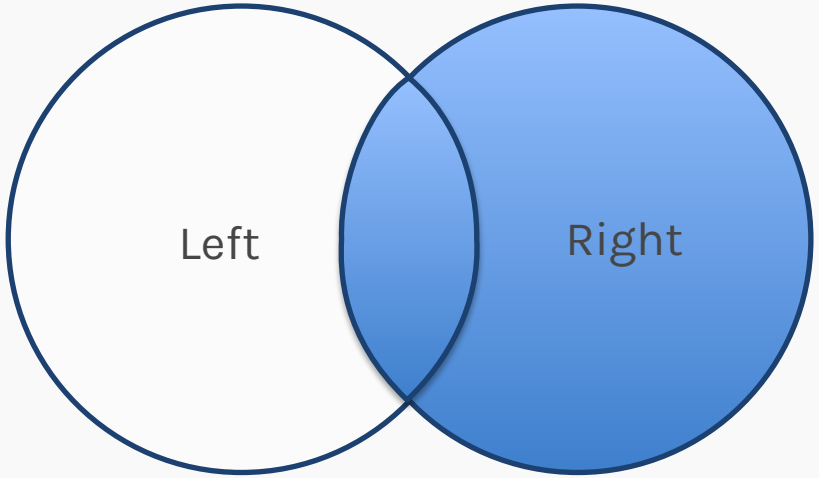
SQL

```
SELECT left.id,left.KEY,left.A,left.B,right.C,right.D FROM left
LEFT JOIN right ON left.key = right.key;
```

Right Outer Join

LEFT	key	A	B
0	K0	A0	B0
1	K1	A1	B1
2	K2	A2	B2
3	K3	A3	B3

RIGHT	key	C	D
0	K0	C0	D0
1	K1	C1	D1
2	K1	C2	D2
3	K4	C3	D3



Right Merge

RESULT	key	A	B	C	D
0	K0	A0	B0	C0	D0
1	K1	A1	B1	C1	D1
2	K1	A1	B1	C2	D2
3	K4	NaN	NaN	C3	D3

Pandas

```
pd.merge(left, right, on='key', how='right')
```

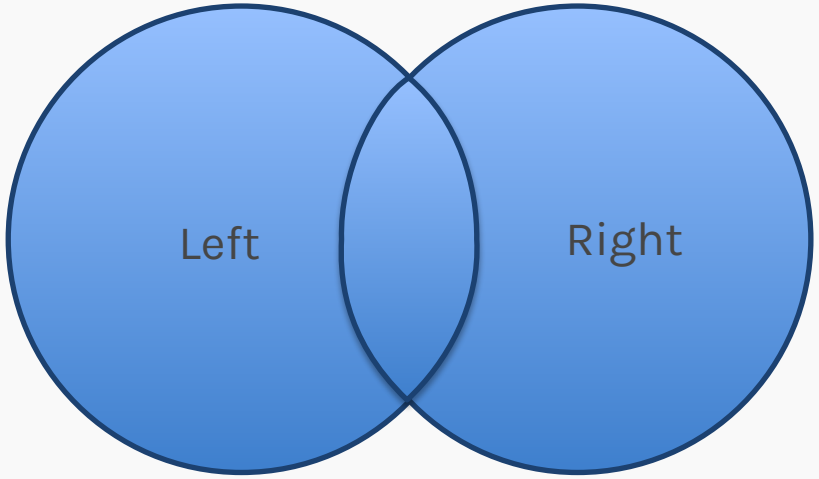
SQL

```
SELECT right.id,right.KEY,left.A,left.B,right.C,right.D FROM right
LEFT JOIN left ON right.key = left.key;
```

Full Outer Join

LEFT	key	A	B
0	K0	A0	B0
1	K1	A1	B1
2	K2	A2	B2
3	K3	A3	B3

RIGHT	key	C	D
0	K0	C0	D0
1	K1	C1	D1
2	K1	C2	D2
3	K4	C3	D3



Outer Merge

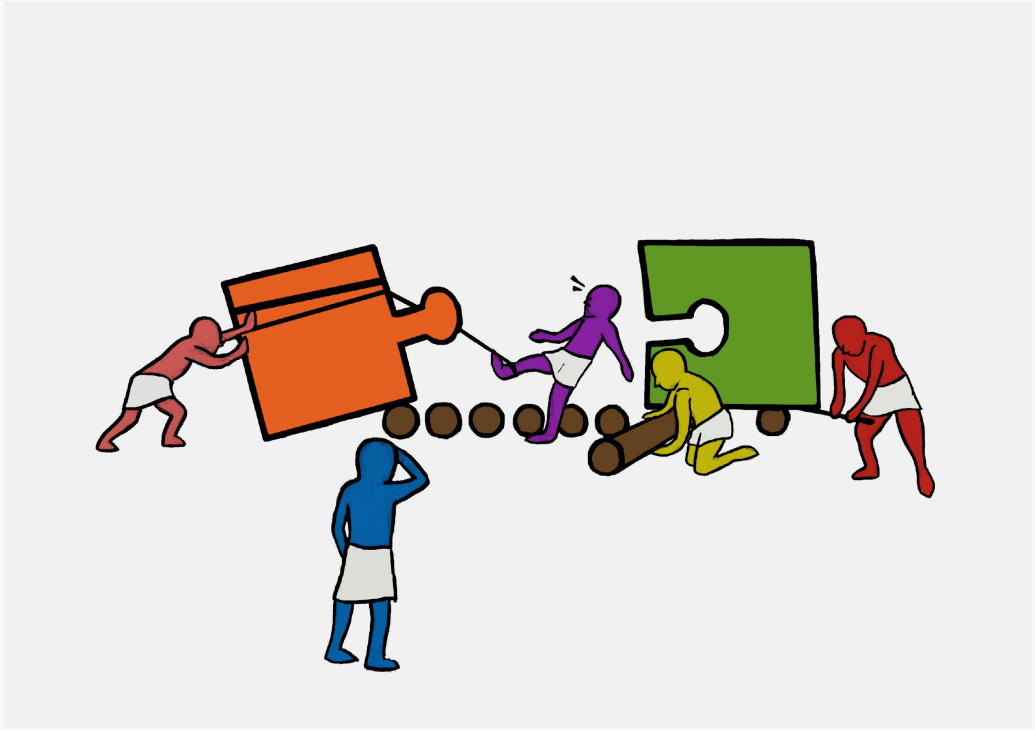
RESULT	key	A	B	C	D
0	K0	A0	B0	C0	D0
1	K1	A1	B1	C1	D1
2	K1	A1	B1	C2	D2
3	K2	A2	B2	NaN	NaN
4	K3	A3	B3	NaN	NaN
5	K4	NaN	NaN	C3	D3

Pandas

```
pd.merge(left, right, on='key', how='outer')
```

SQL

Left Outer Join ∪ Right Outer Join



Exercise: B.2 - Data manipulation with Pandas and SQL

The aim of this exercise is to get familiar with Pandas and SQL. You will learn how to create databases and query data to answer questions.

Instructions:

1. Pandas

- Load in the two txt files as dataframes. Note the format in which files are present and delete any unnecessary columns.

2. SQLITE

- Create a schema to build an SQL Database and set the type
- Set up a DBAPI-2 connection
- Initialize the database with tables
- Populate the tables with the loaded in Pandas dataframes
- Query the database
    - Define a function to make a query to the database using the `cursor.execute(sql [, optional parameters])` function.
    - Define another function to create a dataframe from the output of the query for easy readability.

3. Play around with the dataframe with Pandas and SQL!

- Find the columns for which the state column in NULL