# Introduction to databases

STREAMLINED DATA INGESTION WITH PANDAS

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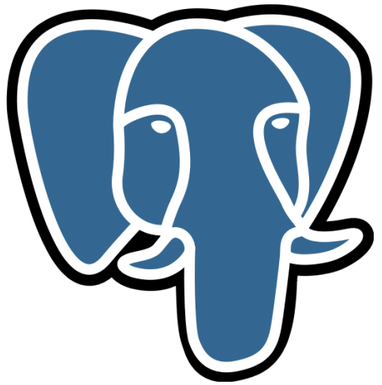
# Relational Databases

- Data about entities is organized into tables
- Each row or record is an instance of an entity
- Each column has information about an attribute
- Tables can be linked to each other via unique keys
- Support more data, multiple simultaneous users, and data quality controls
- Data types are specified for each column
- SQL (Structured Query Language) to interact with databases

# Common Relational Databases



- SQLite databases are computer files

# Connecting to Databases

- Two-step process:
  1. Create way to connect to database
  2. Query database

# Creating a Database Engine


- `sqlalchemy` 's `create_engine()` makes an engine to handle database connections
  - Needs string URL of database to connect to
  - SQLite URL format: `sqlite:///filename.db`

# Querying Databases

- `pd.read_sql(query, engine)` to load in data from a database
- Arguments
  - `query` : String containing SQL query to run or table to load
  - `engine` : Connection/database engine object

# SQL Review: SELECT

- Used to query data from a database
- Basic syntax:

```
SELECT [column_names] FROM [table_name];
```

- To get all data in a table:

```
SELECT * FROM [table_name];
```

- Code style: keywords in ALL CAPS, semicolon (;) to end a statement

# Getting Data from a Database

```
# Load pandas and sqlalchemy's create_engine
import pandas as pd
from sqlalchemy import create_engine

# Create database engine to manage connections
engine = create_engine("sqlite:///data.db")

# Load entire weather table by table name
weather = pd.read_sql("weather", engine)
```

```
# Create database engine to manage connections
engine = create_engine("sqlite:///data.db")

# Load entire weather table with SQL
weather = pd.read_sql("SELECT * FROM weather", engine)

print(weather.head())
```

```
      station                         name  latitude  ...   prcp  snow  tavg tmax  tmin
0  USW00094728  NY CITY CENTRAL PARK, NY US  40.77898  ...   0.00   0.0          52    42
1  USW00094728  NY CITY CENTRAL PARK, NY US  40.77898  ...   0.00   0.0          48    39
2  USW00094728  NY CITY CENTRAL PARK, NY US  40.77898  ...   0.00   0.0          48    42
3  USW00094728  NY CITY CENTRAL PARK, NY US  40.77898  ...   0.00   0.0          51    40
4  USW00094728  NY CITY CENTRAL PARK, NY US  40.77898  ...   0.75   0.0          61    50

[5 rows x 13 columns]
```

# Let's practice!

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# Refining imports with SQL queries

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# SELECTing Columns

- `SELECT [column names] FROM [table name];`
- Example:

```
SELECT date, tavg
FROM weather;
```

# WHERE Clauses

- Use a `WHERE` clause to selectively import records

```
SELECT [column_names]
  FROM [table_name]
 WHERE [condition];
```

# Filtering by Numbers

- Compare numbers with mathematical operators
  - `=`
  - `>` and `>=`
  - `<` and `<=`
  - `<>` (not equal to)
  - Example:

```
SELECT *
FROM weather
WHERE tmax > 32;
```

# Filtering Text

- Match exact strings with the `=` sign and the text to match
- String matching is case-sensitive
- Example:

```
/* Get records about incidents in Brooklyn */
SELECT *
FROM hpd311calls
WHERE borough = 'BROOKLYN';
```

# SQL and pandas

```
# Load libraries
import pandas as pd
from sqlalchemy import create_engine
# Create database engine
engine = create_engine("sqlite:///data.db")
# Write query to get records from Brooklyn
query = """SELECT *
             FROM hpd311calls
            WHERE borough = 'BROOKLYN';"""
# Query the database
brooklyn_calls = pd.read_sql(query, engine)
print(brookyn_calls.borough.unique())
```

```
['BROOKLYN']
```

# Combining Conditions: AND

- `WHERE` clauses with `AND` return records that meet all conditions

```
# Write query to get records about plumbing in the Bronx
and_query = """SELECT *
                 FROM hpd311calls
                WHERE borough = 'BRONX'
                  AND complaint_type = 'PLUMBING';"""
# Get calls about plumbing issues in the Bronx
bx_plumbing_calls = pd.read_sql(and_query, engine)

# Check record count
print(bx_plumbing_calls.shape)
```

```
(2016, 8)
```

# Combining Conditions: OR

- `WHERE` clauses with `OR` return records that meet at least one condition

```
# Write query to get records about water leaks or plumbing
or_query = """SELECT *
                FROM hpd311calls
               WHERE complaint_type = 'WATER LEAK'
                  OR complaint_type = 'PLUMBING';"""
# Get calls that are about plumbing or water leaks
leaks_or_plumbing = pd.read_sql(or_query, engine)

# Check record count
print(leaks_or_plumbing.shape)
```

```
(10684, 8)
```

# Let's practice!

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# More complex SQL queries

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# Getting DISTINCT Values

- Get unique values for one or more columns with `SELECT DISTINCT`
- Syntax:

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

- Remove duplicate records:

```
SELECT DISTINCT * FROM [table];
```

```
/* Get unique street addresses and boroughs */
SELECT DISTINCT incident_address,
       borough
  FROM hpd311calls;
```

# Aggregate Functions

- Query a database directly for descriptive statistics
- Aggregate functions
  - `SUM`
  - `AVG`
  - `MAX`
  - `MIN`
  - `COUNT`

# Aggregate Functions

- `SUM`, `AVG`, `MAX`, `MIN`
  - Each takes a single column name

```
SELECT AVG(tmax) FROM weather;
```

- `COUNT`
  - Get number of rows that meet query conditions

```
SELECT COUNT(*) FROM [table_name];
```

  - Get number of unique values in a column

```
SELECT COUNT(DISTINCT [column_names]) FROM [table_name];
```

# GROUP BY

- Aggregate functions calculate a single summary statistic by default
- Summarize data by categories with `GROUP BY` statements
- Remember to also select the column you're grouping by!

```
/* Get counts of plumbing calls by borough */
SELECT borough,
       COUNT(*)
  FROM hpd311calls
 WHERE complaint_type = 'PLUMBING'
 GROUP BY borough;
```

# Counting by Groups

```
# Create database engine
engine = create_engine("sqlite:///data.db")

# Write query to get plumbing call counts by borough
query = """SELECT borough, COUNT(*)
             FROM hpd311calls
            WHERE complaint_type = 'PLUMBING'
            GROUP BY borough;"""

# Query databse and create data frame
plumbing_call_counts = pd.read_sql(query, engine)
```

# Counting by Groups

```
print(plumbing_call_counts)
```

```
         borough  COUNT(*)
0          BRONX      2016
1       BROOKLYN      2702
2      MANHATTAN      1413
3         QUEENS       808
4  STATEN ISLAND       178
```

# Let's practice!

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# Loading multiple tables with joins

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# Keys

- Database records have unique identifiers, or keys

| unique_key | created_date | agency | complaint_type | incident_zip | incident_address | community_board | borough |
|---|---|---|---|---|---|---|---|
| Filter | Filter | Fi... | Filter | Filter | Filter | Filter | Filter |
| 38070822 | 01/01/2018 | HPD | HEAT/HOT WATER | 10468 | 2786 JEROME AVEN... | 07 BRONX | BRONX |
| 38065299 | 01/01/2018 | HPD | PLUMBING | 10003 | 323 EAST  12 STRE... | 03 MANHATTAN | MANHA... |
| 38066653 | 01/01/2018 | HPD | HEAT/HOT WATER | 10452 | 1235 GRAND CONC... | 04 BRONX | BRONX |
| 38070264 | 01/01/2018 | HPD | HEAT/HOT WATER | 10032 | 656 WEST  171 STR... | 12 MANHATTAN | MANHA... |
| 38072466 | 01/01/2018 | HPD | HEAT/HOT WATER | 11213 | 1030 PARK PLACE | 08 BROOKLYN | BROOK... |

# Keys

- Database records have unique identifiers, or keys

| course_code | course_title | department | faculty | credits | level | term | instructor_id |
|---|---|---|---|---|---|---|---|
| Filter | Filter | Filter | Filter | Filter | Filter | Filter | Filter |
| ANAT212 | Molecular Me... | Anatomy and ... | Medicine | 3 | Undergra... | Spring | 199157185 |
| ANAT214 | Systemic Hu... | Anatomy and ... | Medicine | 3 | Undergra... | Fall | 199157185 |
| ANAT261 | Introduction t... | Anatomy and ... | Medicine | 4 | Undergra... | Fall | 175319914 |
| ANAT69D1 | Cell and Deve... | Anatomy and ... | Medicine | 3 | Graduate | Fall | 193644393 |
| ANTH201 | Prehistoric Ar... | Anthropology | Arts | 3 | Undergra... | Spring | 182832540 |

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| ANAT69D1 | Cell and Deve... | Anatomy and ... | Medicine | 3 | Graduate | Fall | 193644393 |
| ANTH201 | Prehistoric Ar... | Anthropology | Arts | 3 | Undergra... | Spring | 182832540 |

# Keys

| id | name | title | degree_institution | faculty |
|---|---|---|---|---|
| Filter | Filter | Filter | Filter | Filter |
| 112013131 | Isabel Morales | Assistant Professor | Complutense Uni... | Science |
| 184601849 | Abraham Waldman | Assistant Professor | LMU Munich | Science |
| 182832540 | Henry Jones | Professor | University of Chi... | Arts |
| 146661411 | Anna Ng | Associate Professor | Queen's University | Arts |
| 199157185 | Vanessa Hawkins | Professor | Queen's University | Medicine |

# Keys

| course_code | course_title | department | faculty | credits | level | term | instructor_id | name |
|---|---|---|---|---|---|---|---|---|
| ANAT212 | Molecular Mechanisms of Cell Function | Anatomy and Cell Biology | Medicine | 3 | Undergraduate | Spring | 199157185 | Vanessa Hawkins |
| ANAT214 | Systemic Human Anatomy | Anatomy and Cell Biology | Medicine | 3 | Undergraduate | Fall | 199157185 | Vanessa Hawkins |
| ANAT261 | Introduction to Dynamic Histology | Anatomy and Cell Biology | Medicine | 4 | Undergraduate | Fall | 175319914 | Arun Agarwal |
| ANAT69D1 | Cell and Developmental Biology | Anatomy and Cell Biology | Medicine | 3 | Graduate | Fall | 193644393 | Alexis Cook |
| ANTH201 | Prehistoric Archaeology | Anthropology | Arts | 3 | Undergraduate | Spring | 182832540 | Henry Jones |

# Joining Tables

| station | name | latitude | longitude | elevation | date | month | awnd | prcp | snow | tavg | tmax | tmin |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Filter | Filter | Filter | Filter | Filter | Filter | Filter | Filter | Filter | Filter | ... | Filter | Filter |
| USW00094728 | NY CITY CEN... | 40.77898 | -73.96925 | 42.7 | 01/01/2018 | January | 7.83 | 0 | 0 | | 19 | 7 |
| USW00094728 | NY CITY CEN... | 40.77898 | -73.96925 | 42.7 | 01/02/2018 | January | 8.05 | 0 | 0 | | 26 | 13 |
| USW00094728 | NY CITY CEN... | 40.77898 | -73.96925 | 42.7 | 01/03/2018 | January | 3.13 | 0 | 0 | | 30 | 16 |
| USW00094728 | NY CITY CEN... | 40.77898 | -73.96925 | 42.7 | 01/04/2018 | January | 12.53 | 0.76 | 9.8 | | 29 | 19 |
| USW00094728 | NY CITY CEN... | 40.77898 | -73.96925 | 42.7 | 01/05/2018 | January | 12.97 | 0 | 0 | | 19 | 9 |
| USW00094728 | NY CITY CEN... | 40.77898 | -73.96925 | 42.7 | 01/06/2018 | January | 10.96 | 0 | 0 | | 13 | 6 |
| USW00094728 | NY CITY CEN... | 40.77898 | -73.96925 | 42.7 | 01/07/2018 | January | 6.49 | 0 | 0 | | 18 | 5 |

| unique_key | created_date | agency | complaint_type | incident_zip | incident_address | community_board | borough |
|---|---|---|---|---|---|---|---|
| Filter | Filter | Fi... | Filter | Filter | Filter | Filter | Filter |
| 38070822 | 01/01/2018 | HPD | HEAT/HOT WATER | 10468 | 2786 JEROME AVEN... | 07 BRONX | BRONX |
| 38065299 | 01/01/2018 | HPD | PLUMBING | 10003 | 323 EAST 12 STRE... | 03 MANHATTAN | MANHATTAN |
| 38066653 | 01/01/2018 | HPD | HEAT/HOT WATER | 10452 | 1235 GRAND CONC... | 04 BRONX | BRONX |
| 38070264 | 01/01/2018 | HPD | HEAT/HOT WATER | 10032 | 656 WEST 171 STR... | 12 MANHATTAN | MANHATTAN |
| 38072466 | 01/01/2018 | HPD | HEAT/HOT WATER | 11213 | 1030 PARK PLACE | 08 BROOKLYN | BROOKLYN |

# Joining Tables

```
SELECT *
  FROM hpd311calls
```

# Joining Tables

```
SELECT *
  FROM hpd311calls
       JOIN weather
       ON hpd311calls.created_date = weather.date;
```

- Use dot notation ( `table.column` ) when working with multiple tables
- Default join only returns records whose key values appear in both tables
- Make sure join keys are the same data type or nothing will match

# Joining and Filtering

```
/* Get only heat/hot water calls and join in weather data */
SELECT *
  FROM hpd311calls
       JOIN weather
       ON hpd311calls.created_date = weather.date
 WHERE hpd311calls.complaint_type = 'HEAT/HOT WATER';
```

# Joining and Aggregating

```
/* Get call counts by borough */
SELECT hpd311calls.borough,
         COUNT(*)
  FROM hpd311calls
 GROUP BY hpd311calls.borough;
```

# Joining and Aggregating

```
/* Get call counts by borough
   and join in population and housing counts */
SELECT hpd311calls.borough,
       COUNT(*),
       boro_census.total_population,
       boro_census.housing_units
  FROM hpd311calls
 GROUP BY hpd311calls.borough
```

# Joining and Aggregating

```
/* Get call counts by borough
   and join in population and housing counts */
SELECT hpd311calls.borough,
       COUNT(*),
       boro_census.total_population,
       boro_census.housing_units
  FROM hpd311calls
       JOIN boro_census
       ON hpd311calls.borough = boro_census.borough
 GROUP BY hpd311calls.borough;
```

```
query = """SELECT hpd311calls.borough,
                  COUNT(*),
                  boro_census.total_population,
                  boro_census.housing_units
             FROM hpd311calls
                  JOIN boro_census
                  ON hpd311calls.borough = boro_census.borough
            GROUP BY hpd311calls.borough;"""

call_counts = pd.read_sql(query, engine)
print(call_counts)
```

```
         borough  COUNT(*)  total_population  housing_units
0          BRONX     29874           1455846         524488
1       BROOKLYN     31722           2635121        1028383
2      MANHATTAN     20196           1653877         872645
3         QUEENS     11384           2339280         850422
4  STATEN ISLAND      1322            475948         179179
```

# Review

- SQL order of keywords
  - `SELECT`
  - `FROM`
  - `JOIN`
  - `WHERE`
  - `GROUP BY`

# Let's practice!

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