Introduction to Databases

INTRODUCTION TO DATABASES IN PYTHON

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A database consists of tables

Census

state	sex	age	pop2000	pop2008
New York	F	0	120355	122194
New York	F	1	118219	119661
New York	F	2	119577	116413

State_Fact

name	abbreviation	type
New York	NY	state
Washington DC	DC	capitol
Washington	WA	state

Table consist of columns and rows

Census

state	sex	age	pop2000	pop2008
New York	F	0	120355	122194
New York	F	1	118219	119661
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Table consist of columns and rows

Census

state	sex	age	pop2000	pop2008
New York	F	0	120355	122194
New York	F	1	118219	119661
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Tables can be related

Census

state	sex	age	pop2000	pop2008
New York	F	0	120355	122194
New York	F	1	118219	119661
New York	F	2	119577	116413

State_Fact

name	abbreviation	type
New York	NY	state
Washington DC	DC	capitol
Washington	WA	state

Let's practice!

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Connecting to your database

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Meet SQLAlchemy

- Two main pieces
  - Core (Relational Model focused)
  - ORM (User Data Model focused)

There are many types of databases

- SQLite
- PostgreSQL
- MySQL
- Microsoft SQL Server
- Oracle SQL
- Many more

Connecting to a database

```
from sqlalchemy import create_engine
engine = create_engine('sqlite:///census_nyc.sqlite')
connection = engine.connect()
```

- Engine: common interface to the database from SQLAlchemy
- Connection string: All the details required to find the database (and login, if necessary)

A word on connection strings

```
'sqlite:///census_nyc.sqlite'
```

Driver + Dialect

A word on connection strings

```
'sqlite:///census_nyc.sqlite'
```

Filename

What's in your database?

Before querying your database, you'll want to know what is in it: what the tables are, for example:

```
from sqlalchemy import create_engine
engine = create_engine('sqlite:///census_nyc.sqlite')
print(engine.table_names())
```

```
['census', 'state_fact']
```

Reflection

Reflection reads database and builds SQLAlchemy `Table` objects

```
from sqlalchemy import MetaData, Table
metadata = MetaData()
census = Table('census', metadata, autoload=True,
  autoload_with=engine)
print(repr(census))
```

```
Table('census', MetaData(bind=None), Column('state', VARCHAR(
length=30), table=<census>), Column('sex', VARCHAR(length=1),
table=<census>), Column('age', INTEGER(), table=<census>),
Column('pop2000', INTEGER(), table=<census>), Column('pop2008',
INTEGER(), table=<census>), schema=None)
```

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Introduction to SQL queries

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SQL Statements

- Select, insert, update, and delete data
- Create and alter data

Basic SQL querying

```
SELECT column_name FROM table_name
```

- `SELECT pop2008 FROM People`
- `SELECT * FROM People`

Basic SQL querying

```
from sqlalchemy import create_engine
engine = create_engine('sqlite:///census_nyc.sqlite')
connection = engine.connect()
stmt = 'SELECT * FROM people'
result_proxy = connection.execute(stmt)
results = result_proxy.fetchall()
```

ResultProxy vs ResultSet

```
result_proxy = connection.execute(stmt)


results = result_proxy.fetchall()
```

- `result_proxy` is a `ResultProxy`
- `results` is a `ResultSet`

Handling ResultSets

```
first_row = results[0]
print(first_row)
```

```
('Illinois', 'M', 0, 89600, 95012)
```

```
print(first_row.keys())
```

```
['state', 'sex', 'age', 'pop2000', 'pop2008']
```

```
print(first_row.state)
```

```
'Illinois'
```

SQLAlchemy to build queries

- Provides a Pythonic way to build SQL statements
- Hides differences between backend database types

SQLAlchemy querying

```
from sqlalchemy import Table, MetaData
metadata = MetaData()
census = Table('census', metadata, autoload=True,
  autoload_with=engine)
stmt = select([census])
results = connection.execute(stmt).fetchall()
```

SQLAlchemy select statement

- Requires a list of one or more Tables or Columns
- Using a table will select all the columns in it

```
stmt = select([census])
print(stmt)
```

```
'SELECT * from CENSUS'
```

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Congratulations!

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You already...

- Know about the relational model
- Can make basic SQL queries

Coming up next...

- Beef up your SQL querying skills
- Learn how to extract all types of useful information from your databases using SQLAlchemy
- Learn how to create and write to relational databases
- Deep dive into the US census dataset!

See you in the next chapter!

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Filtering and targeting data

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Where clauses

```
stmt = select([census])
stmt = stmt.where(census.columns.state == 'California')
results = connection.execute(stmt).fetchall()
for result in results:
    print(result.state, result.age)
```

```
California 0
California 1
California 2
California 3
California 4
California 5
...
```

Where clauses

- Restrict data returned by a query based on Boolean conditions
- Compare a column against a value or another column
- Often use comparisons `==` , `<=` , `>=` , or `!=`

Expressions

- Provide more complex conditions than simple operators
- E.g. `in_()`, `like()`, `between()`
- Many more in documentation
- Available as method on a `Column`

Expressions

```
stmt = select([census])
stmt = stmt.where(census.columns.state.startswith('New'))
for result in connection.execute(stmt):
    print(result.state, result.pop2000)
```

```
New Jersey 56983
New Jersey 56686
New Jersey 57011
...
```

Conjunctions

- Allow us to have multiple criteria in a where clause
- Eg. `and_()` , `or_()` , `not_()`

Conjunctions

```
from sqlalchemy import or_
stmt = select([census])
stmt = stmt.where(
    or_(census.columns.state == 'California',
        census.columns.state == 'New York'
    )
)
for result in connection.execute(stmt):
    print(result.state, result.sex)
```

```
New York M
...
California F
```

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Ordering query results

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Order by clauses

- Allows us to control the order in which records are returned in the query results
- Available as a method on statements `order_by()`

Order by ascending

```
print(results[:10])
```

```
[('Illinois',), ...]
```

```
stmt = select([census.columns.state])
stmt = stmt.order_by(census.columns.state)
results = connection.execute(stmt).fetchall()
print(results[:10])
```

```
[('Alabama',), ...]
```

Order by descending

- Wrap the column with `desc()` in the `order_by()` clause

Order by multiple

- Just separate multiple columns with a comma
- Orders completely by the first column
- Then if there are duplicates in the first column, orders by the second column
- Repeat until all columns are ordered

Order by multiple

```
print(results)
```

```
('Alabama', 'M')
```

```
stmt = select([census.columns.state, census.columns.sex])
stmt = stmt.order_by(census.columns.state, census.columns.sex)
results = connection.execute(stmt).first()
print(results)
```

```
('Alabama', 'F')
('Alabama', 'F')
...
('Alabama', 'M')
```

Let's practice!

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Counting, summing, and grouping data

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SQL functions

- E.g. `COUNT`, `SUM`
- `from sqlalchemy import func`
- More efficient than processing in Python
- Aggregate data

Sum example

```
from sqlalchemy import func
stmt = select([func.sum(census.columns.pop2008)])
results = connection.execute(stmt).scalar()
print(results)
```

```
302876613
```

Group by

- Allows us to group row by common values

Group by

```
stmt = select([census.columns.sex,
  func.sum(census.columns.pop2008)])
stmt = stmt.group_by(census.columns.sex)
results = connection.execute(stmt).fetchall()
print(results)
```

```
[('F', 153959198), ('M', 148917415)]
```

Group by

- Supports multiple columns to group by with a pattern similar to `order_by()`
- Requires all selected columns to be grouped or aggregated by a function

Group by multiple

```
stmt = select([census.columns.sex,
         census.columns.age,
         func.sum(census.columns.pop2008)
    ])
stmt = stmt.group_by(census.columns.sex,
         census.columns.age)
results = connection.execute(stmt).fetchall()
print(results)
```

```
[('F', 0, 2105442), ('F', 1, 2087705), ('F', 2, 2037280),
('F', 3, 2012742), ('F', 4, 2014825), ('F', 5, 1991082),
('F', 6, 1977923), ('F', 7, 2005470), ('F', 8, 1925725), ..
```

Handling ResultSets from functions

- SQLAlchemy auto generates "column names" for functions in the `ResultSet`
- The column names are often `func_#` such as `count_1`
- Replace them with the `label()` method

Using label()

```
print(results[0].keys())
```

```
['sex', u'sum_1']
```

```
stmt = select([census.columns.sex,
        func.sum(census.columns.pop2008).label('pop2008_sum')
    ])
stmt = stmt.group_by(census.columns.sex)
results = connection.execute(stmt).fetchall()
print(results[0].keys())
```

```
['sex', 'pop2008_sum']
```

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SQLAlchemy and pandas for visualization

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SQLAlchemy and pandas

- DataFrame can take a SQLAlchemy `ResultSet`
- Make sure to set the DataFrame columns to the `ResultSet` keys

DataFrame example

```
import pandas as pd
df = pd.DataFrame(results)
df.columns = results[0].keys()
print(df)
```

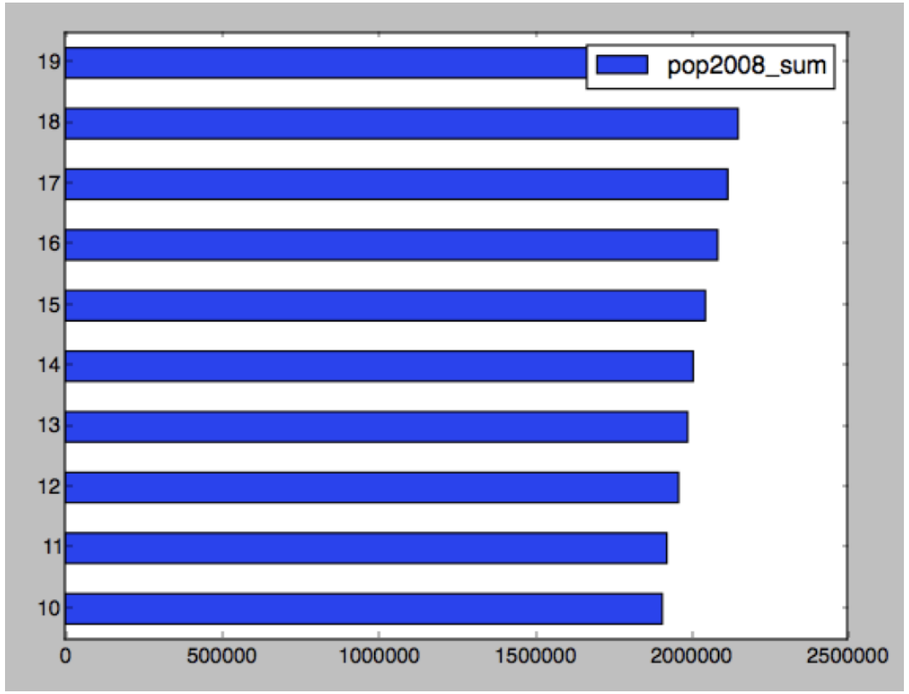
```
    sex  pop2008_sum
0     F      2105442
1     F      2087705
2     F      2037280
3     F      2012742
4     F      2014825
5     F      1991082
```

Graphing

- We can graph just like we would normally

Graphing example

```
import matplotlib.pyplot as plt
df[10:20].plot.barh()
plt.show()
```



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Calculating values in a query

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Math operators

- addition `+`
- subtraction `-`
- multiplication `*`
- division `/`
- modulus `%`
- Work differently on different data types

Calculating difference

```
stmt = select([census.columns.age,
         (census.columns.pop2008 -
         census.columns.pop2000).label('pop_change')
    ])
stmt = stmt.group_by(census.columns.age)
stmt = stmt.order_by(desc('pop_change'))
stmt = stmt.limit(5)
results = connection.execute(stmt).fetchall()
print(results)
```

```
[(61, 52672), (85, 51901), (54, 50808), (58, 45575),
(60, 44915)]
```

Case statement

- Used to treat data differently based on a condition
- Accepts a list of conditions to match and a column to return if the condition matches
- The list of conditions ends with an else clause to determine what to do when a record doesn't match any prior conditions

Case example

```
from sqlalchemy import case
stmt = select([
        func.sum(
            case([
                (census.columns.state == 'New York',
                 census.columns.pop2008)
            ], else_=0))])
results = connection.execute(stmt).fetchall()
print(results)
```

```
[(19465159,)]
```

Cast statement

- Converts data to another type
- Useful for converting...
  - integers to floats for division
  - strings to dates and times
- Accepts a column or expression and the target Type

Percentage example

```
from sqlalchemy import case, cast, Float
stmt = select([
        (func.sum(
            case([
                (census.columns.state == 'New York',
                 census.columns.pop2008)
            ], else_=0)) /
         cast(func.sum(census.columns.pop2008),
              Float) * 100).label('ny_percent')])
results = connection.execute(stmt).fetchall()
print(results)
```

```
[(Decimal('6.4267619765'),)]
```

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SQL relationships

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Relationships

- Allow us to avoid duplicate data
- Make it easy to change things in one place
- Useful to break out information from a table we don't need very often

Relationships

Census

state	sex	age	pop2000	pop2008
New York	F	0	120355	122194
New York	F	1	118219	119661
New York	F	2	119577	116413

State_Fact

name	abbreviation	type
New York	NY	state
Washington DC	DC	capitol
Washington	WA	state

Automatic joins

```
stmt = select([census.columns.pop2008,
               state_fact.columns.abbreviation])
results = connection.execute(stmt).fetchall()
print(results)
```

```
[(95012, u'IL'),
 (95012, u'NJ'),
 (95012, u'ND'),
 (95012, u'OR'),
 (95012, u'DC'),
 (95012, u'WI'),
 ...
```

Join

- Accepts a Table and an optional expression that explains how the two tables are related
- The expression is not needed if the relationship is predefined and available via reflection
- Comes immediately after the `select()` clause and prior to any `where()`, `order_by()` or `group_by()` clauses

select_from()

- Used to replace the default, derived FROM clause with a join
- Wraps the `join()` clause

select_from() example

```
stmt = select([func.sum(census.columns.pop2000)])
stmt = stmt.select_from(census.join(state_fact))
stmt = stmt.where(state_fact.columns.circuit_court == '10')
result = connection.execute(stmt).scalar()
print(result)
```

```
14945252
```

Joining tables without predefined relationship

- Join accepts a Table and an optional expression that explains how the two tables are related
- Will only join on data that match between the two columns
- Avoid joining on columns of different types

select_from() example

```
stmt = select([func.sum(census.columns.pop2000)])
stmt = stmt.select_from(
        census.join(state_fact, census.columns.state
        == state_fact.columns.name))
stmt = stmt.where(
        state_fact.columns.census_division_name ==
        'East South Central')
result = connection.execute(stmt).scalar()
print(result)
```

```
16982311
```

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Working with hierarchical tables

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Hierarchical tables

- Contain a relationship with themselves
- Commonly found in:
  - Organizational
  - Geographic
  - Network
  - Graph

Hierarchical tables - example

Employees

id	name	job	manager
1	Johnson	Admin	6
2	Harding	Manager	9
3	Taft	Sales I	2
4	Hoover	Sales I	2

Hierarchical tables - alias()

- Requires a way to view the table via multiple names
- Creates a unique reference that we can use

Querying hierarchical data

```
managers = employees.alias()
stmt = select(
        [managers.columns.name.label('manager'),
         employees.columns.name.label('employee')])
stmt = stmt.select_from(employees.join(
        managers, managers.columns.id ==
        employees.columns.manager)
stmt = stmt.order_by(managers.columns.name)
print(connection.execute(stmt).fetchall())
```

```
[(u'FILLMORE', u'GRANT'),
 (u'FILLMORE', u'ADAMS'),
 (u'HARDING', u'TAFT'), ...
```

group_by and func

- It's important to target `group_by()` at the right alias
- Be careful with what you perform functions on
- If you don't find yourself using both the alias and the table name for a query, don't create the alias at all

Querying hierarchical data

```
managers = employees.alias()
stmt = select([managers.columns.name,
        func.sum(employees.columns.sal)])
stmt = stmt.select_from(employees.join(
        managers, managers.columns.id ==
        employees.columns.manager)
stmt = stmt.group_by(managers.columns.name)
print(connection.execute(stmt).fetchall())
```

```
[(u'FILLMORE', Decimal('96000.00')),
 (u'GARFIELD', Decimal('83500.00')),
 (u'HARDING', Decimal('52000.00')),
 (u'JACKSON', Decimal('197000.00'))]
```

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Handling large ResultSets

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Dealing with large ResultSets

- `fetchmany()` lets us specify how many rows we want to act upon
- We can loop over `fetchmany()`
- It returns an empty list when there are no more records
- We have to close the `ResultProxy` afterwards

Fetching many rows

```
while more_results:
    partial_results = results_proxy.fetchmany(50)
    if partial_results == []:
        more_results = False
    for row in partial_results:
        state_count[row.state] += 1
results_proxy.close()
```

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Creating databases and tables

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Creating databases

- Varies by the database type
- Databases like PostgreSQL and MySQL have command-line tools to initialize the database
- With SQLite, the `create_engine()` statement will create the database and file is they do not already exist

Building a table

```
from sqlalchemy import (Table, Column, String,
       Integer, Decimal, Boolean)
employees = Table('employees', metadata,
       Column('id', Integer()),
       Column('name', String(255)),
       Column('salary', Decimal()),
       Column('active', Boolean()))
metadata.create_all(engine)
engine.table_names()
```

```
[u'employees']
```

Creating tables

- Still uses the Table object like we did for reflection
- Replaces the `autoload` keyword arguments with Column objects
- Creates the tables in the actual database by using the `create_all()` method on the MetaData instance
- You need to use other tools to handle database table updates, such as Alembic or raw SQL

Creating tables - additional column options

- `unique` forces all values for the data in a column to be unique
- `nullable` determines if a column can be empty in a row
- `default` sets a default value if one isn't supplied.

Building a table with additional options

```
employees = Table('employees', metadata,
       Column('id', Integer()),
       Column('name', String(255), unique=True, nullable=False),
       Column('salary', Float(), default=100.00),
       Column('active', Boolean(), default=True))
employees.constraints
```

```
{CheckConstraint(...
Column('name', String(length=255), table=<employees>, nullable=Fals
Column('salary', Float(), table=<employees>,
       default=ColumnDefault(100.0)),
Column('active', Boolean(), table=<employees>,
       default=ColumnDefault(True)), ...
UniqueConstraint(Column('name', String(length=255),
                 table=<employees>, nullable=False))}
```

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Inserting data into a table

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Adding data to a table

- Done with the `insert()` statement
- `insert()` takes the table we are loading data into as the argument
- We add all the values we want to insert in with the `values` clause as `column=value` pairs
- Doesn't return any rows, so no need for a fetch method

Inserting one row

```
from sqlalchemy import insert
```

```
stmt = insert(employees).values(id=1,name='Jason',
           salary=1.00, active=True)
result_proxy = connection.execute(stmt)
print(result_proxy.rowcount)
```

```
1
```

Inserting multiple rows

- Build an insert statement without any values
- Build a list of dictionaries that represent all the values clauses for the rows you want to insert
- Pass both the statement and the values list to the execute method on connection

Inserting multiple rows

```
stmt = insert(employees)
values_list = [{'id': 2, 'name': 'Rebecca',
                'salary': 2.00, 'active': True},
               {'id': 3, 'name': 'Bob',
                'salary': 0.00, 'active': False}]
result_proxy = connection.execute(stmt, values_list)
print(result_proxy.rowcount)
```

```
2
```

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Updating data in a table

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Updating data in a table

- Done with the `update()` statement
- Similar to the `insert()` statement but includes a `where` clause to determine what record will be updated
- We add all the values we want to update with the `values()` clause as `column=value` pairs

Updating one row

```
from sqlalchemy import update
stmt = update(employees)
stmt = stmt.where(employees.columns.id == 3)
stmt = stmt.values(active=True)
result_proxy = connection.execute(stmt)
print(result_proxy.rowcount)
```

```
1
```

Updating multiple rows

- Build a `where` clause that will select all the records you want to update

Inserting multiple rows

```
stmt = update(employees)
stmt = stmt.where(employees.columns.active == True)
stmt = stmt.values(active=False, salary=0.00)
result_proxy = connection.execute(stmt)
print(result_proxy.rowcount)
```

```
3
```

Correlated updates

```
new_salary = select([employees.columns.salary])
new_salary = new_salary.order_by(
    desc(employees.columns.salary))
new_salary = new_salary.limit(1)
stmt = update(employees)
stmt = stmt.values(salary=new_salary)
result_proxy = connection.execute(stmt)
print(result_proxy.rowcount)
```

```
3
```

Correlated updates

- Uses a `select()` statement to find the value for the column we are updating
- Commonly used to update records to a maximum value or change a string to match an abbreviation from another table

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Deleting data from a database

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Deleting data from a table

- Done with the `delete()` statement
- `delete()` takes the table we are loading data into as the argument
- A `where()` clause is used to choose which rows to delete
- Hard to undo so be careful!

Deleting all data from a table

```
from sqlalchemy import delete
stmt = select([func.count(extra_employees.columns.id)])
connection.execute(stmt).scalar()
```

```
3
```

```
delete_stmt = delete(extra_employees)
result_proxy = connection.execute(delete_stmt)
result_proxy.rowcount
```

```
3
```

Deleting specific rows

- Build a `where()` clause that will select all the records you want to delete

Deleting specific rows

```
stmt = delete(employees).where(employees.columns.id == 3)
result_proxy = connection.execute(stmt)
result_proxy.rowcount
```

```
1
```

Dropping a table completely

- Uses the `drop()` method on the table
- Accepts the engine as an argument so it knows where to remove the table from
- Won't remove it from metadata until the Python process is restarted

Dropping a table

```
extra_employees.drop(engine)
print(extra_employees.exists(engine))
```

```
False
```

Dropping all the tables

- Uses the `drop_all()` method on MetaData

Dropping all the tables

```
metadata.drop_all(engine)
engine.table_names()
```

```
[]
```

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Census case study

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Census case study

- Preparing SQLAlchemy and the database
- Loading data into the database
- Solving data science problems with queries

Part 1: preparing SQLAlchemy and the database

- Create an engine and `MetaData` object

```
from sqlalchemy import create_engine, MetaData
engine = create_engine('sqlite:///census_nyc.sqlite')
metadata = MetaData()
```

Part 1: preparing SQLAlchemy and the database

- Create and save the census table

```
from sqlalchemy import (Table, Column, String,
        Integer, Decimal, Boolean)
employees = Table('employees', metadata,
        Column('id', Integer()),
        Column('name', String(255)),
        Column('salary', Decimal()),
        Column('active', Boolean()))
metadata.create_all(engine)
```

Let's practice!

INTRODUCTION TO DATABASES IN PYTHON

Populating the database

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Part 2: populating the database

- Load a CSV file into a values list

```
values_list = []
for row in csv_reader:
    data = {'state': row[0], 'sex': row[1], 'age': row[2],
            'pop2000': row[3], 'pop2008': row[4]}
    values_list.append(data)
```

Part 2: Populating the Database

- Insert the values list into the census table

```
from sqlalchemy import insert
stmt = insert(employees)
result_proxy = connection.execute(stmt, values_list)
print(result_proxy.rowcount)
```

```
2
```

Let's practice!

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Querying the database

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Part 3: answering data science questions with queries

- Determine average age for males and females

```
from sqlalchemy import select
stmt = select([census.columns.sex,
          (func.sum(census.columns.pop2008 *
           census.columns.age) /
           func.sum(census.columns.pop2008)
         ).label('average_age')])
stmt = stmt.group_by('census.columns.sex')
results = connection.execute(stmt).fetchall()
```

Part 3: answering data science questions with queries

- Determine the percentage of Females for each state

```
from sqlalchemy import case, cast, Float
stmt = select([
          (func.sum(
              case([
                  (census.columns.state == 'New York',
                   census.columns.pop2008)
              ], else_=0)) /
           cast(func.sum(census.columns.pop2008),
                Float) * 100).label('ny_percent')])
```

Part 3: answering data science questions with queries

- Determine the top 5 states by population change from 2000 to 2008

```
stmt = select([census.columns.age,
          (census.columns.pop2008-
          census.columns.pop2000).label('pop_change')
      ])
stmt = stmt.order_by('pop_change')
stmt = stmt.limit(5)
```

Let's practice!

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Congratulations!

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