Going Beyond an Initial Python Script

How to Structure Python Code and Common Operations

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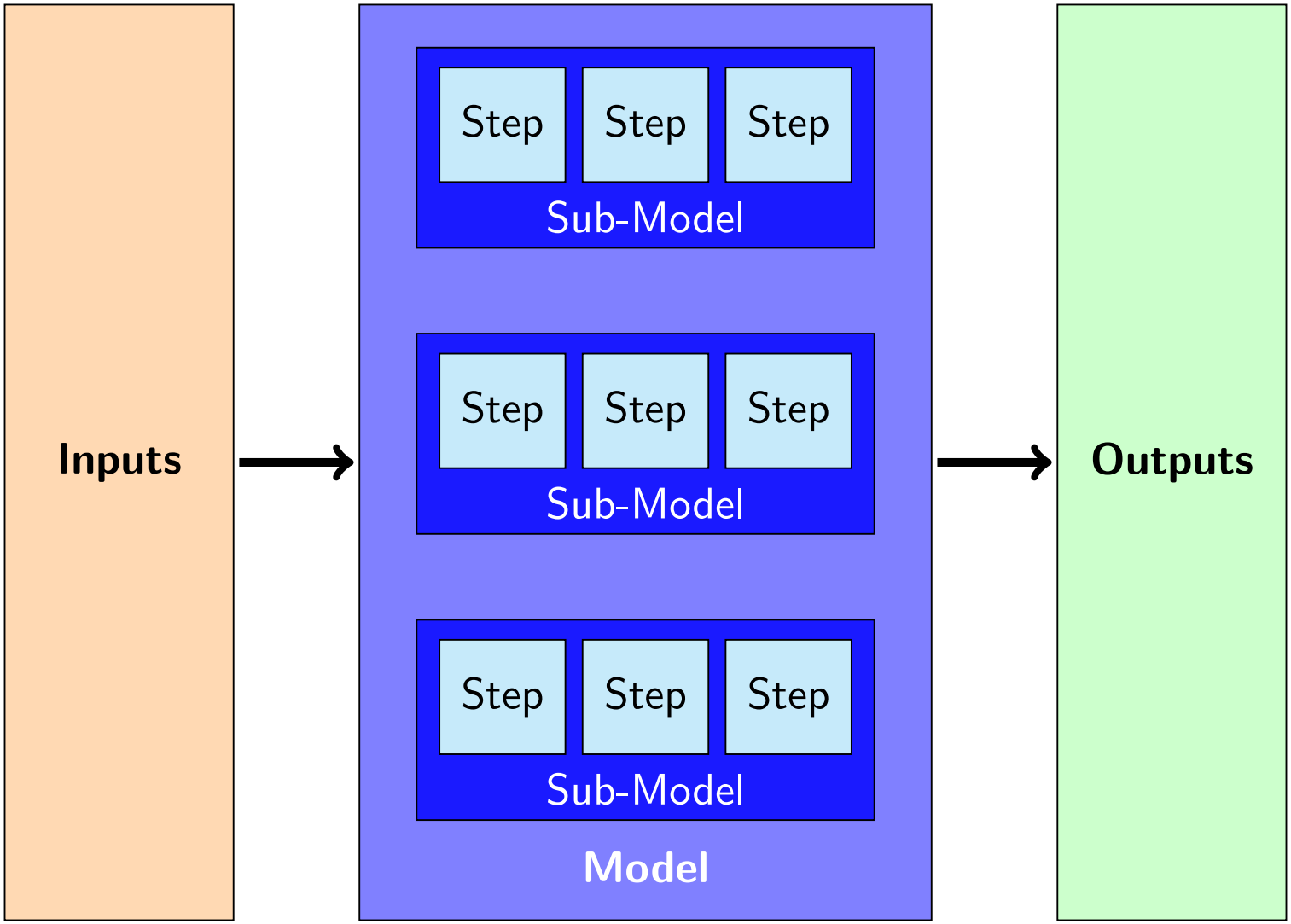
An Organized Structure of an Advanced Python Model

- Now we are going to build our first complex Python model
- We will also learn a bit more Python before we can get there
- Just as we did in Excel, we need to add structure to make the model navigatable
- Logic should be organized in functions and be documented

The Structure of a Complex Model



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Python Conditionals - If Statement

If Statements in Python

```
>>> if 5 == 6:
>>>     print('not true')
>>> else:
>>>     print('else clause')
>>>
>>> this = 'woo'
>>> that = 'woo'
>>>
>>> if this == that:
>>>     print('yes, print me')
>>> if this == 5:
>>>     print('should not print')

else clause
yes, print me
```

Explaining the If-Else Statements

- Use two equals signs to compare things (single to assign things)
- Else is equivalent to value if false behavior in Excel
- We can do a lot more than just set a single value, anything can be done in an if or else statement
- `elif` is a shorthand for else if, e.g. not the last condition, but this condition

Conditionals Example

Trying out Conditionals

- On the course site, there is a Jupyter notebook called Python Basics containing all of the examples for today's lecture
- Now I will go through the example material under "Conditionals"

Conditionals Lab, Level 1

Python Conditionals, Level 1

1. On the course site, there is a Jupyter notebook called Python Basics Lab containing all of the labs for today's lecture
2. Please complete the exercises under "Conditionals"

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Python Patterns - Building a List

List Building

```
>>> inputs = [1, 2, 3]
>>> outputs = []
>>> for inp in inputs:
>>>     outputs.append(
>>>         inp + 10
>>>     )
>>> outputs.insert(0, 'a')
>>> print(outputs)
['a', 11, 12, 13]
```

- Use `.append` to add an item to the end of a list
- Use `.insert` to add an item at a certain position

List Indexing and Slicing

- Index is base zero (0 means first item, 1 means second item)

```
>>> my_list = ['a', 'b', 'c', 'd']
>>> my_list[0]  # first item
'a'
>>> my_list[1]  # second item
'b'
>>> my_list[-1]  # last item
'd'
>>> my_list[:-1]  # up until last item
['a', 'b', 'c']
>>> my_list[1:]  # after the first item
['b', 'c', 'd']
>>> my_list[1:3]  # from the second to the third item
['b', 'c']
```

Lists Example

Doing More with Lists

- We will keep working off of Python Basics.ipynb
- Now I will go through the example material under "Working more with Lists"

Lists Lab, Level 1

Python Lists - Beyond the Basics, Level 1

1. Keep working off of Python Basics Lab.ipynb
2. Please complete the exercises under "Working with Lists"

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Functions - Grouping Reusable Logic

- In Python, we can group logic into functions
- Functions have a name, inputs, and outputs
- Functions are objects like everything else in Python
- ```
  def my_func(a, b, c=10):
      return a + b + c

  >>> my_func(5, 6)
  21
  ```
  ```

Functions Example

Structuring Code using Functions

- We will keep working off of Python Basics.ipynb
- Now I will go through the example material under "Functions"

Functions Lab, Level 1

Using Functions to Structure Code, Level 1

1. Keep working off of Python Basics Lab.ipynb
2. Please complete the exercises under "Functions"

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What are Types?

- In Python, everything is an object except for variable names, which are references to objects
- Every object has a type. We have learned about strings, numbers, lists, and booleans (True, False)
- In the next section on classes, we will learn more about the relationship between the type and the object

Formatting Python Strings

- You may have noticed that we can end up with a lot of decimals in Python output
- Further, you may want to include your results as part of a larger output, such as a sentence.
- For these operations, we have `f` strings: `f''`

Example

```
>>> my_num = 5 / 6
>>> print(my_num)
0.8333333333333334
>>> print(f'My number is {my_num:.2f}')
'My number is 0.83'
```

Numeric Types

- So far I have just said that numbers are a type in Python, but this is a simplification
- There are two main types of numbers in python: `float` and `int` corresponding to a floating point number and an integer, respectively
- An `int` is a number without decimals, while a `float` has decimals, regardless of whether they are zero
- For example, `3.5` and `3.0` are floats, while `3` is an int, even though `3.0 == 3 is True`
- Usually, this doesn't matter. But to loop a number of times, you must pass an `int`

Additional Built-In Types

- A `tuple` is like a `list` but you can't change it after it has been created (it is immutable)
- Tuples are in parentheses instead of brackets, e.g. `("a", "b")`
- A `dict` short for dictionary, stores a mapping. Use them if you want to store values associated to other values
- We will come back to `dicts` later in the course, but I wanted to introduce them now as they are a very fundamental data type

Data Types Example

Understanding the Different Data Types

- We will keep working off of Python Basics.ipynb
- Now I will go through the example material under "Exploring Data Types"

Data Types Lab, Level 1

Working with Data Types, Level 1

1. Keep working off of Python Basics Lab.ipynb
2. Please complete the exercises under "Data Types"

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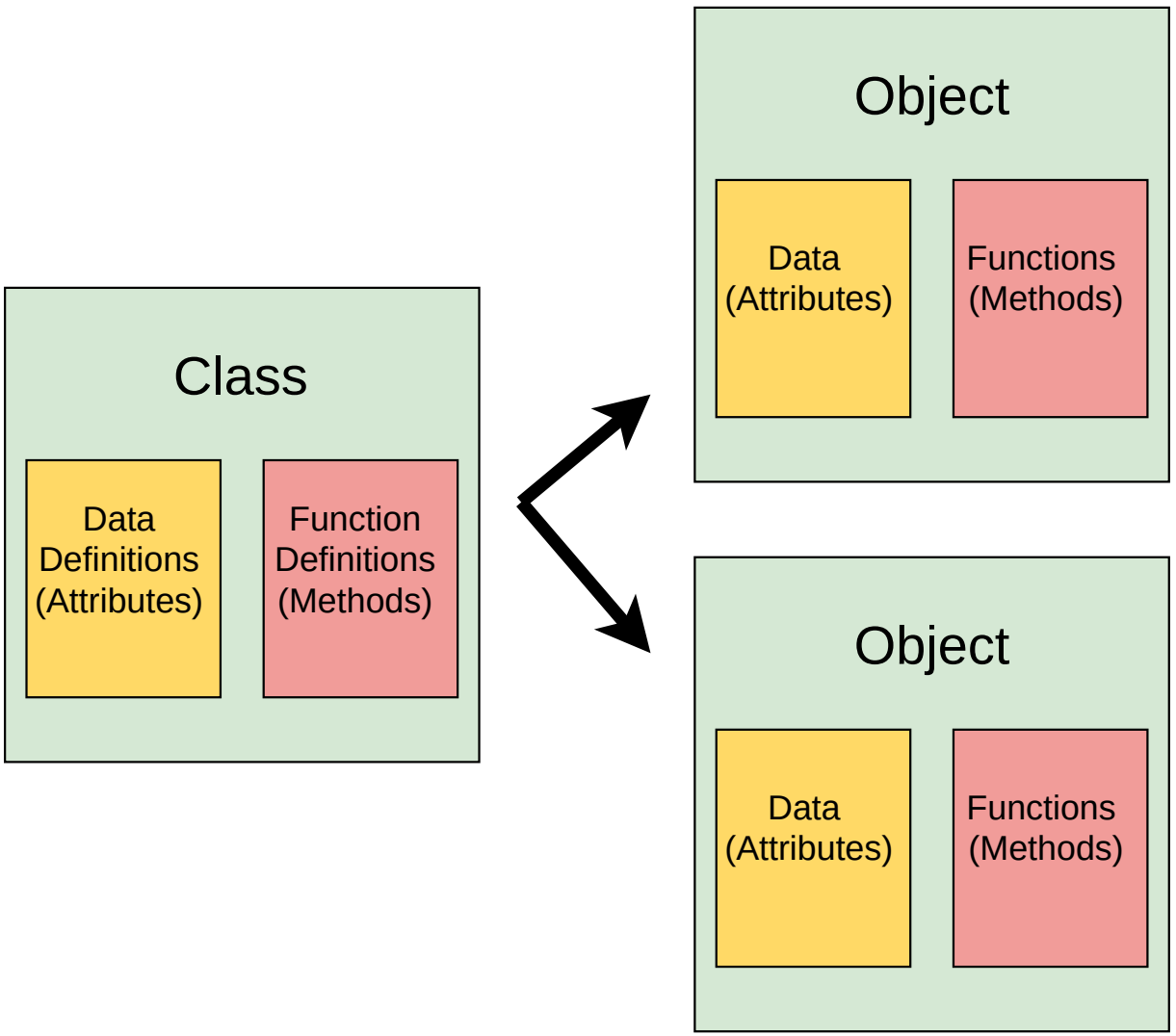
Overview of Classes and Objects



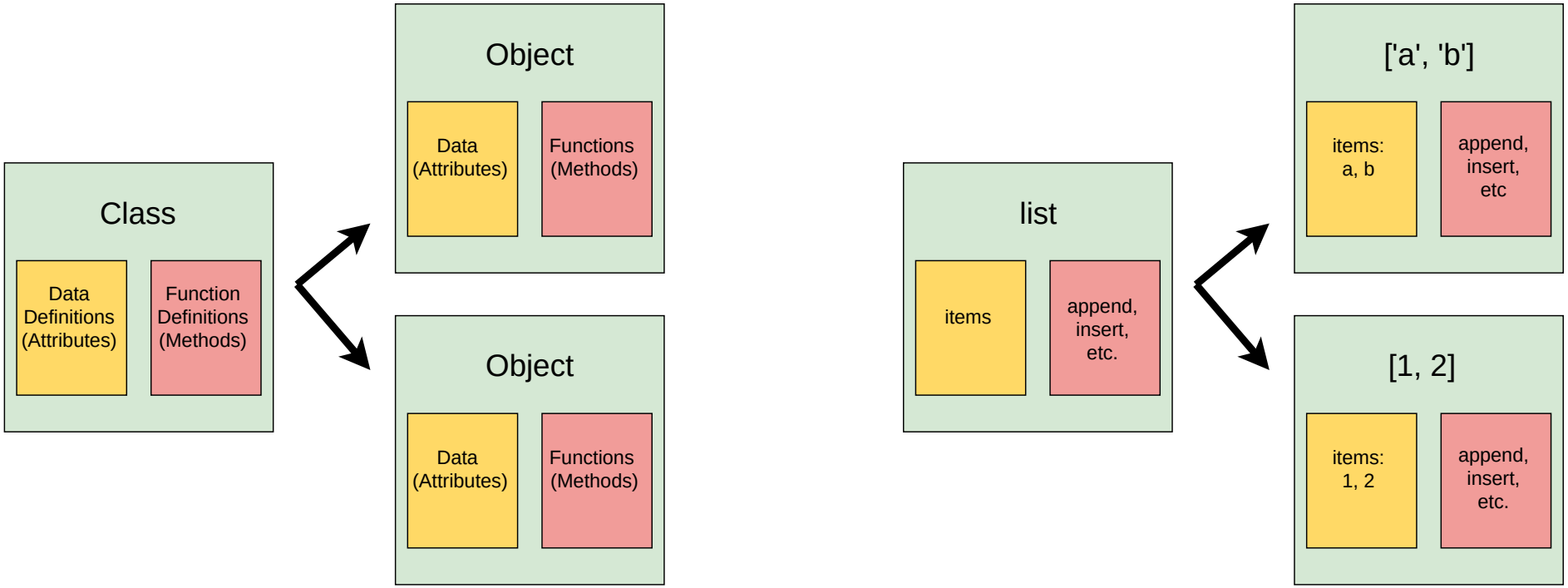
Everything is an Object. Every Object has a Class

- In Python, everything is an object except for variable names, which are references to objects
- Strings, floats, ints, lists, and tuples are types of objects. There are many more types of objects and users can define their own types of objects
- A class is a definition for a type of object. It defines how it is created, the data stored in it, and the functions attached to it
- We can write our own classes to create new types of objects to work with

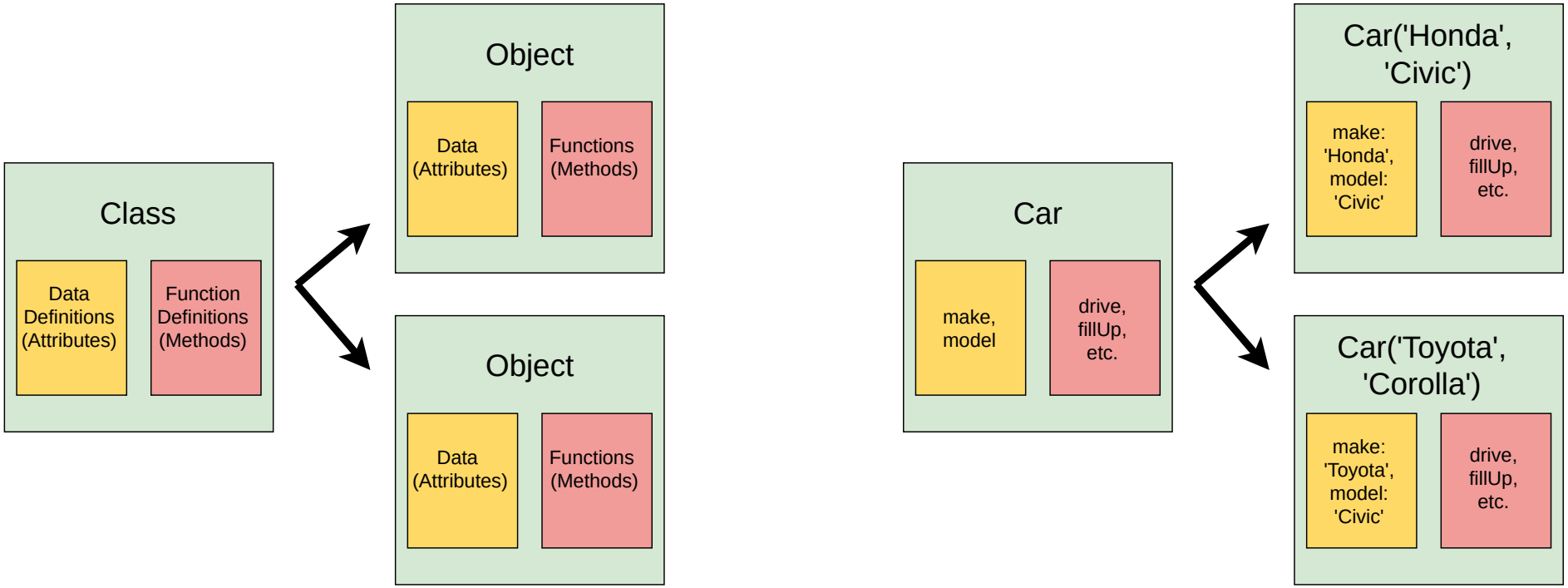
Many Objects to One Class

- From a single class definition, an unlimited number of objects can be created
- Typically the class definition says it should accept some data to create the object
- Then when you have multiple objects of the same type (created from the same class), they will have the same functions (methods) attached to them, but different data stored within
- For example, we can create two different lists. They will have different contents, but we can do `.append` on either of the lists

Lists are Objects



We can Make Custom Objects Too



Creating and Using Objects

- Constructing an object from a class looks like calling a function:

Using Custom Classes in Python

```
from car_example import Car

>>> my_car = Car('Honda', 'Civic')
>>> print(my_car)
Car(make='Honda', model='Civic')
>>> type(my_car)
car_example.Car
>>> my_car.make
'Honda'
>>> my_car.drive()
'The Honda Civic is driving away!'
```

Where we Will Focus in This Course

- I will not be teaching you about creating general classes in this course. It is very useful but is generally more advanced. I encourage you to learn them outside the course.
- We covered this material for two reasons:
- To give a better understanding of how Python works in general, and why sometimes we call functions as `something.my_func()` rather than `my_func()`
- We are going to use `dataclasses` to store our model data. They are a simplified version of classes used mainly for storing data.

Dataclass Intro

- An organized way to store our model input data:

Using Dataclasses in Python

```
from dataclasses import dataclass

@dataclass
class ModelInputs:
    interest_rates: tuple = (0.05, 0.06, 0.07)
    pmt: float = 1000

>>> inputs = ModelInputs(pmt=2000)
>>> print(inputs)
ModelInputs(interest_rates=(0.05, 0.06, 0.07), pmt=2000)
>>> type(inputs)
__main__.ModelInputs
>>> inputs.interest_rates
(0.05, 0.06, 0.07)
>>> inputs.pmt
2000
```

What, When and Why Dataclasses?

- A `dataclass` is just a class which is more convenient to create, and is typically used to group data together
- If you need to pass around multiple variables together, they make sense. For our models, we will want to pass around all the inputs, so one `dataclass` for all the inputs to the model makes sense
- This way instead of having to pass around every input individually to every function, just pass all the input data as one argument
- Also enables easy tab-completion. What were the names of my inputs? Just hit tab after `data.`

Classes Example

Working with Classes and Creating Dataclasses

- We will keep working off of Python Basics.ipynb
- For this example, also go and download car_example.py and put it in the same folder
- Now I will go through the example material under "Working with Classes"

Classes Lab, Level 1

Getting Started with Classes, Level 1

1. Keep working off of Python Basics Lab.ipynb
2. Make sure you have car_example.py in the same folder
3. Please complete the exercises under "Working with Classes"

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Python Error Handling

- You have certainly already seen errors coming from your Python code. When they have come up, the code doesn't run.
- Sometimes you actually expect to get an error, and want to handle it in some way, rather than having your program fail.

Example

```
>>> my_list = ['a', 'b']
>>> try:
>>>     my_value = my_list[10]
>>> except IndexError:
>>>     print('caught the error')
caught the error
```

An Example where Error Handling is Useful

- Let's say you're receiving annuities. There is a single annuity which produces $100 for 5 years. You receive this annuity in year 0 and in year 3.
- You might define the annuity cash flows as a list of 100, 5 times (`[100] * 5`)
- Then you want to come up with your overall cash flows, going out to 15 years

Applying Error Handling

Calculating the Sum of Unaligned Annuity Cash-Flows

```
>>> annuity = [100] * 5
>>> annuities = [
>>>     annuity,
>>>     [0, 0, 0] + annuity
>>> ]
>>> n_years = 10
>>> output = [0] * n_years
>>> for i in range(n_years):
>>>     for ann in annuities:
>>>         try:
>>>             output[i] += ann[i]
>>>         except IndexError:
>>>             pass
>>> print(output)
[100, 100, 100, 200, 200, 100, 100, 100, 0, 0]
```