10.2 Defining Our Own Data Types, Part 3

All the way back in Chapter 5, we learned how to create our own simple data types in Python using the `@dataclass` decorator. While data classes are very useful, they are just one (simplified) form of classes in Python. The `@dataclass` decorator takes our data class definition—its *public interface*—and automatically creates an implementation of class. This makes it very simple to create data classes, at the cost of flexibility of implementation.

In this section, we'll learn about how to create a Python data type from scratch, without the automatic implementation that `@dataclass` provides. In future sections, we'll apply what we've learned to defining new Python data types to solve various computational problems.

What if we just remove the `@dataclass`?

To start with, recall the `Person` data class example we used when we first introduced data classes:

```
@dataclass
class Person:
    """A custom data type that represents data for a perso
    given_name: str
    family_name: str
    age: int
    address: str
```

We were able to use this data class to create and display an instance of the class and access its attributes:

```
>>> david = Person('David', 'Liu', 100, '40 St. George Street')
>>> david
Person(given_name='David', family_name='Liu', age=100, address='40 St. George Street')
>>> david.given_name
'David'
>>> david.family_name
'Liu'
>>> david.age
100
>>> david.address
'40 St. George Street'
```

Now let's see what happens if we remove the `@dataclass` decorator from our class definition. This is indeed valid Python syntax, but with perhaps an unexpected consequence.

```
# @dataclass (We've commented out this line)
class Person:
    """A custom data type that represents data for a perso
    given_name: str
    family_name: str
    age: int
    address: str


>>> david = Person('David', 'Liu', 100, '40 St. George Str
TypeError: Person() takes no arguments
```

Okay, something went wrong. Even though our class declaration still contains attribute names and type annotations, we cannot call `Person` and pass in values for those attributes. According to the error message, `Person() takes no arguments`. So what happens when we try to create an instance of `Person` and pass in zero arguments?

```
>>> david = Person()
>>> type(david)
<class 'Person'>
```

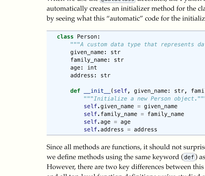
We successfully created an instance of the `Person` class. But what happens when we try to access the instance attributes?

```
>>> david.given_name
AttributeError: 'Person' object has no attribute 'given_na
```

This should make sense: by just calling `Person()` with no arguments, we haven't specified values for any of the instance attributes, so we shouldn't expect to see a value when we access `david.given_name`.

Defining an initializer

When we execute the statement `david = Person()`, all we have in memory is this:



A `Person` object has been created, but it has no attributes. To fix this (without using `@dataclass`), we need to define a new method for `Person` called the **initializer**. The initializer method of a class is called when an instance of the class is created in Python. As its name suggests, the purpose of this method it to initialize all of the instance attributes for the new object. To distinguish it from regular functions, Python **always uses the name `__init__` for the initializer method of a class**.

When we use the `@dataclass` decorator, the Python interpreter automatically creates an initializer method for the class. So let's start by seeing what this "automatic" code for the initializer looks like.

```
class Person:
    """A custom data type that represents data for a person."""
    given_name: str
    family_name: str
    age: int
    address: str

    def __init__(self, given_name: str, family_name: str, age: int, address: str) -> None:
        """Initialize a new Person object."""
        self.given_name = given_name
        self.family_name = family_name
        self.age = age
        self.address = address
```

Since all methods are functions, it should not surprise you to learn that we define methods using the same keyword (`def`) as other functions. However, there are two key differences between this method definition and all top-level function definitions we've studied so far. The first is that this method definition is *indented* so that it is inside the body of the `class Person` definition. This is how we signal that the function being defined is a method for the `Person` class.

The second difference is the presence of the parameter `self`. Every initializer has a first parameter that refers to the instance that has just been created and is to be initialized. By convention, we always call it `self`. This is such a strong Python convention that most code checkers will complain if you don't follow it.[1] In fact, this convention is so strong that we also typically omit the type annotation for `self`. We could have written `self: Person`, but because the type of `self` should *always* be the class that the initializer belongs to, this is considered redundant in Python!

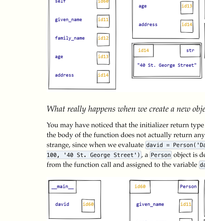
To understand how `self` works, let's examine how we call the initializer:

```
>>> david = Person('David', 'Liu', 100, '40 St. George Str
```

Notice that we never mention the initializer `__init__` by name; it is called automatically, and the values in parentheses are passed to it. Also notice that we pass four values to the initializer, even though it has five parameters. We never have to pass a value for `self`; Python automatically sets it to the instance that is to be initialized.

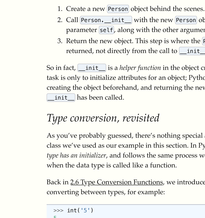
Visualizing object initialization

Let's look at some memory model diagrams to get a better sense of what's going on. Here is the state of memory when the `Person.__init__` method is first called:



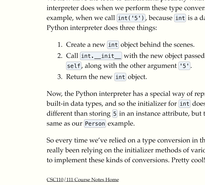
The initializer's job is to create and initialize the instance attributes. To do this, we use one assignment statement per instance attribute. This uses the same dot notation syntax that we saw in Chapter 6 for assigning to instance attributes: `self.given_name = given_name`, for example. Note that `given_name` and `self.given_name` are two different expressions! `given_name` is a *parameter* of the initialize, while `self.given_name` is an *instance attribute*.[2]

We can illustrate this distinction by showing the state of memory after all attributes have been initialized, immediately before the initializer returns:



What really happens when we create a new object

You may have noticed that the initializer return type is `None`, and that the body of the function does not actually return anything. This is a bit strange, since when we evaluate `david = Person('David', 'Liu', 100, '40 St. George Street')`, a `Person` object is definitely returned from the function call and assigned to the variable `david`.



What's going on? It turns out that calling `Person` doesn't just cause `__init__` to be called. To evaluate this call, the Python interpreter actually does three things:[3]

1. Create a new `Person` object behind the scenes.
2. Call `Person.__init__` with the new `Person` object passed as the parameter `self`, along with the other arguments.
3. Return the new object. This step is where the `Person` object is returned, not directly from the call to `__init__` in Step 2.

So in fact, `__init__` is a *helper function* in the object creation process. Its task is only to initialize attributes for an object; Python handles both creating the object beforehand, and returning the new object after `__init__` has been called.

Type conversion, revisited

As you've probably guessed, there's nothing special about the `Person` class we've used as our example in this section. In Python, *every data type has an initializer*, and follows the same process we described above when the data type is called like a function.

Back in 2.6 Type Conversion Functions, we introduced ways of converting between types, for example:

```
>>> int('5')
5
>>> str([1, 2, 3])
'[1, 2, 3]'
```

We now have the tools to understand precisely what the Python interpreter does when we perform these type conversions. For example, when we call `int('5')`, because `int` is a data type, the Python interpreter does three things:

1. Create a new `int` object behind the scenes.
2. Call `int.__init__` with the new object passed as the parameter `self`, along with the other argument `'5'`.
3. Return the new `int` object.

Now, the Python interpreter has a special way of representing most built-in data types, and so the initializer for `int` does something a bit different than storing `5` in an instance attribute, but the principle is the same as our `Person` example.

So every time we've relied on a type conversion in this course, we've really been relying on the initializer methods of various built-in classes to implement these kinds of conversions. Pretty cool!

[1] This name is the reason we refer to attributes as `self.<attr>` in class representation invariants.

[2] Some other programming languages like Java allow you to refer to instance attributes without using dot notation. In Python, however, dot notation is *mandatory* for accessing and assigning to instance attributes.

[3] Of course, this is true not just for our `Person` class, but in fact *every* class in Python.