Chapter 8. A Little Bit of Class: Abstracting Behavior and State

Well...just lookee here: all of my state, and all of your behavior...
...and it's all in the one place. Fancy that!

Classes let you bundle code behavior and state together.
In this chapter, you're setting your webapp aside while you learn about creating Python **classes.** You're doing this in order to get to the point where you can create a context manager with the help of a Python class. As creating and using classes is such a useful thing to know about anyway, we're dedicating this chapter to them. We won't cover everything about classes, but we'll touch on all the bits you'll need to understand in order to confidently create the context manager your webapp is waiting for. Let's dive in and see what's involved.

Hooking into the "with" Statement

At stated at the end of the last chapter, understanding how to hook your setup and teardown code into Python's `with` statement is straightforward...assuming you know how to create a Python **class**.

Despite being well over halfway through this book, you've managed to get by without having to define a class. You've written useful and reusable code using nothing more than Python's function machinery. There are other ways to write and organize your code, and object orientation is very popular.

You're never forced to program exclusively in the object-oriented paradigm when using Python, and the language is flexible when it comes to how you go about writing your code. But, when it comes to hooking into the `with` statement, doing so through a class is the **recommended approach**, even though the standard library comes with support for doing something similar *without* a class (although the standard library's approach is less widely applicable, so we aren't going to use it here).

The context management protocol lets your write a class that hooks into the "with" statement.

So, to hook into the `with` statement, you'll have to create a class. Once you know how to write classes, you can then create one that implements and adheres to the **context management protocol**. This protocol is the mechanism (built into Python) that hooks into the `with` statement.

Let's learn how to create and use classes in Python, before returning to our context management protocol discussion in the next chapter.

THERE ARE NO DUMB QUESTIONS

Q: **Q: Exactly what type of programming language is Python: object-oriented, functional, or procedural?**

A: **A:** *That's a great question, which many programmers moving to Python eventually ask. The answer is that Python supports programming paradigms borrowed from all three of these popular approaches, and Python encourages programmers to mix and match as needed. This concept can be hard to get your head around, especially if you come from the perspective where all the code you write has to be in a class that you instantiate objects from (as in other programming languages like, for instance, Java).*
Our advice is not to let this worry you: create code in whatever paradigm you're comfortable with, but don't discount the others simply because—as approaches—they appear alien to you.

Q: **Q: So...is it wrong to always start by creating a class?**

A: **A:** *No, it isn't, if that's what your application needs. You don't have to put all your code in classes, but if you want to, Python won't get in your way.*
So far in this book, we've gotten by without having to create a class, but we're now at the point where it makes sense to use one to solve a specific application issue we're grappling with: how best to share our database processing code within our webapp. We're mixing and matching programming paradigms to solve our current problem, and that's OK.

An Object-Oriented Primer

Before we get going with classes, it’s important to note that we don’t intend to cover everything there is to know about classes in Python in this chapter. Our intention is merely to show you enough to enable you to confidently create a class that implements the context management protocol.

Therefore, we won’t discuss some topics that seasoned practitioners of object-oriented programming (OOP) might expect to see here, such as *inheritance* and *polymorphism* (even though Python provides support for both). That’s because we’re primarily interested in **encapsulation** when creating a context manager.

If the jargon in that last paragraph has put you in a *blind panic*, don’t worry: you can safely read on without knowing what any of that OOP-speak actually means.

On the last page, you learned that you need to create a class in order to hook into the `with` statement. Before getting to the specifics of how to do that, let’s look at what constitutes a class in Python, writing an example class as we go. Once you understand how to write a class, we’ll return to the problem of hooking into the `with` statement (in the next chapter).

RELAX

Don’t be freaked out by all the buzzwords on this page!

If we were to run a competition to determine the page in this book with this most buzzwords on it, this one would win hands-down. Don’t be put off by all the jargon used here, though. If you already know OOP, this should all make sense. **If not, the really important bits are shown below**. Don’t worry: all this will become clearer as you work through the example on the next few pages.

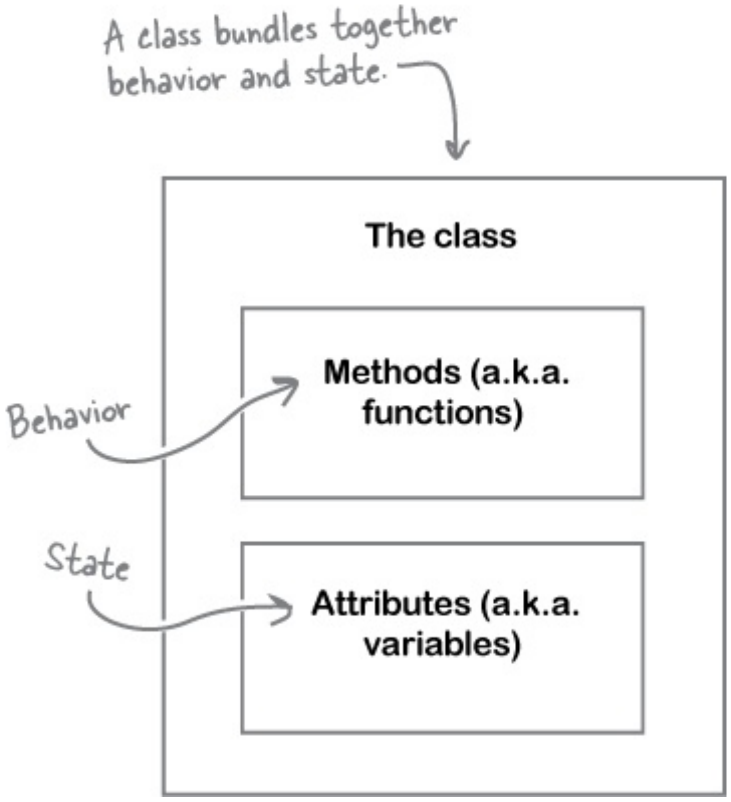
A CLASS BUNDLES BEHAVIOR AND STATE

Using a class lets you bundle **behavior** and **state** together in an object.

When you hear the word *behavior*, think *function*—that is, a chunk of code that does something (or *implements a behavior*, if you prefer).

When you hear the word *state*, think *variables*—that is, a place to store values within a class. When we assert that a class bundles behavior and state *together*, we're simply stating that a class packages functions and variables.

The upshot of all of the above is this: if you know what a function is and what variables are, you're most of the way to understanding what a class is (as well as how to create one).


A class bundles together behavior and state.
The class
Methods (a.k.a. functions)
Attributes (a.k.a. variables)
Behavior
State

CLASSES HAVE METHODS AND ATTRIBUTES

In Python, you define a class behavior by creating a method.

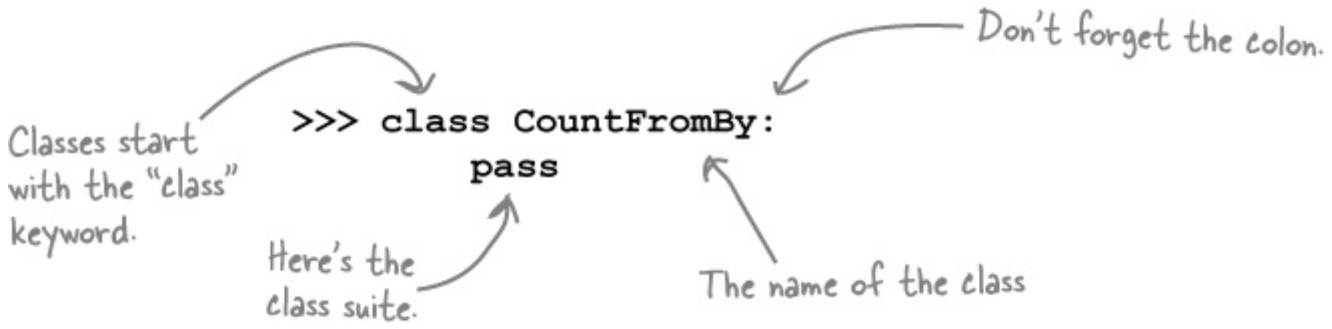
The word *method* is the OOP name given to a function that's defined within a class. Just why methods aren't simply known as *class functions* has been lost in the mists of time, as has the fact that *class variables* aren't referred to as such—they are known by the name *attribute*.

Creating Objects from Classes

To use a class, you create an object from it (you'll see an example of this below). This is known as **object instantiation**. When you hear the word *instantiate*, think *invoke*; that is, you invoke a class to create an object.

Perhaps surprisingly, you can create a class that has no state or behavior, yet is still a class as far as Python is concerned. In effect, such a class is *empty*. Let's start our class examples with an empty one and take things from there. We'll work at the interpreter's >>> prompt, and you're encouraged to follow along.

We begin by creating an empty class called `CountFromBy`. We do this by prefixing the class name with the `class` keyword, then providing the suite of code that implements the class (after the obligatory colon):

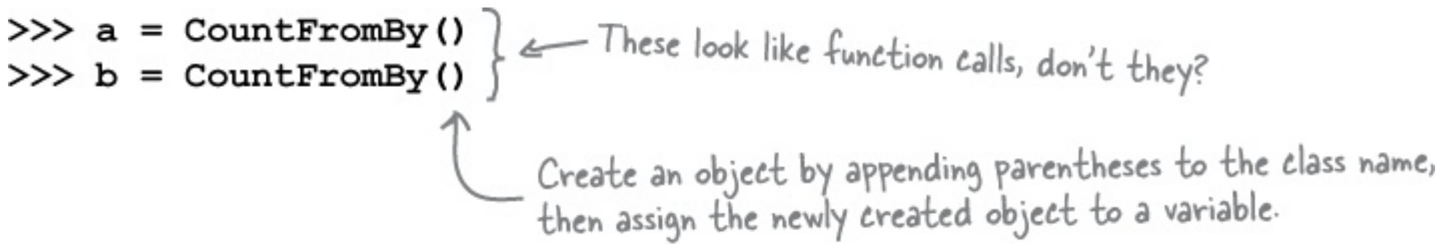


```
>>> class CountFromBy:
        pass
```

"pass" is a valid statement (i.e., it is syntactically correct), but it does nothing. Think of it as an empty statement.

Note how this class's suite contains the Python keyword `pass`, which is Python's empty statement (in that it does nothing). You can use `pass` in any place the interpreter expects to find actual code. In this case, we aren't quite ready to fill in the details of the `CountFromBy` class, so we use `pass` to avoid any syntax errors that would normally result when we try to create a class without any code in its suite.

Now that the class exists, let's create two objects from it, one called `a` and another called `b`. Note how creating an object from a class looks very much like calling a function:



```
>>> a = CountFromBy()
>>> b = CountFromBy()
```

These look like function calls, don't they?
Create an object by appending parentheses to the class name, then assign the newly created object to a variable.

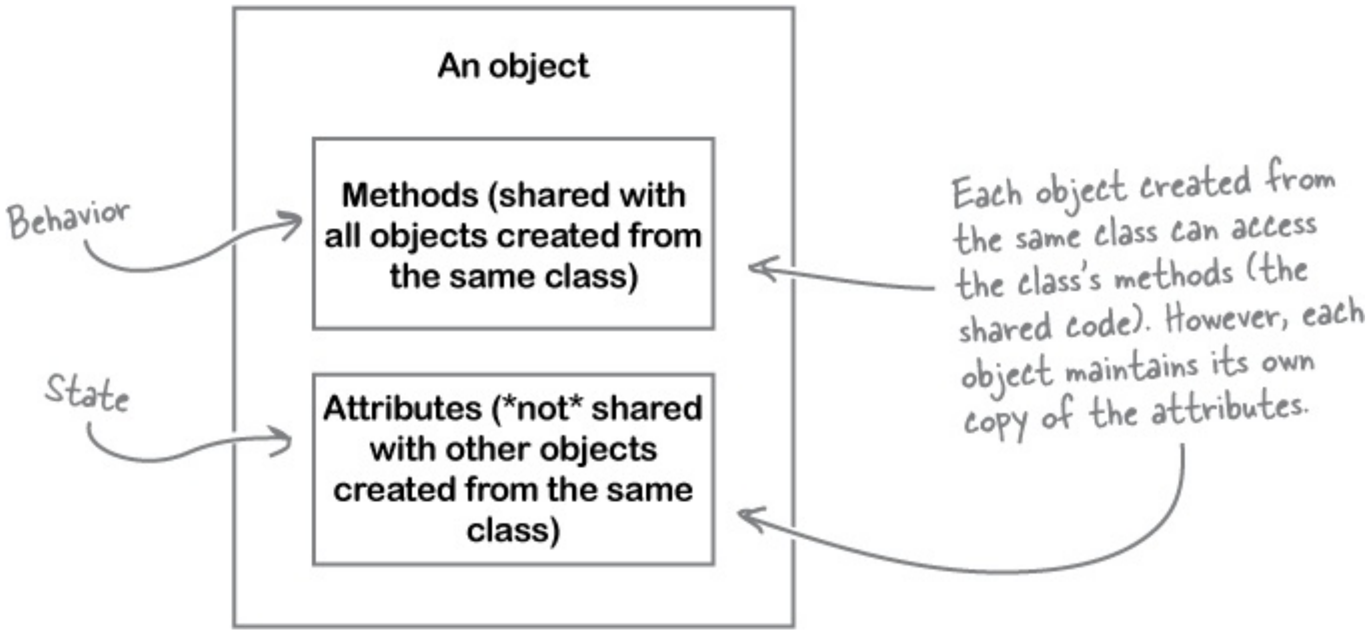
THERE ARE NO DUMB QUESTIONS

Q: Q: When I'm looking at someone else's code, how do I know if something like `CountFromBy()` is code that creates an object or code that calls a function? That looks like a function call to me...

A: **A:** *That's a great question. On the face of things, you don't know. However, there's a well-established convention in the Python programming community to name functions using lowercase letters (with underscores for emphasis), while CamelCase (concatenated words, capitalized) is used to name classes. Following this convention, it should be clear that* `count_from_by()` *is a function call, whereas* `CountFromBy()` *creates an object. All is fine* *just so long as everyone follows this convention, and you're* **strongly encouraged** *to do so, too. However, if you ignore this suggestion, all bets are off, and most Python programmers will likely avoid you and your code.*

Objects Share Behavior but Not State

When you create objects from a class, each object shares the class's coded behaviors (the methods defined in the class), but maintains its own copy of any state (the attributes):


An object
Behavior
Methods (shared with all objects created from the same class)
State
Attributes (*not* shared with other objects created from the same class)
Each object created from the same class can access the class's methods (the shared code). However, each object maintains its own copy of the attributes.

This distinction will make more sense as we flesh out the `CountFromBy` example.

DEFINING WHAT WE WANT COUNTFROMBY TO DO

Let's now define what we want the `CountFromBy` class to actually do (as an empty class is rarely useful).

Note: this new "CountFromBy" class doesn't exist just yet. You'll create it in a little bit.

Let's make `CountFromBy` an incrementing counter. By default, the counter will start at 0 and be incremented (on request) by 1. We'll also make it possible to provide an alternative starting value and/or amount to increment by. This means you'll be able to create, for example, a `CountFromBy` object that starts at 100 and increments by 10.

Let's preview what the `CountFromBy` class will be able to do (once we have written its code). By understanding how the class will be used, you'll be better equipped to understand the `CountFromBy` code as we write it. Our first example uses the class defaults: start at 0, and increment by 1 on request by calling the `increase` method. The newly created object is assigned to a new variable, which we've called `c`:

```
>>> c = CountFromBy()
>>> c
0
>>> c.increase()
>>> c.increase()
>>> c.increase()
>>> c
3
```

Create another new object, and assign it to an object called "c".

The starting value is 0.

Invoke the "increase" method to increment the value of the counter by one each time.

After the three calls to the "increase" method, the value of the object is now three.

Doing More with CountFromBy

The example usage of `CountFromBy` at the bottom of the last page demonstrated the default behavior: unless specified, the counter maintained by a `CountFromBy` object starts at 0 and is incremented by 1. It's also possible to specify an alternative starting value, as demonstrated in this next example, where the count starts from 100:

```
>>> d = CountFromBy(100)
>>> d
100
>>> d.increase()
>>> d.increase()
>>> d.increase()
>>> d
103
```

When creating this new object, specify the starting value.

The starting value is 100.

Invoke the "increase" method to increment the value of the counter by one each time.

After the three calls to the "increase" method, the value of the "d" object is now 103.

As well as specifying the starting value, it's also possible to specify the amount to increase by, as shown here, where we start at 100 and increment by 10:

```
>>> e = CountFromBy(100, 10)
>>> e
100
>>> for i in range(3):
        e.increase()

>>> e
130
```

Specifies both the starting value as well as the amount to increment by

"e" starts at 100, and ends up at 130.

Invoke the "increase" method three times within a "for" loop, incrementing the value of "e" by 10 each time.

In this final example, the counter starts at 0 (the default), but increments by 15. Rather than having to specify `(0, 15)` as the arguments to the class, this example uses a keyword argument that allows us to specify the amount to increment by, while leaving the starting value at the default (0):

```
>>> f = CountFromBy(increment=15)
>>> f
0
>>> for j in range(3):
        f.increase()

>>> f
45
```

Specifies the amount to increment by

"f" starts at 0, and ends up at 45.

As before, call "increase" three times.

It's Worth Repeating Ourselves: Objects Share Behavior but Not State

The previous examples created four new `CountFromBy` objects: `c`, `d`, `e`, and `f`, each of which has access to the `increase` method, which is a behavior that's shared by all objects created from the `CountFromBy` class. There's only ever one copy of the `increase` method's code, which all these objects use. However, each object maintains its own attribute values. In these examples, that's the current value of the counter, which is different for each of the objects, as shown here:

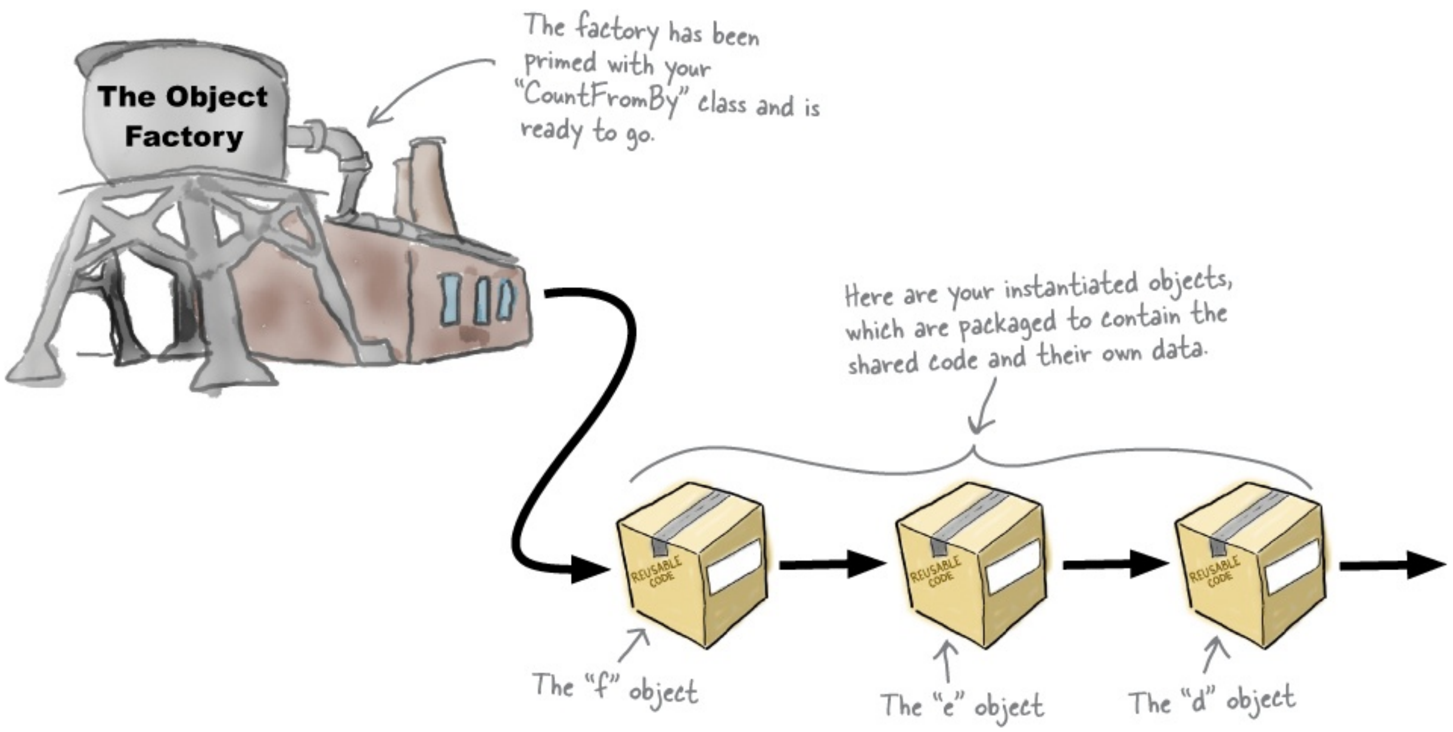
```
>>> c
3
>>> d
103
>>> e
130
>>> f
45
```

These four "CountFromBy" objects maintain their own attribute values.

Class behavior is shared by each of its objects, whereas state is not. Each object maintains its own state.

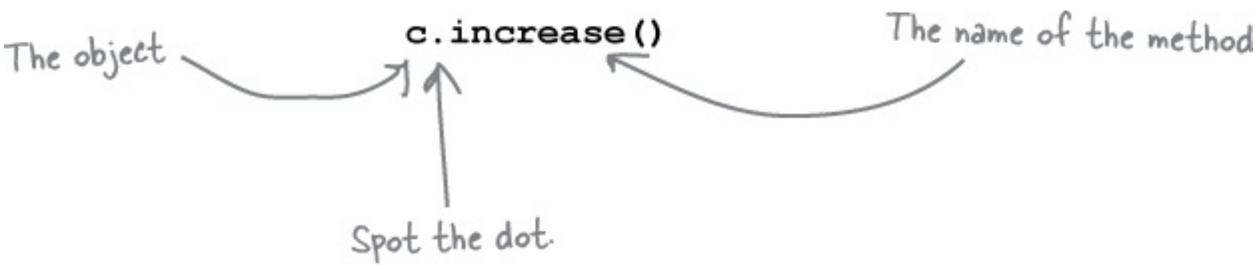
Here's the key point again: the method code is shared, but the attribute data isn't.

It can be useful to think of a class as a "cookie-cutter template" that is used by a factory to churn out objects that all behave the same, but have their own data.


The Object Factory
The factory has been primed with your "CountFromBy" class and is ready to go.
Here are your instantiated objects, which are packaged to contain the shared code and their own data.
REUSABLE CODE
The "f" object
The "e" object
The "d" object

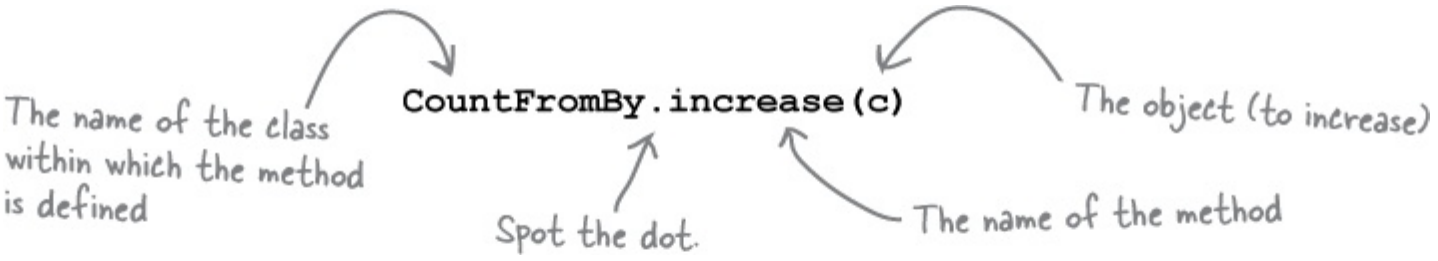
Invoking a Method: Understand the Details

We stated earlier that a method is *a function defined within a class*. We also saw examples of a method from `CountFromBy` being invoked. The `increase` method is invoked using the familiar dot notation:



```
c.increase()
```

It is instructive to consider the code the interpreter *actually* executes (behind the scenes) when it encounters the above line. Here is the call the interpreter *always* turns the above line of code into. Note what happens to `c`:



```
CountFromBy.increase(c)
```

Does the fact that this happens mean I can write "CountFromBy.increase(c)" in my code and it'll work as if I'd written "c.increase()"?

Yes, it does. But nobody ever does that.

And neither should you, as the Python interpreter does this for you anyway...so why write more code to do something that can be written more succinctly?

Just why the interpreter does this will become clearer as you learn more about how methods work.

Method Invocation: What Actually Happens

At first sight, the interpreter turning `c.increase()` into `CountFromBy.increase(c)` may look a little strange, but understanding that this happens helps explain why every method you write takes *at least* one argument.

It's OK for methods to take more than one argument, but the first argument *always* has to exist in order to take the object as an argument (which, in the example from the last page, is `c`). In fact, it is a well-established practice in the Python programming community to give each method's first argument a special name: `self`.

When `increase` is invoked as `c.increase()`, you'd imagine the method's `def` line should look like this:

```
def increase():
```

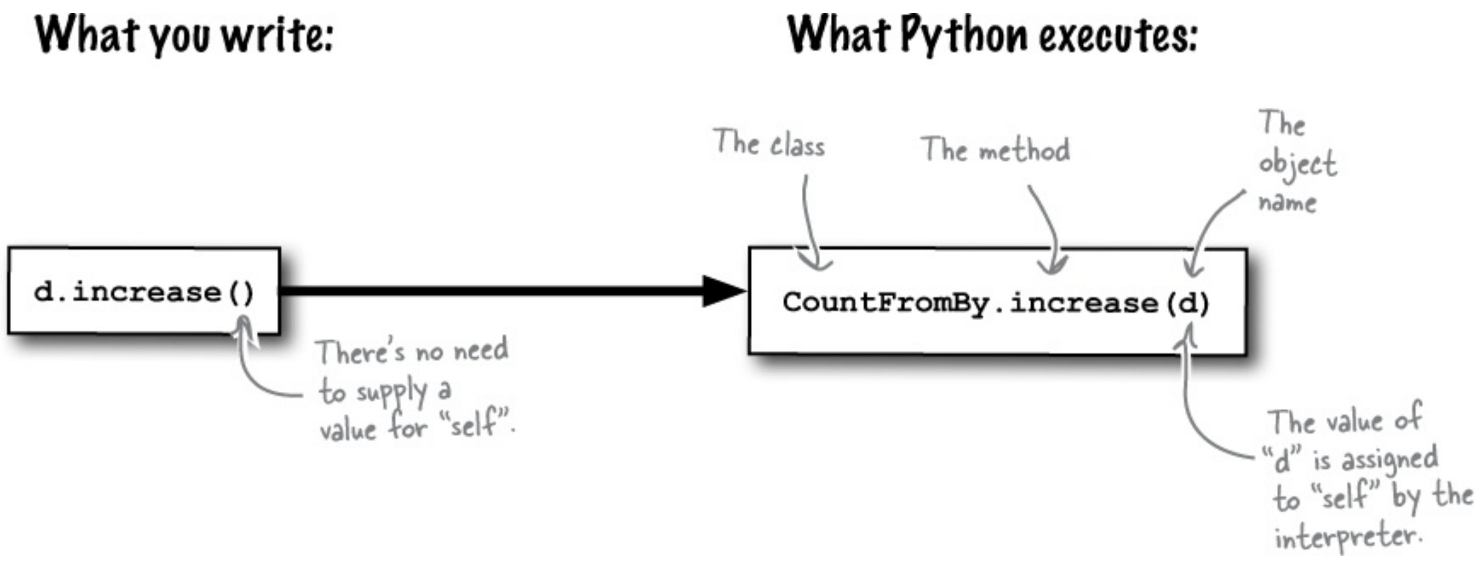
However, defining a method without the mandatory first argument will cause the interpreter to raise an error when your code runs. Consequently, the `increase` method's `def` line actually needs to be written as follows:

```
def increase(self):
```

When writing code in a class, think of "self" as an alias to the current object.

It is regarded as **very bad form** to use something other than the name `self` in your class code, even though the use of `self` does take a bit of getting used to. (Many other programming languages have a similar notion, although they favor the name `this`. Python's `self` is basically the same idea as `this`.)

When you invoke a method on an object, Python arranges for the first argument to be the invoking object instance, which is *always* assigned to each method's `self` argument. This fact alone explains why `self` is so important and also why `self` needs to be the *first argument* to every object method you write. When you invoke a method, you don't need to supply a value for `self`, as the interpreter does this for you:



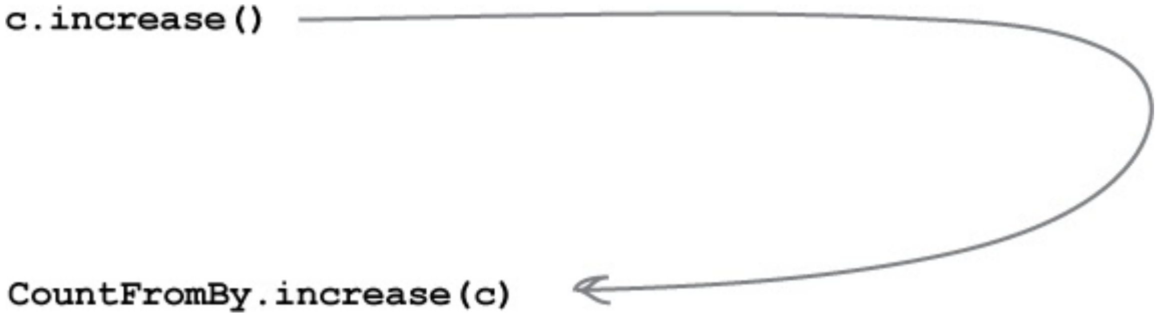
Now that you've been introduced to the importance of `self`, let's take a look at writing the code for the `increase` method.

Adding a Method to a Class

Let's create a new file to save our class code into. Create `countfromby.py`, then add in the class code from earlier in this chapter:

```
class CountFromBy:
    pass
```

We’re going to add the `increase` method to this class, and to do so we’ll remove the `pass` statement and replace it with `increase`’s method definition. Before doing this, recall how `increase` is invoked:

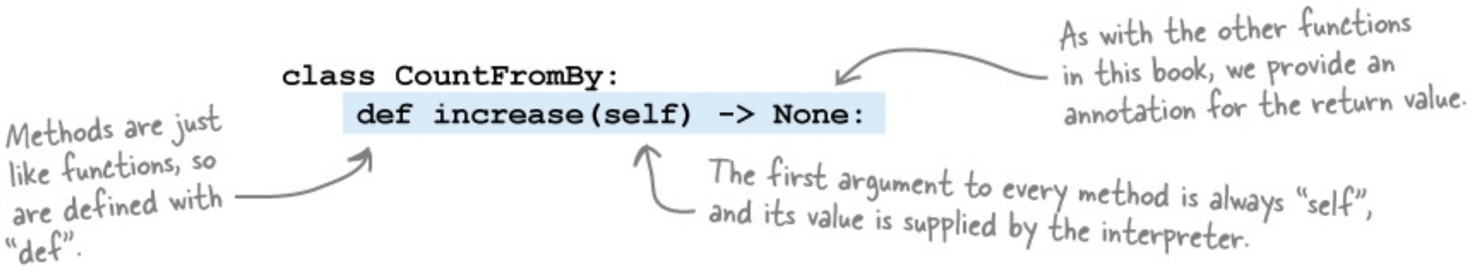


```
c.increase()
```

```
CountFromBy.increase(c)
```

Based on this call, you’d be forgiven for assuming the `increase` method takes no arguments, as there’s nothing between the parentheses, right? However, this is only half true. As you just learned, the interpreter transforms the above line of code into the following call:

The method code we write needs to take this transformation into consideration. With all of the above in mind, here’s the `def` line for the `increase` method that we’d use in this class:



```
class CountFromBy:
    def increase(self) -> None:
```

As with the other functions in this book, we provide an annotation for the return value.
Methods are just like functions, so are defined with “def”.
The first argument to every method is always “self”, and its value is supplied by the interpreter.

There are no other arguments to the `increase` method, so we do not need to provide anything other than `self` on the `def` line. However, it *is* vitally important that we include `self` here, as forgetting to results in syntax errors.

With the `def` line written, all we need to do now is add some code to `increase`. Let’s assume that the class maintains two attributes: `val`, which contains the current value of the current object, and `incr`, which contains the amount to increment `val` by every time `increase` is invoked. Knowing this, you might be tempted to add this **incorrect** line of code to `increase` in an attempt to perform the increment:

```
val += incr
```

But here’s the **correct** line of code to add to the `increase` method:

```
class CountFromBy:
    def increase(self) -> None:
        self.val += self.incr
```

Take the object's current value of "val" and increase it by the value of "incr".

Why do you think this line of code is correct, whereas the previous was incorrect?

Are You Serious About "self"?

Wait a minute...I thought one of Python's big wins was that its code is easy to read. I find that use of "self" anything but easy on the eye, and the fact that it's part of classes (which must get a lot of use) has me thinking: seriously?!?

Don't worry. Getting used to `self` won't take long.

We agree that Python's use of `self` does look a little weird...at first. However, over time, you'll get used to it, so much so that you'll hardly even notice it's there.

If you completely forget about it and fail to add it to your methods, you'll know pretty quickly that something is amiss—the interpreter will display a slew of `TypeError`s informing you that something is missing, and that something is `self`.

As to whether or not the use of `self` makes Python's class code harder to read...well, we're not so sure. In our mind, every time we see `self` used as the first argument to a function, our brains automatically know that we're looking at a method, *not* a function. This, for us, is a good thing.

Think of it this way: the use of `self` indicates that the code you're reading is a method, as opposed to a function (when `self` is *not* used).

The Importance of "self"

The `increase` method, shown below, prefixes each of the class's attributes with `self` within its suite. You were asked to consider why this might be:

```
class CountFromBy:
    def increase(self) -> None:
        self.val += self.incr
```

What's the deal with using "self" within the method's suite?

You already know that `self` is assigned the current object by the interpreter when a method is invoked, and that the interpreter expects each method's first argument to take this into account (so that the assignment can occur).

Now, consider what we already know about each object created from a class: it shares the class's method code (a.k.a. behavior) with every other object created from the same class, but maintains its *own copy* of any attribute data (a.k.a. state). It does this by associating the attribute values with the object—that is, with `self`.

Knowing this, consider this version of the `increase` method, which, as we said a couple of pages ago, is **incorrect**:

```
class CountFromBy:
    def increase(self) -> None:
        val += incr
```

Don't do this—it won't do what you think it should.

On the face of things, that last line of code seems innocent enough, as all it does is increment the current value of `val` by the current value of `incr`. But consider what happens when this `increase` method terminates: `val` and `incr`, which exist *within* `increase`, both go out of scope and consequently are destroyed the moment the method ends.

Ummm...let me just make a note of "going out of scope" and "destroyed." I'll need to look both of those up later...or did I miss something?

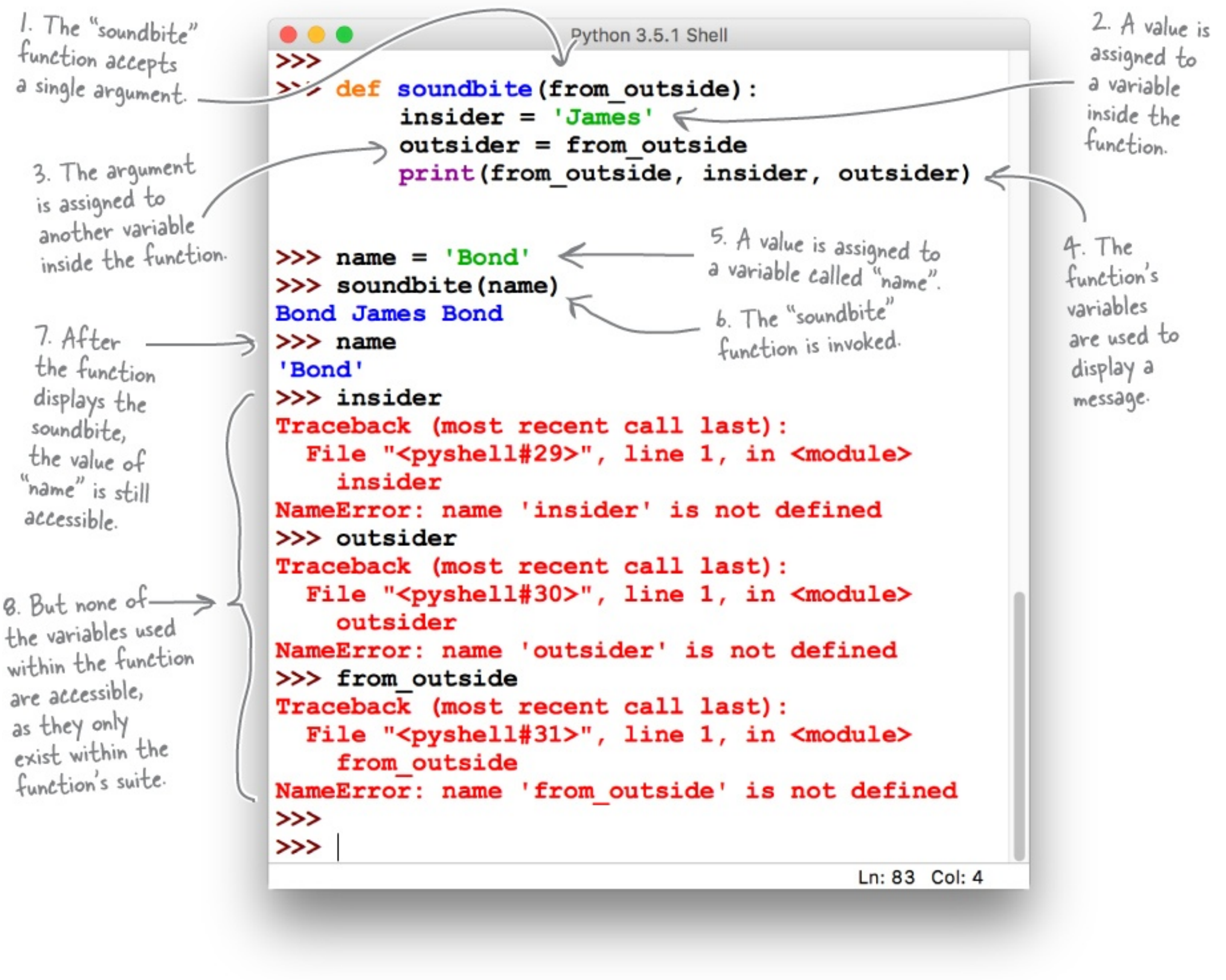
Whoops. That's our bad...

We slipped in that statement about scope without much explanation, didn't we?

In order to understand what has to happen when you refer to attributes in a method, let's first spend some time understanding what happens to variables used in a function.

Coping with Scoping

To demonstrate what happens to variables used within a function, let's experiment at the >>> prompt. Try out the code below as you read it. We've numbered the annotations 1 through 8 to guide you as you follow along:



```
>>>
>>> def soundbite(from_outside):
        insider = 'James'
        outsider = from_outside
        print(from_outside, insider, outsider)

>>> name = 'Bond'
>>> soundbite(name)
Bond James Bond
>>> name
'Bond'
>>> insider
Traceback (most recent call last):
  File "<pyshell#29>", line 1, in <module>
    insider
NameError: name 'insider' is not defined
>>> outsider
Traceback (most recent call last):
  File "<pyshell#30>", line 1, in <module>
    outsider
NameError: name 'outsider' is not defined
>>> from_outside
Traceback (most recent call last):
  File "<pyshell#31>", line 1, in <module>
    from_outside
NameError: name 'from_outside' is not defined
>>>
>>> |
```

Python 3.5.1 Shell
1. The "soundbite" function accepts a single argument.
2. A value is assigned to a variable inside the function.
3. The argument is assigned to another variable inside the function.
4. The function's variables are used to display a message.
5. A value is assigned to a variable called "name".
6. The "soundbite" function is invoked.
7. After the function displays the soundbite, the value of "name" is still accessible.
8. But none of the variables used within the function are accessible, as they only exist within the function's suite.
Ln: 83 Col: 4

When variables are defined within a function's suite, they exist while the function runs. That is, the variables are "in scope," both visible and usable within the function's suite. However, once the function ends, any variables defined within the function are destroyed—they are "out of scope," and any resources they used are reclaimed by the interpreter.

This is what happens to the three variables used within the `soundbite` function, as shown above. The moment the function terminates, `insider`, `outsider`, and `from_outside` cease to exist. Any attempt to refer to them outside the suite of function (a.k.a. outside the function's scope) results in a `NameError`.

Prefix Your Attribute Names with “self”

This function behavior described on the last page is fine when you’re dealing with a function that gets invoked, does some work, and then returns a value. You typically don’t care what happens to any variables used within a function, as you’re usually only interested in the function’s return value.

Now that you know what happens to variables when a function ends, it should be clear that this (incorrect) code is likely to cause problems when you attempt to use variables to store and remember attribute values with a class. As methods are functions by another name, neither `val` nor `incr` will survive an invocation of the `increase` method if this is how you code `increase`:

```
class CountFromBy:
    def increase(self) -> None:
        val += incr
```

Don’t do this, as these variables won’t survive once the method ends.

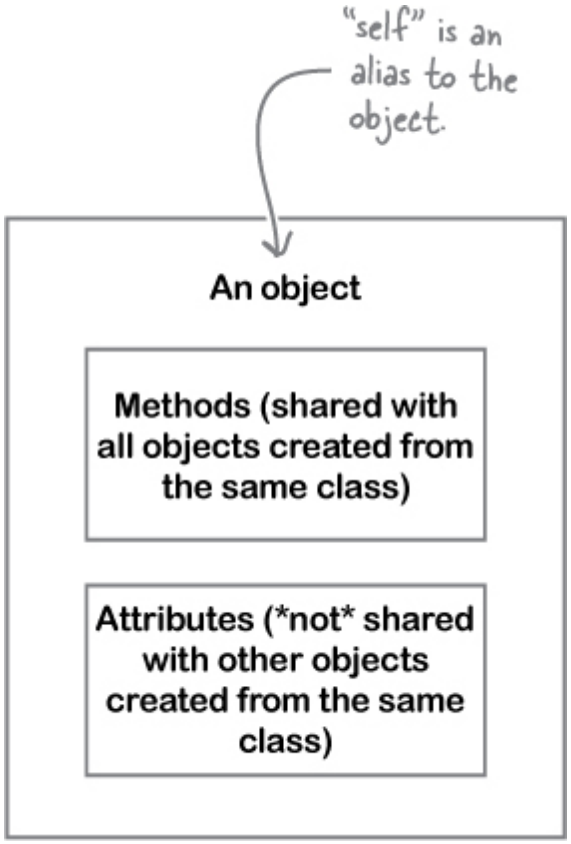
However, with methods, things are *different*. The method uses attribute values that belong to an object, and the object’s attributes continue to exist *after* the method terminates. That is, an object’s attribute values are **not** destroyed when the method terminates.

In order for an attribute assignment to survive method termination, the attribute value has to be assigned to something that doesn’t get destroyed as soon as the method ends.
That *something* is the current object invoking the method, which is stored in `self`, which explains why each attribute value needs to be prefixed with `self` in your method code, as shown here:

```
class CountFromBy:
    def increase(self) -> None:
        self.val += self.incr
```

This is much better, as “val” and “incr” are now associated with the object thanks to the use of “self”.

The rule is straightforward: if you need to refer to an attribute in your class, you *must* prefix the attribute name with `self`. The value in `self` as an *alias* that points back to the object invoking the method.

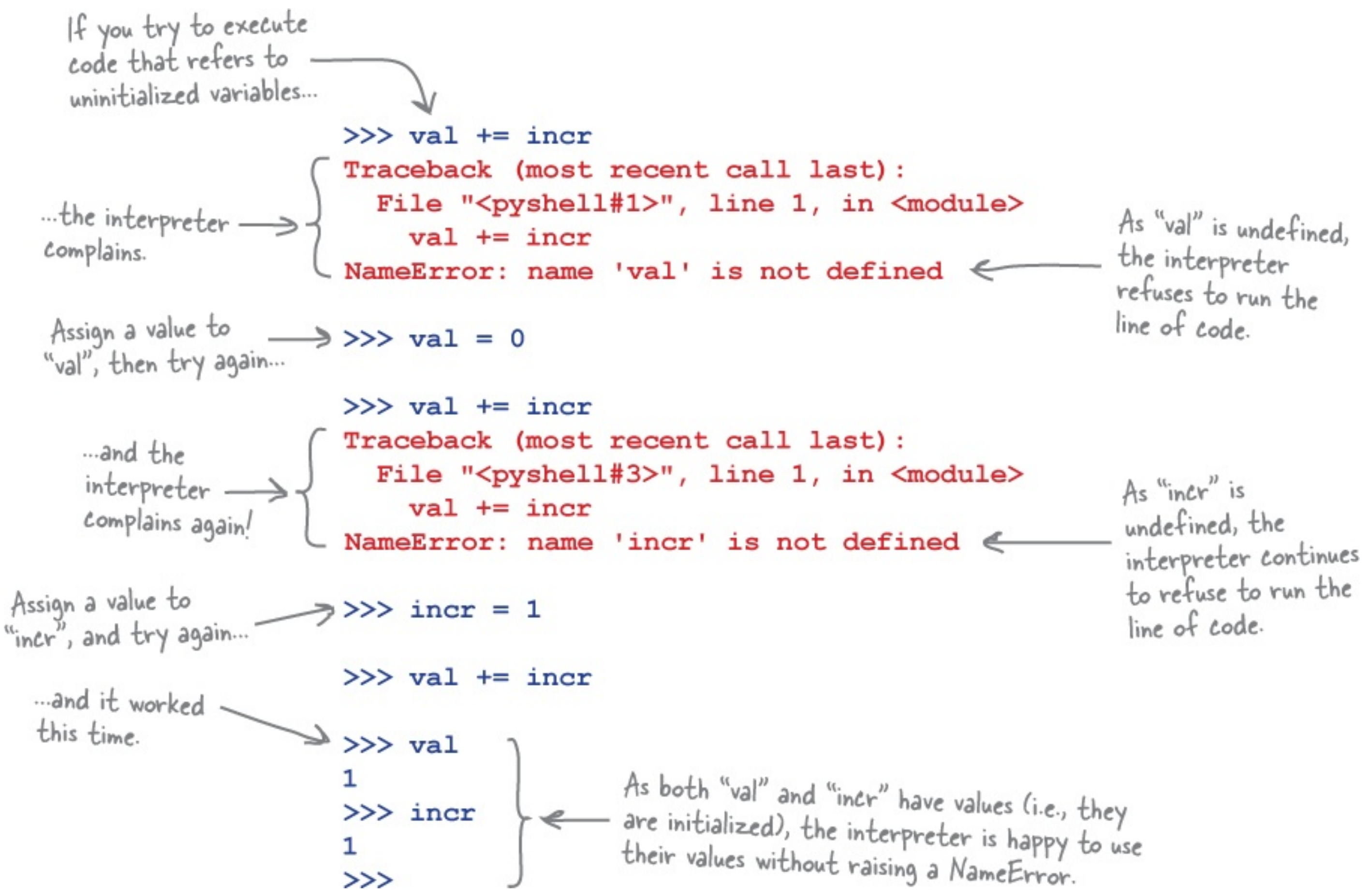

"self" is an alias to the object.
An object
Methods (shared with all objects created from the same class)
Attributes (*not* shared with other objects created from the same class)

In this context, when you see `self`, think "this object's." So, `self.val` can be read as "this object's `val`."

Initialize (Attribute) Values Before Use

All of the discussion of the importance of `self` sidestepped an important issue: how are attributes assigned a starting value? As it stands, the code in the `increase` method—the correct code, which uses `self`—fails if you execute it. This failure occurs because in Python you can't use a variable before it has been assigned a value, no matter where the variable is used.

To demonstrate the seriousness of this issue, consider this short session at the >>> prompt. Note how the first statement fails to execute when *either* of the variables is undefined:



```
>>> val += incr
Traceback (most recent call last):
  File "<pyshell#1>", line 1, in <module>
    val += incr
NameError: name 'val' is not defined

>>> val = 0

>>> val += incr
Traceback (most recent call last):
  File "<pyshell#3>", line 1, in <module>
    val += incr
NameError: name 'incr' is not defined

>>> incr = 1

>>> val += incr

>>> val
1
>>> incr
1
>>>
```

If you try to execute code that refers to uninitialized variables...
...the interpreter complains.
As "val" is undefined, the interpreter refuses to run the line of code.
Assign a value to "val", then try again...
...and the interpreter complains again!
As "incr" is undefined, the interpreter continues to refuse to run the line of code.
Assign a value to "incr", and try again...
...and it worked this time.
As both "val" and "incr" have values (i.e., they are initialized), the interpreter is happy to use their values without raising a NameError.

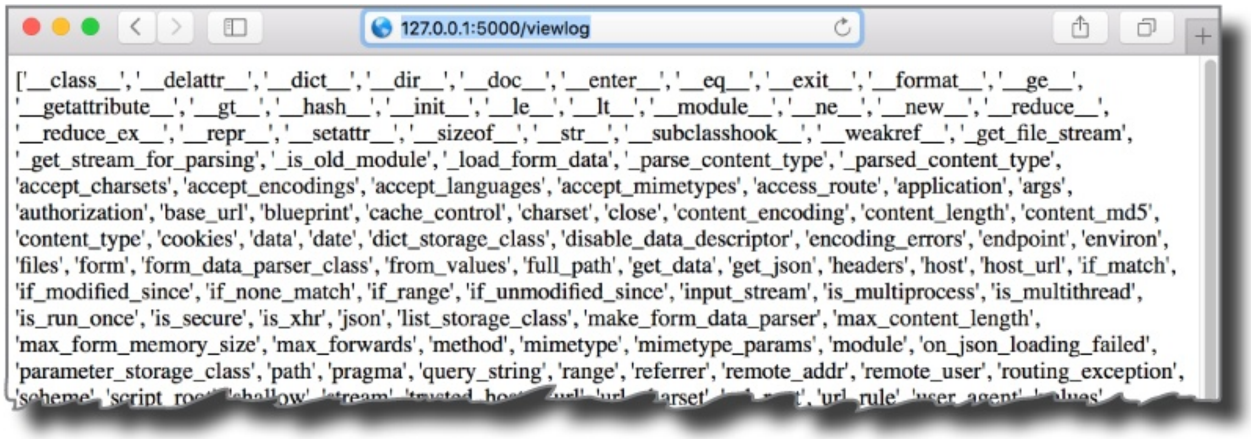
No matter where you use variables in Python, you have to initialize them with a starting value. The question is: *how do we do this for a new object created from a Python class?*

If you know OOP, the word "constructor" may be popping into your brain right about now. In other languages, a constructor is a special method that lets you define what happens when an object is first created, and it usually involves both object instantiation and attribute initialization. In Python, object instantiation is handled automatically by the interpreter, so you don't need to define a constructor to do this. A magic method called `__init__` lets you initialize attributes as needed. Let's take a look at what dunder `init` can do.

Dunder "init" Initializes Attributes

Cast your mind back to the last chapter, when you used the `dir` built-in function to display all the details of Flask's `req` object. Remember this output?

Look at all those dunders!



```
['__class__', '__delattr__', '__dict__', '__dir__', '__doc__', '__enter__', '__eq__', '__exit__', '__format__', '__ge__',
'__getattribute__', '__gt__', '__hash__', '__init__', '__le__', '__lt__', '__module__', '__ne__', '__new__', '__reduce__',
'__reduce_ex__', '__repr__', '__setattr__', '__sizeof__', '__str__', '__subclasshook__', '__weakref__', '_get_file_stream',
'_get_stream_for_parsing', '_is_old_module', '_load_form_data', '_parse_content_type', '_parsed_content_type',
'accept_charsets', 'accept_encodings', 'accept_languages', 'accept_mimetypes', 'access_route', 'application', 'args',
'authorization', 'base_url', 'blueprint', 'cache_control', 'charset', 'close', 'content_encoding', 'content_length', 'content_md5',
'content_type', 'cookies', 'data', 'date', 'dict_storage_class', 'disable_data_descriptor', 'encoding_errors', 'endpoint', 'environ',
'files', 'form', 'form_data_parser_class', 'from_values', 'full_path', 'get_data', 'get_json', 'headers', 'host', 'host_url', 'if_match',
'if_modified_since', 'if_none_match', 'if_range', 'if_unmodified_since', 'input_stream', 'is_multiprocess', 'is_multithread',
'is_run_once', 'is_secure', 'is_xhr', 'json', 'list_storage_class', 'make_form_data_parser', 'max_content_length',
'max_form_memory_size', 'max_forwards', 'method', 'mimetype', 'mimetype_params', 'module', 'on_json_loading_failed',
'parameter_storage_class', 'path', 'pragma', 'query_string', 'range', 'referrer', 'remote_addr', 'remote_user', 'routing_exception',
'scheme', 'script_ro [illegible] 'shallow', 'stream', 'trusted_ho [illegible] 'url', 'url [illegible] arset', [illegible] t', 'url_rule', 'user_agent', 'values',
```

At the time, we suggested you ignore all those dunders. However, it's now time to reveal their purpose: the dunders provide hooks into every class's standard behavior.

Unless you override it, this standard behavior is implemented in a class called `object`. The `object` class is built into the interpreter, and every other Python class *automatically* inherits from it (including yours). This is OOP-speak for stating that the dunder methods provided by `object` are available to your class to use as is, or to override as needed (by providing your own implementation of them).

You don't have to override any `object` methods if you don't want to. But if, for example, you want to specify what happens when objects created from your class are used with the equality operator (`==`), then you can write your own code for the `__eq__` method. If you want to specify what happens when objects are used with the greater-than operator (`>`), you can override the `__ge__` method. And when you want to *initialize* the attributes associated with your object, you can use the `__init__` method.

The standard dunder methods, available to all classes, are known as "the magic methods."

As the dunders provided by `object` are so useful, they're held in near-mystical reverence by Python programmers. So much so, in fact, that many Python programmers refer to these dunders as *the magic methods* (as they give the appearance of doing what they do "as if by magic").

All of this means that if you provide a method in your class with a `def` line like the one below, the interpreter will call your `__init__` method every time you create a new object from your class. Note the inclusion of `self` as this dunder `init`'s first argument (as per the rule for all methods in all classes):

```
def __init__(self):
```

Despite the strange-looking name, dunder "init" is a method like any other. Remember: you must pass "self" as its first argument.

Initializing Attributes with Dunder “init”

Let’s add __init__ to our CountFromBy class in order to initialize the objects we create from our class.

For now, let’s add an *empty* __init__ method that does nothing but pass (we’ll add behavior in just a moment):

```
class CountFromBy:
    def __init__(self) -> None:
        pass
    def increase(self) -> None:
        self.val += self.incr
```

At the moment, this dunder “init” doesn’t do anything. However, the use of “self” as its first argument is a BIG CLUE that dunder “init” is a method.

We know from the code already in increase that we can access attributes in our class by prefixing their names with self. This means we can use self.val and self.incr to refer to our attributes within __init__, too. However, we want to use __init__ to *initialize* our class’s attributes (val and incr). The question is: where do these initialization values come from and how do their values get into __init__?

PASS ANY AMOUNT OF ARGUMENT DATA TO DUNDER “INIT”

As __init__ is a method, and methods are functions in disguise, you can pass as many argument values as you like to __init__ (or any method, for that matter). All you have to do is give your arguments names. Let’s give the argument that we’ll use to initialize self.val the name v, and use the name i for self.incr.

Let’s add v and i to the def line of our __init__ method, then use the values in dunder init’s suite to initialize our class attributes, as follows:

```
class CountFromBy:
    def __init__(self, v: int, i: int) -> None:
        self.val = v
        self.incr = i
    def increase(self) -> None:
        self.val += self.incr
```

Add “v” and “i” as arguments to dunder “init”.

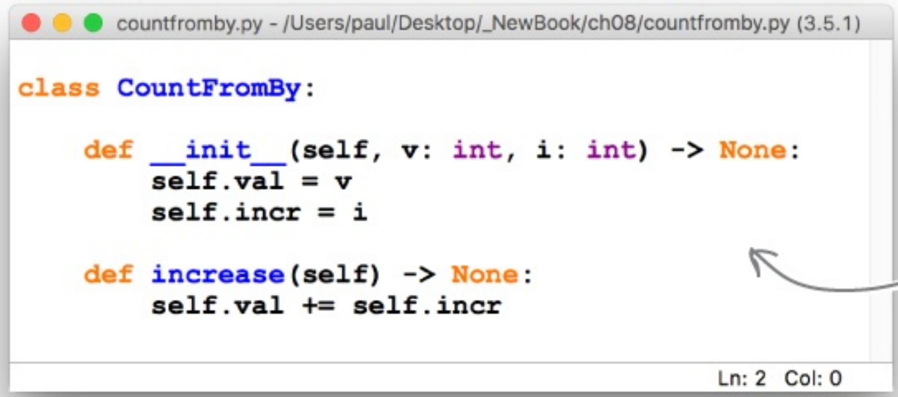
Use the values of “v” and “i” to initialize the class’s attributes (which are “self.val” and “self.incr”, respectively).

If we can now somehow arrange for v and i to acquire values, the latest version of __init__ will initialize our class’s attributes. Which raises yet another question: how do we get values into v and i? To help answer this question, we need to try out this version of our class and see what happens. Let’s do that now.

TEST DRIVE

Using the edit window in IDLE, take a moment to update the code in your `countfromby.py` file to look like that shown below. When you're done, press F5 to start creating objects at IDLE's >>> prompt:

Press F5 to try out the "CountFromBy" class in IDLE's shell.



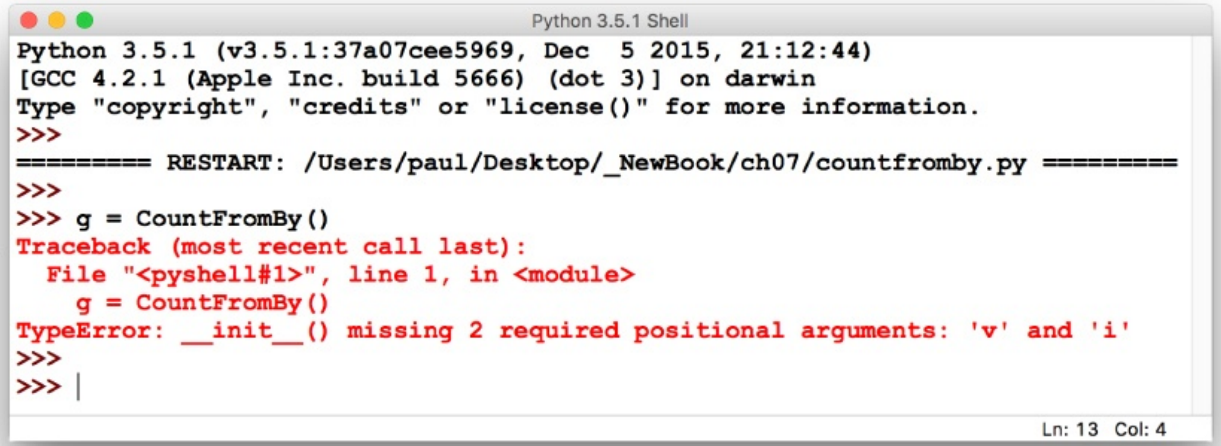
countfromby.py - /Users/paul/Desktop/_NewBook/ch08/countfromby.py (3.5.1)

```
class CountFromBy:

    def __init__(self, v: int, i: int) -> None:
        self.val = v
        self.incr = i

    def increase(self) -> None:
        self.val += self.incr
```

The latest version of our "CountFromBy" class.

Pressing F5 executes the code in the edit window, which imports the `CountFromBy` class into the interpreter. Look at what happens when we try to create a new object from our `CountFromBy` class:

Create a new object (called "g") from the class...but when you do this, you get an error!



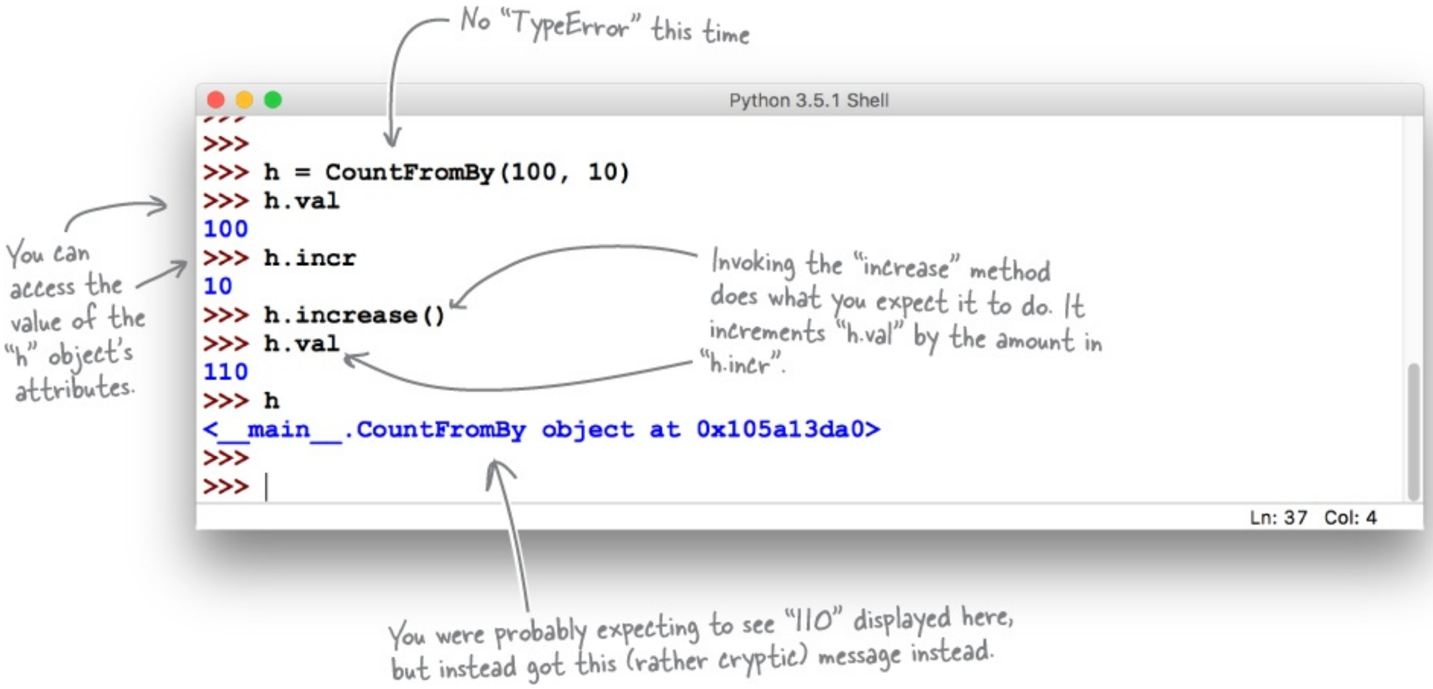
Python 3.5.1 Shell

```
Python 3.5.1 (v3.5.1:37a07cee5969, Dec  5 2015, 21:12:44)
[GCC 4.2.1 (Apple Inc. build 5666) (dot 3)] on darwin
Type "copyright", "credits" or "license()" for more information.
>>>
========= RESTART: /Users/paul/Desktop/_NewBook/ch07/countfromby.py =========
>>>
>>> g = CountFromBy()
Traceback (most recent call last):
  File "<pyshell#1>", line 1, in <module>
    g = CountFromBy()
TypeError: __init__() missing 2 required positional arguments: 'v' and 'i'
>>>
>>> |
```

This may not have been what you were expecting to see. But take a look at the error message (which is classed as a `TypeError`), paying particular attention to the message on the `TypeError` line. The interpreter is telling us that the `__init__` method expected to receive two argument values, `v` and `i`, but received something else (in this case, nothing). We provided no arguments to the class, but this error message tells us that any arguments provided to the class (when creating a new object) are passed to the `__init__` method.

Bearing this in mind, let's have another go at creating a `CountFromBy` object.

Let's return to the >>> prompt, and create another object (called `h`) that takes two integer values as arguments for `v` and `i`:



```
>>>
>>> h = CountFromBy(100, 10)
>>> h.val
100
>>> h.incr
10
>>> h.increase()
>>> h.val
110
>>> h
<__main__.CountFromBy object at 0x105a13da0>
>>>
>>> |
```

No "TypeError" this time
Python 3.5.1 Shell
You can access the value of the "h" object's attributes.
Invoking the "increase" method does what you expect it to do. It increments "h.val" by the amount in "h.incr".
You were probably expecting to see "110" displayed here, but instead got this (rather cryptic) message instead.
Ln: 37 Col: 4

As you can see above, things work better this time, as the `TypeError` exception is gone, which means the `h` object was created successfully. You can access the values of `h`'s attributes using `h.val` and `h.incr`, as well as call the object's `increase` method. Only when you try to access the value of `h` do things get strange again.

WHAT HAVE WE LEARNED FROM THIS TEST DRIVE?

Here are the main takeaways from this *Test Drive*:

- When you're creating objects, any argument values provided to the class are passed to the `__init__`method, as was the case with `100` and `10` above. (Note that `v` and `i` cease to exist as soon as dunder `init` ends, but we aren't worried, as their values are safely stored in the object's `self.val` and `self.incr` attributes, respectively.)
- We can access the attribute values by combining the object's name with the attribute name. Note how we used `h.val` and `h.incr` to do this. (For those readers coming to Python from a "stricter" OOP language, note that we did this without having to create *getters* or *setters*.)
- When we use the object name on its own (as in the last interaction with the shell above), the interpreter spits back a cryptic message. Just what this is (and why this happens) will be discussed next.

Understanding CountFromBy's Representation

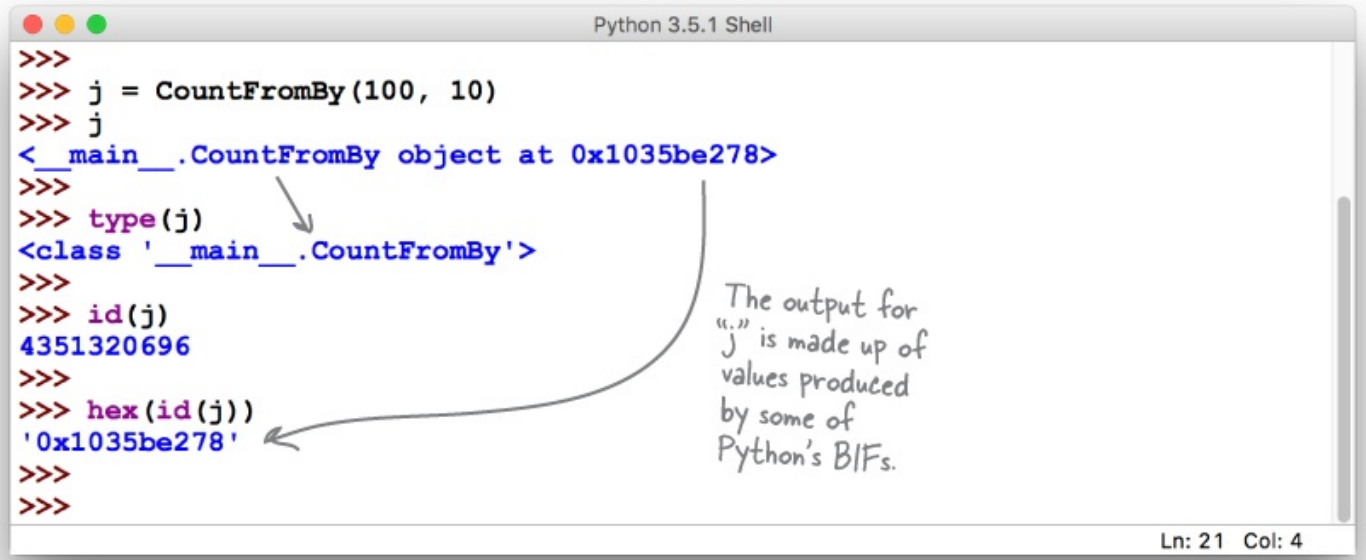
When we typed the name of the object into the shell in an attempt to display its current value, the interpreter produced this output:

```
<__main__.CountFromBy object at 0x105a13da0>
```

Don't worry if you have a different value here. All will become clear before the end of this page.

We described the above output as "strange," and on first glance, it would certainly appear to be. To understand what this output means, let's return to IDLE's shell and create yet another object from `CountFromBy`, which due to our deeply ingrained unwillingness to rock the boat, we're calling `j`.

In the session below, note how the strange message displayed for `j` is made up of values that are produced when we call certain built-in functions (BIFs). Follow along with the session first, then read on for an explanation of what these BIFs do:


Python 3.5.1 Shell
Ln: 21 Col: 4
The output for "j" is made up of values produced by some of Python's BIFs.

```
>>>
>>> j = CountFromBy(100, 10)
>>> j
<__main__.CountFromBy object at 0x1035be278>
>>>
>>> type(j)
<class '__main__.CountFromBy'>
>>>
>>> id(j)
4351320696
>>>
>>> hex(id(j))
'0x1035be278'
>>>
>>>
```

The `type` BIF displays information on the class the object was created from, reporting (above) that `j` is a `CountFromBy` object.

The `id` BIF displays information on an object's memory address (which is a unique identifier used by the interpreter to keep track of your objects). What you see on your screen is likely different from what is reported above.

The memory address displayed as part of `j`'s output is the value of `id` converted to a hexadecimal number (which is what the `hex` BIF does). So, the entire message displayed for `j` is a combination of `type`'s output, as well as `id`'s (converted to hexadecimal).

Override dunder "repr" to specify how your objects are represented by the interpreter.

A reasonable question is: *why does this happen?*

In the absence of you telling the interpreter how you want to represent your objects, the interpreter has to do *something*, so it does what's shown above. Thankfully, you can override this default behavior by coding your own `__repr__` magic method.

Defining CountFromBy's Representation

As well as being a magic method, the `__repr__` functionality is also available as a built-in function called `repr`. Here's part of what the `help` BIF displays when you ask it to tell you what `repr` does: "Return the canonical string representation of the object." In other words, the `help` BIF is telling you that `repr` (and by extension, `__repr__`) needs to return a stringified version of an object.

What this "stringified version of an object" looks like depends on what each individual object does. You can control what happens for *your* objects by writing a `__repr__` method for your class. Let's do this now for the `CountFromBy` class.

Begin by adding a new `def` line to the `CountFromBy` class for dunder `repr`, which takes no arguments other than the required `self` (remember: it's a method). As is our practice, let's also add an annotation that lets readers of our code know this method returns a string:

Like every other method you'll write, this one has to take into account that the interpreter always provides a value for the first argument.

```
def __repr__(self) -> str:
```

This lets users of this method know that this function intends to return a string. Remember: using annotations in your code is optional, but helpful.

With the `def` line written, all that remains is to write the code that returns a string representation of a `CountFromBy` object. For our purposes, all we want to do here is take the value in `self.val`, which is an integer, and convert it to a string.

Thanks to the `str` BIF, doing so is straightforward:

```
def __repr__(self) -> str:
    return str(self.val)
```

Take the value in "self.val", turn it into a string, and then return it to this method's caller.

When you add this short function to your class, the interpreter uses it whenever it needs to display a `CountFromBy` object at the `>>>` prompt. The `print` BIF also uses dunder `repr` to display objects.

Before making this change and taking the updated code for a spin, let's return briefly to another issue that surfaced during the last *Test Drive*.

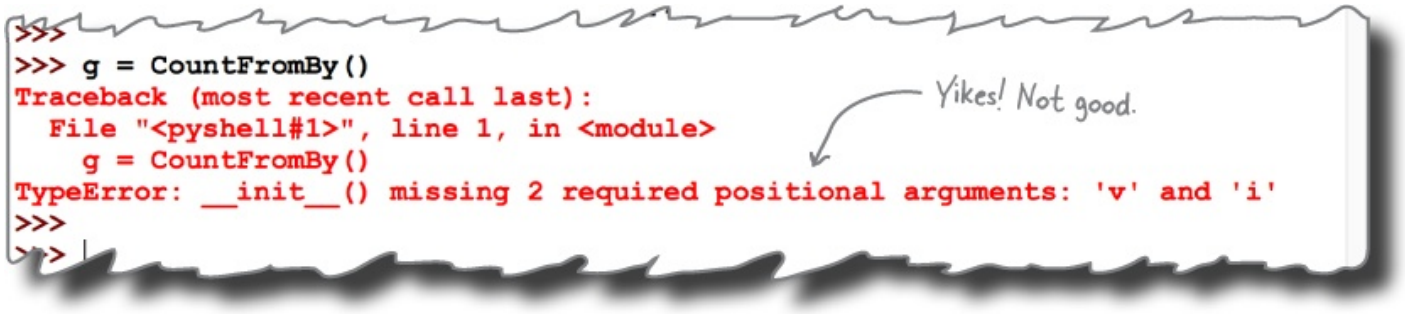
Providing Sensible Defaults for CountFromBy

Let's remind ourselves of the current version of the `CountFromBy` class's `__init__`method:

```
        ...
def __init__(self, v: int, i: int) -> None:
    self.val = v
    self.incr = i
        ...
```

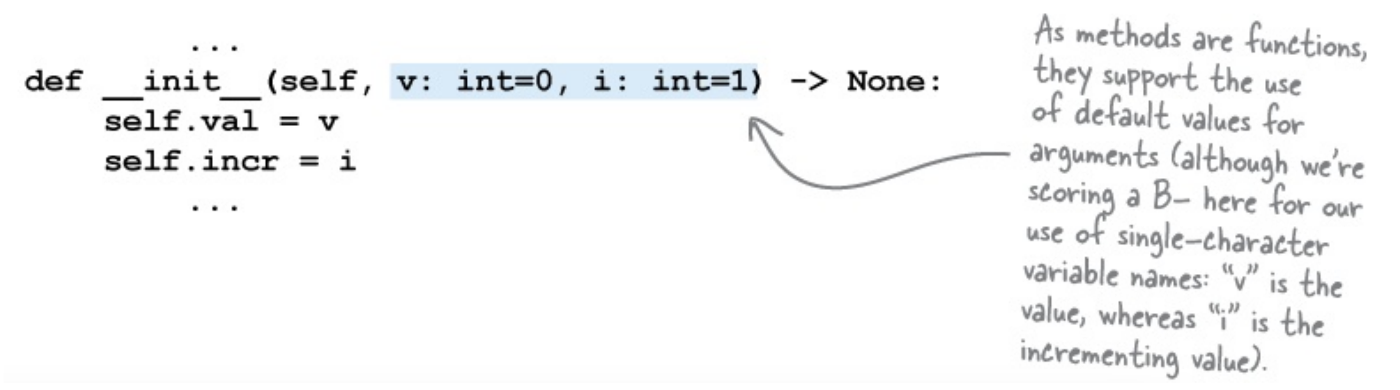
This version of the dunder "init" method expects two argument values to be provided every time it is invoked.

Recall that when we tried to create a new object from this class without passing values for `v` and `i`, we got a `TypeError`:



```
>>>
>>> g = CountFromBy()
Traceback (most recent call last):
  File "<pyshell#1>", line 1, in <module>
    g = CountFromBy()
TypeError: __init__() missing 2 required positional arguments: 'v' and 'i'
>>>
>>> |
```

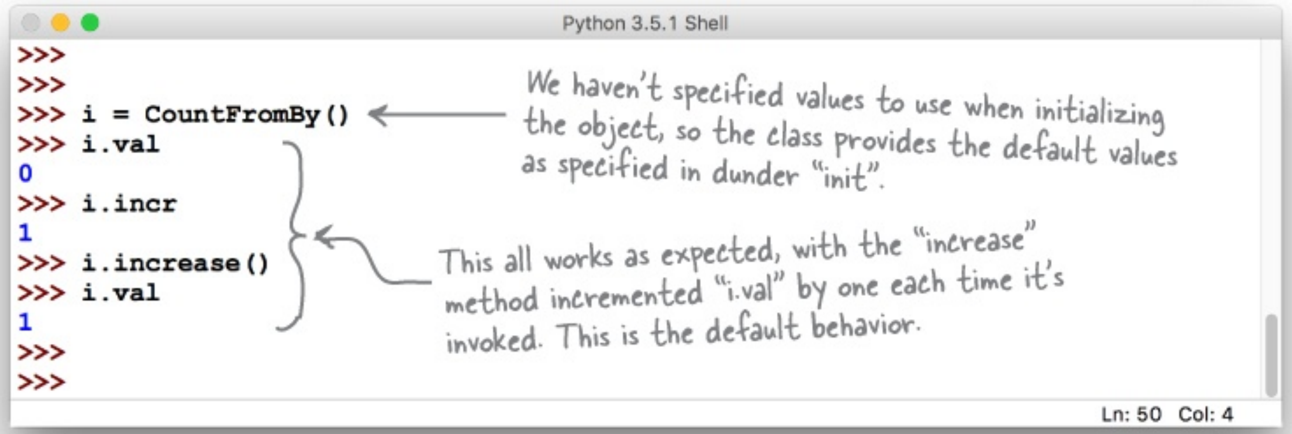
Earlier in this chapter, we specified that we wanted the `CountFromBy` class to support the following default behavior: the counter will start at 0 and be incremented (on request) by 1. You already know how to provide default values to function arguments, and the same goes for methods, too—assign the default values on the `def` line:



```
    ...
def __init__(self, v: int=0, i: int=1) -> None:
    self.val = v
    self.incr = i
    ...
```

As methods are functions, they support the use of default values for arguments (although we're scoring a B– here for our use of single-character variable names: "v" is the value, whereas "i" is the incrementing value).

If you make this small (but important) change to your `CountFromBy` code, then save the file (before pressing F5 once more), you'll see that objects can now be created with this default behavior:



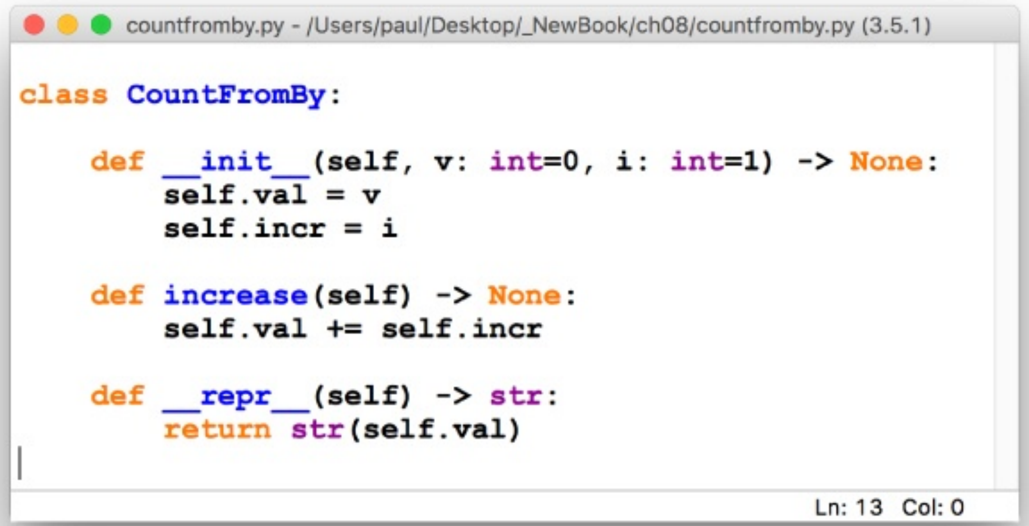
```
>>>
>>>
>>> i = CountFromBy()
>>> i.val
0
>>> i.incr
1
>>> i.increase()
>>> i.val
1
>>>
>>>
```

Python 3.5.1 Shell
We haven't specified values to use when initializing the object, so the class provides the default values as specified in dunder "init".
This all works as expected, with the "increase" method incremented "i.val" by one each time it's invoked. This is the default behavior.
Ln: 50 Col: 4

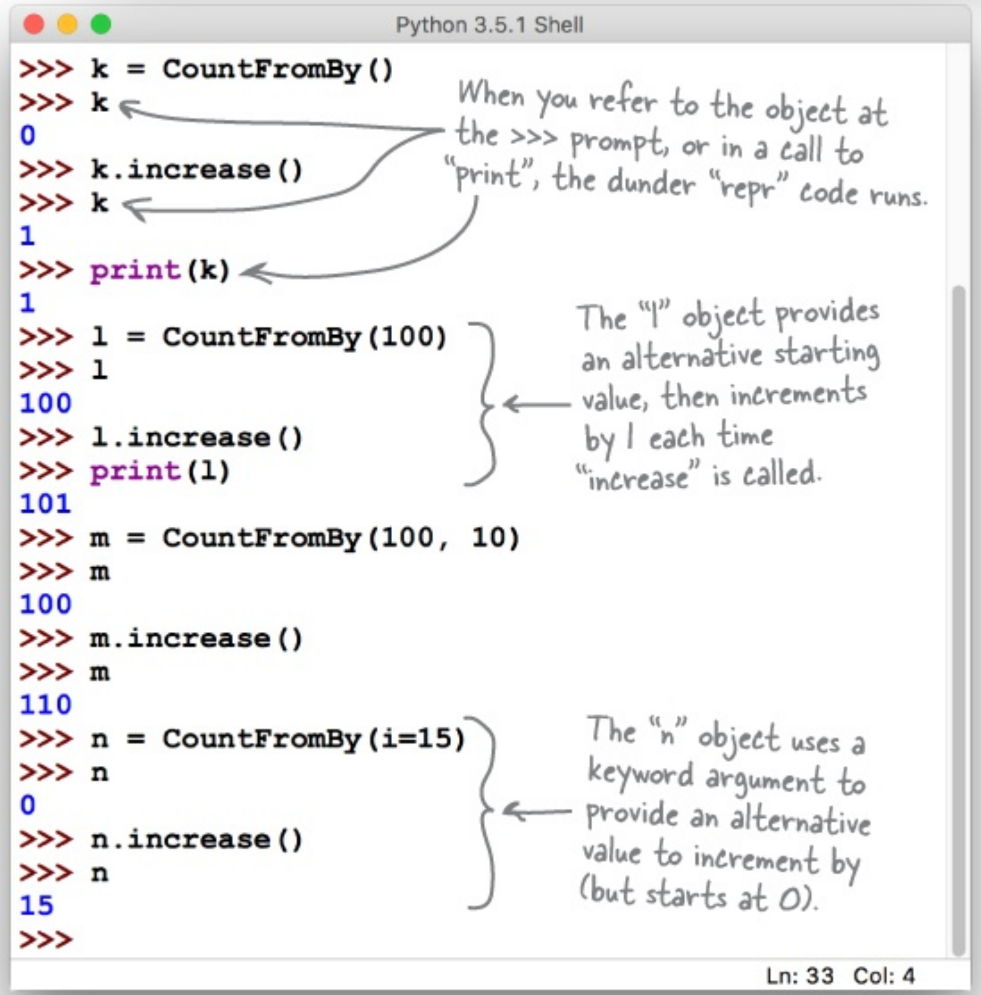
TEST DRIVE

Make sure your class code (in `countfromby.py`) is the same as ours below. With your class code loaded into IDLE's edit window, press F5 to take your latest version of the `CountFromBy` class for a spin:

This is the "CountFromBy" class with the code for dunder "repr" added.


countfromby.py - /Users/paul/Desktop/_NewBook/ch08/countfromby.py (3.5.1)
Ln: 13 Col: 0

```
class CountFromBy:

    def __init__(self, v: int=0, i: int=1) -> None:
        self.val = v
        self.incr = i

    def increase(self) -> None:
        self.val += self.incr

    def __repr__(self) -> str:
        return str(self.val)
```



```
>>> k = CountFromBy()
>>> k
0
>>> k.increase()
>>> k
1
>>> print(k)
1
>>> l = CountFromBy(100)
>>> l
100
>>> l.increase()
>>> print(l)
101
>>> m = CountFromBy(100, 10)
>>> m
100
>>> m.increase()
>>> m
110
>>> n = CountFromBy(i=15)
>>> n
0
>>> n.increase()
>>> n
15
>>>
```

The "k" object uses the class's default values, which start at 0 and are increased by 1.

When you refer to the object at the >>> prompt, or in a call to "print", the dunder "repr" code runs.

The "l" object provides an alternative starting value, then increments by 1 each time "increase" is called.

The "m" object provides alternative values for both defaults.

The "n" object uses a keyword argument to provide an alternative value to increment by (but starts at 0).

Classes: What We Know

With the `CountFromBy` class behaving as specified earlier in this chapter, let's review what we now know about classes in Python:

BULLET POINTS

- Python classes let you share **behavior** (a.k.a. methods) and **state** (a.k.a. attributes).
- If you remember that methods are **functions**, and attributes are **variables**, you won't go far wrong.
- The `class` keyword introduces a new class in your code.
- Creating a new object from a class looks very like a function call. Remember: to create an object called `mycount` from a class called `CountFromBy`, you'd use this line of code:

```
mycount = CountFromBy()
```

- When an object is created from a class, the object **shares** the class's code with every other object created from the class. However, each object maintains its **own copy** of the attributes.
- You add behaviors to a class by creating **methods**. A method is a function defined within a class.
- To add an **attribute** to a class, create a variable.
- Every method is passed an **alias** to the current object as its first argument. Python convention insists that this first argument is called `self`.
- Within a method's suite, referrals to attributes are prefixed with `self`, ensuring the attribute's value **survives** after the method code ends.
- The `__init__` method is one of the many **magic methods** provided with all Python classes.
- Attribute values are initialized by the `__init__` method (a.k.a. dunder `init`). This method lets you assign starting values to your attributes when a new object is created. Dunder `init` receives a **copy** of any values passed to the class when an object is created. For example, the values `100` and `10` are passed into `__init__` when this object is created:

```
mycount2 = CountFromBy(100, 10)
```

- Another magic method is `__repr__`, which allows you to control how an object appears when displayed at the >>> prompt, as well as when used with the `print` BIF.

This is all fine and dandy...but remind me: what was the point of learning all this class stuff?

We wanted to create a context manager.

We know it's been a while, but the reason we started down this path was to learn enough about classes to enable us to create code that hooks into Python's **context management protocol**. If we can hook into the protocol, we can use our webapp's database code with Python's `with` statement, as doing so should make it easier to share the database code, as well as reuse it. Now that you know a bit about classes, you're ready to get hooked into the context management protocol (in the next chapter).

Chapter 8’s Code

This is the code in the “countfromby.py” file.

```
class CountFromBy:

    def __init__(self, v: int=0, i: int=1) -> None:
        self.val = v
        self.incr = i

    def increase(self) -> None:
        self.val += self.incr

    def __repr__(self) -> str:
        return str(self.val)
```