Head First Ruby

A Brain-Friendly Guide

Get more done with less code

Do heavy lifting easily with blocks

he Ruby Library

Avoid embarrassing OO mistakes

Bend y... XX R... exercises

Serve your web app to the world

Early Release

RAW & UNEDITED

Jay McGavren

Head First Ruby

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Head First Ruby

by Jay McGavren

Printed in the United States of America.

Published by O'Reilly Media, Inc., 1005 Gravenstein Highway North, Sebastopol, CA 95472.

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Editors: Meghan Blanchette, Courtney Nash

Cover Designer: Randy Comer

Production Editor:

Indexer:

Proofreader:

Page Viewer:

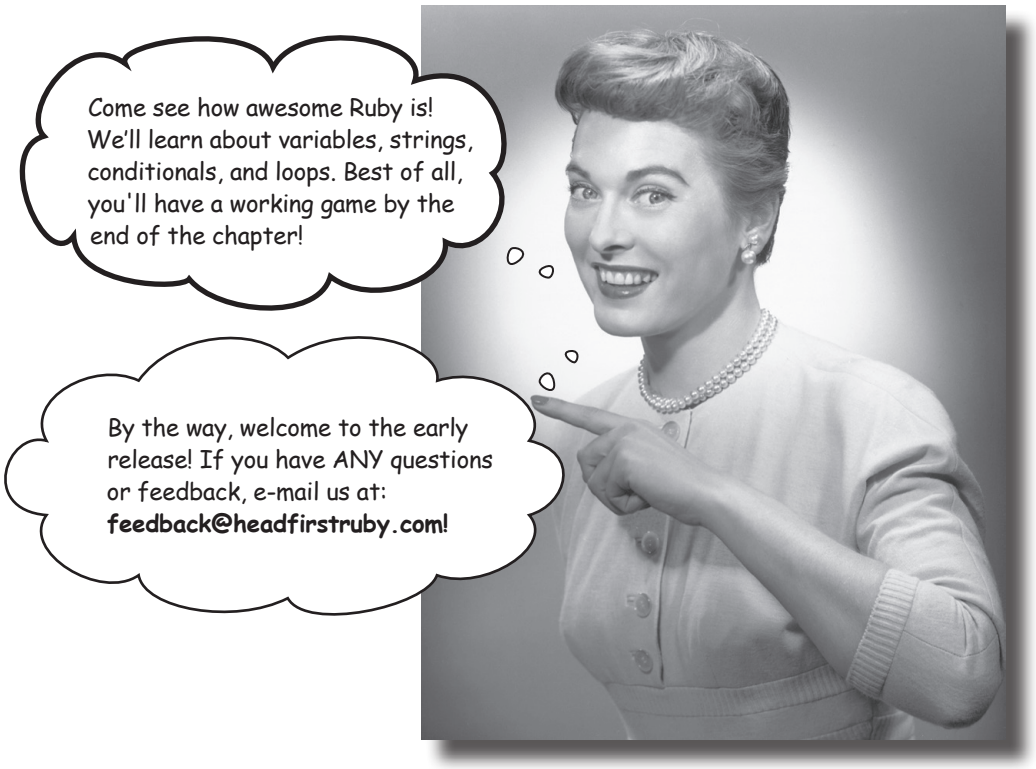
Printing History:

April 2015: First Edition.

ISBN: 978-1-449-37265-1
[LSI]

1 more with less

Code the Way You Want



You're wondering what this crazy Ruby language is all about, and if it's right for you. Let us ask you this: ***Do you like being productive?*** Do you feel like all those extra compilers and libraries and class files and keystrokes in your other language bring you closer to a **finished product**, **admiring co-workers**, and **happy customers**? Would you like a language that **takes care of the details** for you? If you sometimes wish you could stop maintaining boilerplate code and *get to work on your problem*, then Ruby is for you. Ruby lets you **get more done with less code.**

The Ruby Philosophy

Back in the 1990's in Japan, a programmer named Yukihiro Matsumoto ("Matz" for short) was dreaming about his ideal programming language. He wanted something that:

- Was easy to learn and use
- Was flexible enough to handle any programming task
- Let the programmer concentrate on the problem they were trying to solve
- Gave the programmer less stress
- Was object-oriented

He looked at the languages that were available, but felt that none of them was exactly what he wanted. So, he set out to make his own. He called it Ruby.

After tinkering around with Ruby for his own work for a while, Matz released it to the public in 1995. Since then, the Ruby community has done some amazing things:

- Built out a vast collection of Ruby libraries that can help you do anything from reading CSV files to controlling objects over a network
- Written alternate interpreters that can run your Ruby code faster or integrate it with other languages
- Created Ruby on Rails, a hugely popular framework for web applications

This explosion of creativity and productivity was enabled by the Ruby language itself. Flexibility and ease of use are core principles of the language, meaning you can use Ruby to accomplish any programming task, in fewer lines of code than other languages.

Once you've got the basics down, you'll agree: Ruby is a joy to use!

Flexibility and ease of use are core principles of Ruby.

Get Ruby

First things first: you can *write* Ruby code all day, but it won't do you much good if you can't *run* it. Let's make sure you have a working Ruby **interpreter** installed. We want version 2.0 or later. Open up a command-line prompt and type:

```
ruby -v
```

Adding "-v" makes Ruby show the version number.

"ruby" by itself launches a Ruby interpreter.

Press Ctrl-C to exit the interpreter and return to your OS prompt.

```
File  Edit  Window  Help
$ ruby -v
ruby 2.0.0p0 (2013-02-24 revision 39474) [x86_64-darwin11.4.2]
$ ruby
^Cruby: Interrupt

$
```

When you type **`ruby -v`** at a prompt, if you see a response like this, you're in business:

```
ruby 2.0.0p0 (2013-02-24 revision 39474) [x86_64-darwin11.4.2]
```

We don't care about the other stuff in this output, as long as it says "ruby 2.0" or later.

Do this!

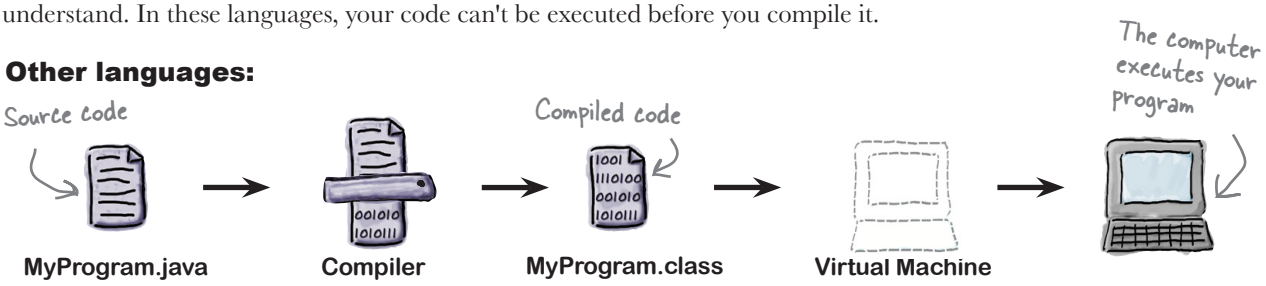
If you don't have Ruby 2.0 or later, visit **www.ruby-lang.org** and download a copy for your favorite OS.

Use Ruby

To run a Ruby script, you simply save your Ruby code in a file, and run that file with the Ruby interpreter. Ruby source files that you can execute are referred to as **scripts**, but they're really just plain text files.

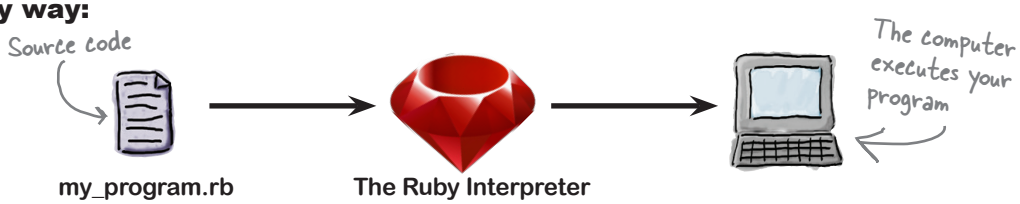
You may be used to other languages (like C++, C#, or Java) where you have to manually compile your code to a binary format that a CPU or virtual machine can understand. In these languages, your code can't be executed before you compile it.

Other languages:



With Ruby, *you skip that step*. Ruby instantly and automatically compiles the source code in your script. This means *less time* between writing your code and trying it out!

The Ruby way:




```
puts "hello world"
```

Type your source code.

Save as: **hello.rb**

```
File Edit Window Help
$ ruby hello.rb
hello world
```

There's your output!

Run your source code with the Ruby interpreter.

Use Ruby - interactively

There's another big benefit to using a language like Ruby. Not only do you not have to run a compiler each time you want to try out your code, you don't even have to put it in a script first.

Ruby comes with a separate program, called `irb` (for **I**nteractive **R**u**b**y). The `irb` shell lets you type any Ruby expression, which it will then immediately evaluate and show you the results. It's a great way to learn the language, because you get immediate feedback. But even Ruby professionals use `irb` to try out new ideas.

Throughout the book, we'll be writing lots of scripts to be run via the Ruby interpreter. But anytime you're testing out a new concept, it's a great idea to launch `irb` and experiment a bit.

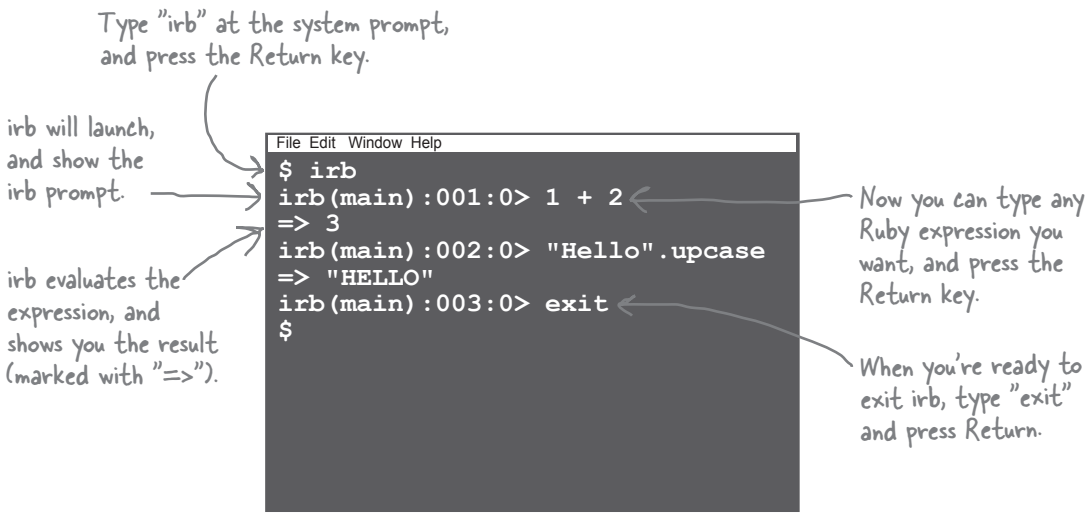
So what are we waiting for? Let's get into `irb` now and play around with some Ruby expressions.

Using the irb shell

Open a terminal window, and type `irb`. This will launch the interactive Ruby interpreter. (You'll know it's running because the prompt will change, although it may not match exactly what you see here.)

From there, you can type any expression you want, followed by the Return key. Ruby will instantly evaluate it and show you the result.

When you're done with `irb`, type `exit` at the prompt, and you'll be returned to your OS's system prompt.



Your first Ruby expressions

Now that we know how to launch `irb`, let's try a few expressions out and see what results we get!

Type the following at the prompt, then press Return:

```
1 + 2
```

You'll be shown the result:

```
=> 3
```

Math operations and comparisons

Ruby's basic math operators work just like they do in most other languages. The + symbol is for addtion, - for subtraction, * for multiplication, / for division, and ** for exponentiation.

If you type:	"irb" displays:
`5.4 - 2.2`	`=> 3.2`
`3 * 4`	`=> 12`
`7 / 3.5`	`=> 2.0`
`2 ** 3`	`=> 8`

You can use < and > to compare two values and see if one is less than or greater than another. You can also use == (that's *two* equals signs) to see if two values are equal.

`4 < 6`	`=> true`
`4 > 6`	`=> false`
`2 + 2 == 5`	`=> false`

Strings

A **string** is a series of text characters. You can use them to hold names, e-mail addresses, phone numbers, and a million other things. Ruby's strings are special because even very large strings are highly efficient to work with (this isn't true in many other languages).

The easiest way to specify a string is to surround it either with double quotes (**"**), or single quotes (**'**). The two types of quotes work a little differently; we'll explain that later in the chapter.

`"Hello"`	`=> "Hello"`
`'world'`	`=> "world"`

Variables

Ruby lets us create **variables** - names that refer to values.

You don't have to declare variables in Ruby; assigning to them creates them. You assign to a variable with the = symbol (that's a *single* equals sign).

If you type:	"irb" displays:
`small = 8`	`=> 8`
`medium = 12`	`=> 12`

A variable name starts with a lower-case letter, and can contain letters, numbers, and underscores.

Once you've assigned to variables, you can access their values whenever you need, in any context where you might use the original value.

```
small + medium      => 20
```

Variables don't have types in Ruby; they can hold any value you want. You can assign a string to a variable, then immediately assign a floating-point number to the same variable, and it's perfectly legal.

```
pie = "Lemon"       => "Lemon"
pie = 3.14          => 3.14
```

The += operator lets you add on to the existing value of a variable.

```
number = 3          => 3
number += 1         => 4
number              => 4

string = "ab"       => "ab"
string += "cd"      => "abcd"
string              => "abcd"
```

Use all lower case letters in variable names. Avoid numbers; they're rarely used. Separate words with underscores.

```
my_rank = 1
```

This style is sometimes called "snake case", because the underscores make the name look like it's crawling on the ground.

Everything is an object!

Ruby is an *object-oriented* language. That means your data has useful **methods** (fragments of code that you can execute on demand) attached directly to it.

In modern languages, it's pretty common for something like a string to be a full-fledged object, so of course strings have methods to call:

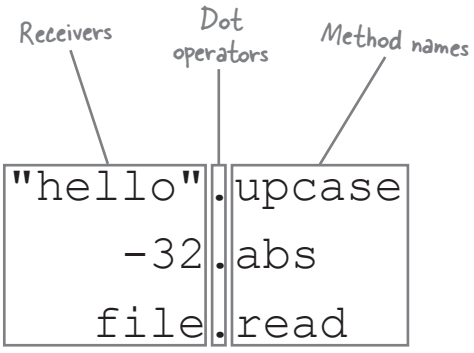
If you type:	"irb" displays:
`"Hello".upcase`	`=> HELLO`
`"Hello".reverse`	`=> olleH`

What's cool about Ruby, though, is that *everything* is an object. Even something as simple as a number is an object. That means they have useful methods, too.

`42.even?`	`=> true`
`-32.abs`	`=> 32`

Calling a method on an object

When you make a call like this, the object you're calling the method on is known as the method **receiver**. It's whatever is to the left of the dot operator. You can think of calling a method on an object like *passing it a message*. Like a note saying, "Hey, can you send me back an upper case version of yourself?" or "Can I have your absolute value?".



Open a new terminal or command prompt, type "irb" and hit the Enter/Return key. For each of the Ruby expressions below, write your guess for what the result will be on the line below it. Then try typing the expression into `irb`, and hit Enter. See if your guess matches what `irb` returns!

```
42 / 6
.....

name = "Zaphod"
.....

name.upcase
.....

"Zaphod".upcase
.....

name.reverse
.....

name.upcase.reverse
.....

name.class
.....

name * 3
.....
```

```
5 > 4
.....

number = -32
.....

number.abs
.....

-32.abs
.....

number += 10
.....

rand(25)
.....

number.class
.....
```

Exercise Solution

Open a new terminal or command prompt, type "irb" and hit the Enter/Return key. For each of the Ruby expressions below, write your guess for what the result will be on the line below it. Then try typing the expression into `irb`, and hit Enter. See if your guess matches what `irb` returns!

```
42 / 6
```
7

```
5 > 4
```
true

Assigning to a variable returns whatever value is assigned.

```
name = "Zaphod"
```
"Zaphod"

```
number = -32
```
-32

```
name.upcase
```
"ZAPHOD"

You can call methods on an object stored in a variable...

```
number.abs
```
32

```
"Zaphod".upcase
```
"ZAPHOD"

But you don't even have to store it in a variable first!

```
-32.abs
```
32

This adds 10 to the value in the variable, then assigns the result back to the variable.

```
number += 10
```
-22

```
name.reverse
```
"dohpaZ"

You can call a method on the value returned from a method.

```
name.upcase.reverse
```
"DOHPAZ"

```
rand(25)
```
A random number

Yes, this IS a method call, we just don't specify a receiver. More about this soon!

The answer will vary (it really is random)

```
name.class
```
String

An object's class decides what kind of object it is.

```
number.class
```
Fixnum

A Fixnum is a kind of integer.

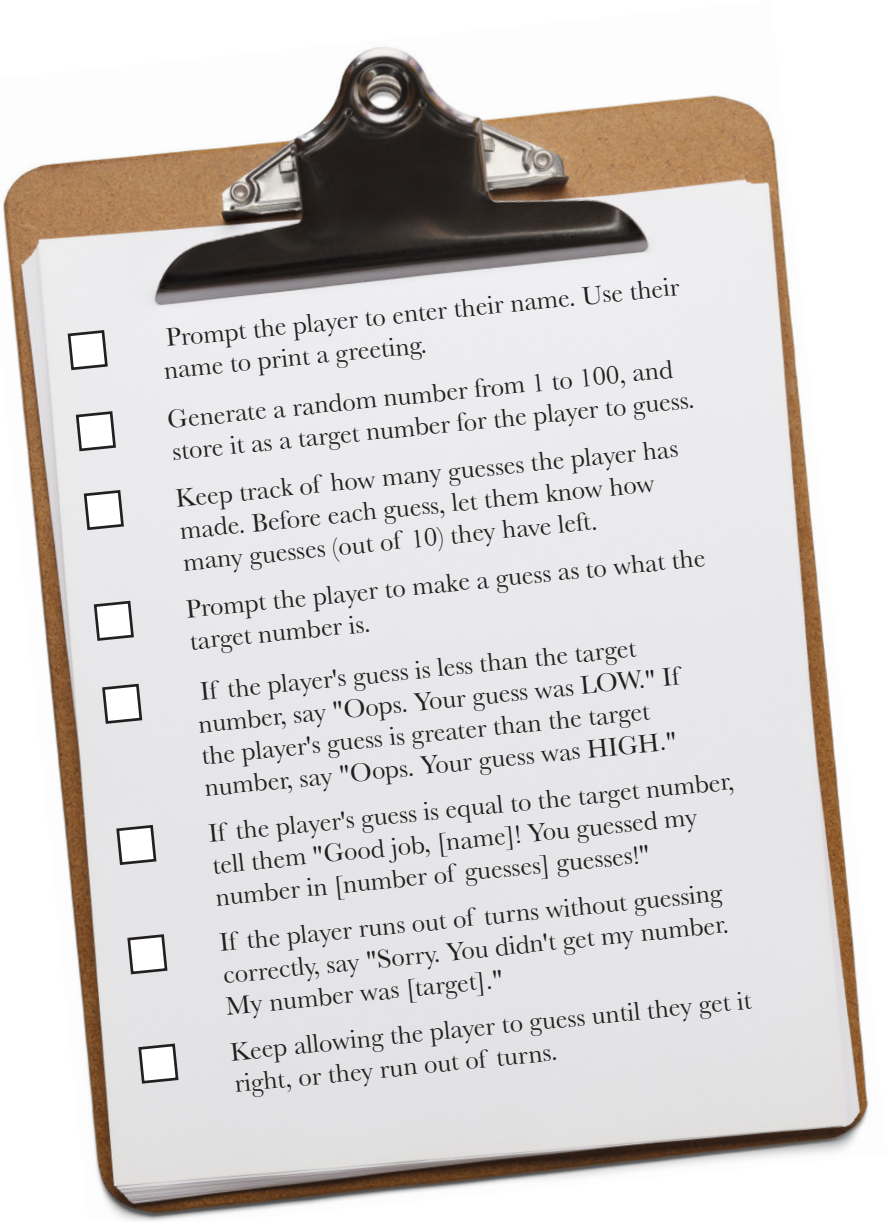
```
name * 3
```
"ZaphodZaphodZaphod"

You can "multiply" strings!

Let's build a game

In this first chapter, we're going to build a simple game. If that sounds daunting, don't worry; it's easy when you're using Ruby!

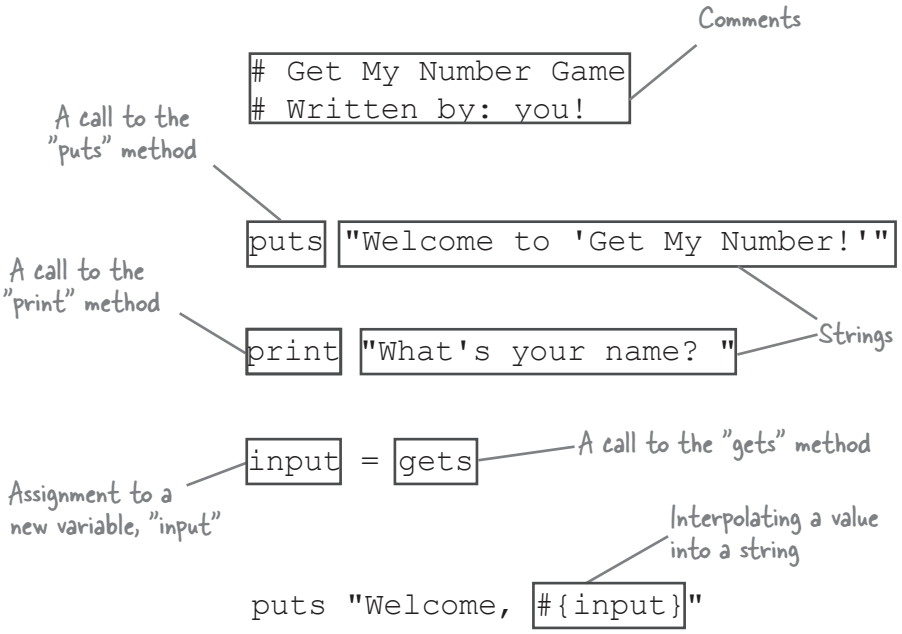
Let's look at what we'll need to do:



Input, storage, and output

Our first requirement is to greet the user by name. To accomplish that, we'll need to write a script that *gets input* from the user, *stores* that input, and then uses that stored value to create some *output*.

We can do all this in just a few lines of Ruby code:



We'll go into detail on each of the components of this script over the next few pages. But first, let's give it a try!

Running scripts

We've written a simple script that fulfills our first requirement: to greet the player by name. Now, we'll show you how to execute the script, so you can see what you've created.

Step One:

Open a new document in your favorite text editor, and type in the following code.

```
# Get My Number Game
# Written by: you!

puts "Welcome to 'Get My Number!'"
print "What's your name? "

input = gets

puts "Welcome, #{input}"
```

get_number.rb

Step Two:

Save the file as "get_number.rb".

Step Three:

Open up a command-line prompt, and change into the directory where you saved your program.

Step Four:

Run the program by typing "`ruby get_number.rb`".

Step Five:

You'll see a greeting, and a prompt. Type your name and hit the Enter/Return key. You'll then see a message that welcomes you by name.

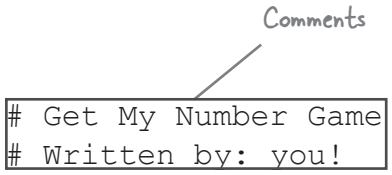
```
File Edit Window Help
$ ruby get_number.rb
Welcome to 'Get My Number!'
What's your name? Jay
Welcome, Jay
```

Let's take a few pages to look at each part of this code in more detail.

Comments

Our source file starts out with a couple comments. Ruby ignores everything from a hash mark (#) up until the end of the line, so that you can leave instructions or notes for yourself and your fellow developers.

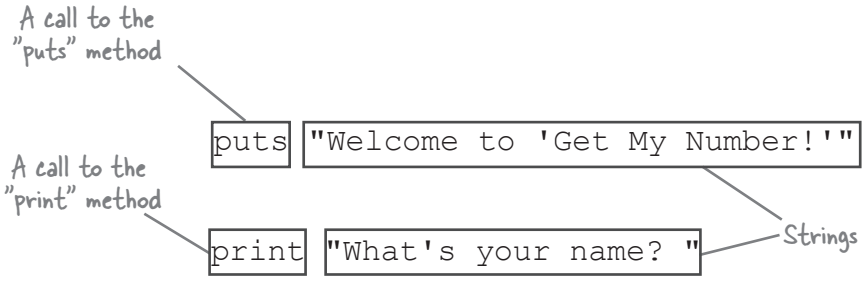
If you place a pound sign (#) in your code, then everything from that point until the end of the line will be treated as a comment, and ignored by Ruby. This works just like the double-slash ("//") marker in Java or JavaScript.



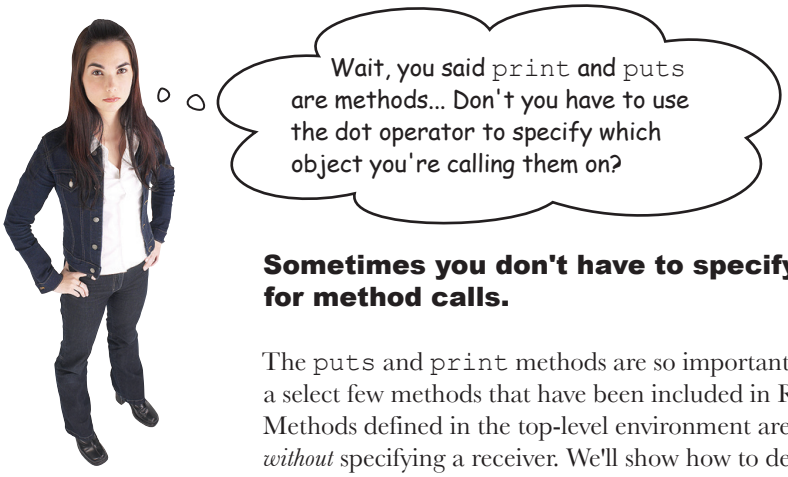

```
i_am = "executed" # I'm not.
# Me neither.
```

"puts" and "print"

The actual code starts with a call to the `puts` method ("puts" is short for "put string"), which displays text on standard output (usually the terminal). We pass `puts` a string containing the text to display.



We pass another string to the `print` method on the following line, to ask the user their name. The `print` method works just like `puts`, except that `puts` adds a newline character at the end of the string (if it doesn't already have one) to skip to the following line, whereas `print` doesn't. For cosmetic reasons, we end the string that we pass to `print` with a space, so that our text doesn't run up against the space where the user types their name.



Sometimes you don't have to specify a receiver for method calls.

The `puts` and `print` methods are so important, and so commonly used, that they're among a select few methods that have been included in Ruby's **top-level execution environment**. Methods defined in the top-level environment are available to call *anywhere* in your Ruby code, *without* specifying a receiver. We'll show how to define methods like this at the start of chapter 2.

Method arguments

The `puts` method takes a string and prints it to standard output (your terminal window).

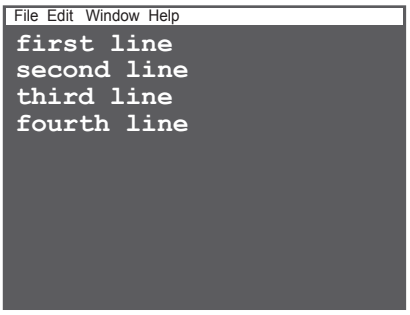
```
puts "first line"
```

The string passed to the `puts` method is known as the method **argument**.

The `puts` method can take more than one argument; just separate the arguments with commas. Each argument gets printed on its own line.

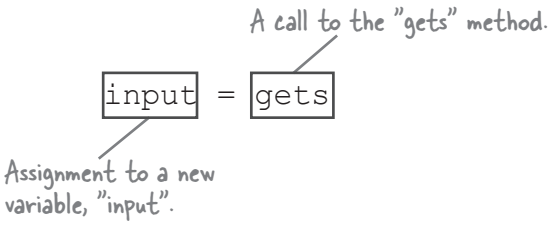
```
puts "second line", "third line", "fourth line"
```

What it looks like in your terminal.



"gets"

The `gets` method (short for "get string") reads a line from standard input (characters typed in the terminal window). When you call it, it causes the program to halt until the user types their name and presses the Enter key. It returns the user's text to the program as another string.



Like `puts` and `print`, the `gets` method can be called from anywhere in your code without specifying a receiver.

Parenthesis are optional on method calls

Method arguments *can* be surrounded with parenthesis in Ruby:

```
puts("one", "two")
```

But the parenthesis are optional, and in the case of `puts`, most Rubyists prefer to leave them off.

```
puts "one", "two"
```

The `gets` method reads a line from standard input (characters typed in the terminal window). It doesn't (usually) need any arguments:

```
gets
```

Rubyists are *adamant* that parenthesis *not* be used if a method takes *no* arguments. So please, don't do this, even though it's valid code:

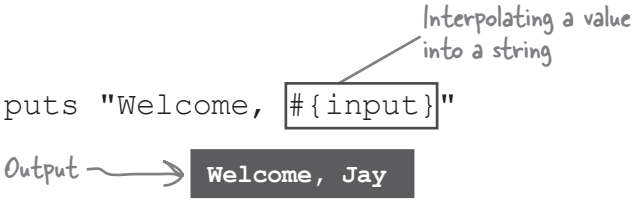
```
gets()
```

No!

Leave parenthesis off of a method call if there are no arguments. You can leave them off for method calls where there *are* arguments as well, but this can make some code more difficult to read. When in doubt, use parenthesis!

String interpolation

The last thing our script does is to call `puts` with one more string. This one is special because we **interpolate** (substitute) the value in the `name` variable into the string. Whenever you include the `#{...}` notation *inside* a string, Ruby uses the value in the curly braces to "fill in the blank". The `#{...}` markers can occur anywhere in the string: the beginning, end, or somewhere in the middle.



You're not limited to using variables within the `#{}` marker - you can use any Ruby expression.

```
puts "The answer is #{6 * 7}."
```

Output → `The answer is 42.`

Note that Ruby only applies interpolation in *double*-quoted strings. If you include a `#{}` marker in a *single*-quoted string, it will be taken literally.

```
puts 'Welcome, #{input}'
```

Output → `Welcome, #{input}`

there are no Dumb Questions

Q: Where are the semicolons?

A: In Ruby, you *can* use semicolons to separate statements, but you generally *shouldn't*. (It's harder to read.)

```
puts "Hello";  <- No!
puts "World";
```

Ruby treats separate lines as separate statements, making semicolons unnecessary.

```
puts "Hello"
puts "World"
```

Q: My other language would require me to put this script in a class with a "main" method. Doesn't Ruby?

A: No! That's one of the great things about Ruby - it doesn't require a bunch of ceremony for simple programs. Just write a few statements, and you're done!

Ruby doesn't require a bunch of ceremony for simple programs.

What's in that string?

```
File Edit Window Help
$ ruby get_number.rb
Welcome to 'Get My Number!'
What's your name? Jay
Welcome, Jay
```

Well, that's easy enough to add. Let's throw an exclamation point on the end of the greeting string, after the interpolated value.

```
puts "Welcome to 'Get My Number!'"
print "What's your name? "

input = gets

puts "Welcome, #{input}!"
```

Just this one little character added!

But if we try running the program again, we'll see that rather than appearing immediately after the user's name, the exclamation point jumps down to the next line!

Uh, oh! Why's it down here?

```
File Edit Window Help
$ ruby get_number.rb
Welcome to 'Get My Number!'
What's your name? Jay
Welcome, Jay
!
```

Why is this happening? Maybe there's something going on within that `input` variable...

Printing it via the `puts` method doesn't reveal anything special about it, though:

```
puts input
```

```
Jay
```

Inspecting objects with the "inspect" and "p" methods

Now, let's try again, using a method meant especially for troubleshooting Ruby programs. The `inspect` method is available on any Ruby object. It converts the object to a string representation that's suitable for debugging. That is, it will reveal aspects of the object that don't normally show up in program output.

Here's the result of calling `inspect` on our string:

```
puts input.inspect
```

```
"Jay\n"
```

What's that `\n` at the end of the string? We'll solve that mystery on the next page...

Printing the result of `inspect` is done so often that Ruby offers another shortcut: the `p` method. It works just like `puts`, except that it calls `inspect` on each argument before printing it.

This call to `p` is effectively identical to the previous code:

```
p input
```

```
"Jay\n"
```

Remember the `p` method; we'll be using it in later chapters to help debug Ruby code!

Escape sequences in strings

Our use of the p method has revealed some unexpected data at the end of the user's input:

```
p input
```

```
"Jay\n"
```

These two characters, the backslash character (\) and the n that follows it, actually represent a single character, a newline character. (The newline character is named thus because it makes terminal output jump down to a *new line*.) There's a newline at the end of the user input because when the user hits the Return key to indicate their entry is done, that gets recorded as an extra character. That newline is then included in the return value of the gets method.

The backslash character (\) and the n that follows it are an **escape sequence** - a portion of a string that represents characters that can't normally be represented in source code.

The most commonly-used escape sequences are \n (newline, as we've seen), and \t (a tab character, for indentation).

```
puts "First line\nSecond line\nThird line"
puts "\tIndented line"
```

```
First line
Second line
Third line
        Indented line
```

Commonly-used escape sequences

If you include this in a double-quoted string...	...you get this character...
\n	newline
\t	tab
\"	double-quotes
\'	single-quote
\\	backslash

Normally, when you try to include a double-quotation mark (") in a double-quoted string, it gets treated as the end of the string, leading to errors:

```
puts ""It's okay," he said."
```

Error: →

```
syntax error, unexpected
tCONSTANT
```

If you escape the double-quotation marks by placing a backslash before each, you can place them in the middle of a double-quoted string.

```
puts "\"It's okay,\" he said."
```

```
"It's okay," he said.
```

Lastly, because \ marks the start of an escape sequence, we also need a way to represent a backlash character that *isn't* part of an escape sequence. Using \\ will give us a literal backslash.

```
puts "One backslash: \\"
```

```
One backslash: \
```

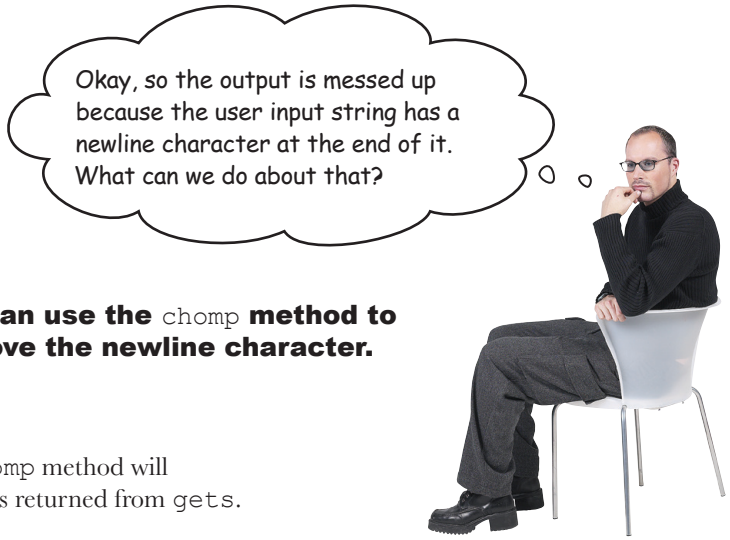
Bear in mind that most of these escape sequences apply only in *double*-quoted strings. In *single*-quoted strings, most escape sequences are treated literally.

```
puts '\n\t\"'
```

```
\n\t\"
```

Calling "chomp" on the string object

```
File Edit Window Help
$ ruby get_number.rb
Welcome to 'Get My Number!'
What's your name? Jay
Welcome, Jay
!
```



We can use the `chomp` method to remove the newline character.

If the last character of a string is a newline, the `chomp` method will remove it. It's great for things like cleaning up strings returned from `gets`.

The `chomp` method is more specialized than `print`, `puts`, and `gets`, so it's available only on individual string objects. That means we need to specify that the string referenced by the `input` variable is the *receiver* of the `chomp` method. We need to use the dot operator on `input`.

```
# Get My Number Game
# Written by: you!

puts "Welcome to 'Get My Number!'"
print "What's your name? "

input = gets

name = input.chomp

puts "Welcome, #{name}!"
```

We'll store the return value of "chomp" in a new variable, "name".

Calling the "chomp" method.

The string in "input" is the receiver of the "chomp" method.

The dot operator.

We'll use "name" in the greeting, instead of "input".

The `chomp` method returns the same string, but without the newline character at the end. We store this in a new variable, `name`, which we then print as part of our welcome message.

If we try running the program again, we'll see that our new, emphatic greeting is working properly now!

```
File Edit Window Help
$ ruby get_number.rb
Welcome to 'Get My Number!'
What's your name? Jay
Welcome, Jay!
```

What methods are available on an object?

You can't call just any method on just any object. If you try something like this, you'll get an error:

```
puts 42.upcase
```

Error →

```
undefined method `upcase' for 42:Fixnum (NoMethodError)
```

Which, if you think about it, isn't so wrong. After all, it doesn't make a lot of sense to capitalize a number, does it?

But, then, what methods *can* you call on a number? That question can be answered with a method called `methods`:

```
puts 42.methods
```

```
to_s
abs
odd?
...
```

Plus too many more to list here!

If you call `methods` on a string, you'll get a different list:

```
puts "hello".methods
```

```
to_i
length
upcase
...
```

Plus too many more to list here!

Why the difference? It has to do with the object's class. A **class** is a blueprint for making new objects, and it decides, among other things, what methods you can call on the object.

There's another method that lets objects tell us what their class is. It's called, sensibly enough, `class`. Let's try it out on a few objects.

```
puts 42.class
puts "hello".class
puts true.class
```

```
Fixnum
String
TrueClass
```

We'll be talking more about classes in the next chapter, so stay tuned!

That's all the code for our first requirement. You can check it off the list!

Generating a random number

Our player greeting is done. Let's look at our next requirement.

The `rand` method will generate a random number within a given range. It should be able to create a target number for us.

We need to pass an argument to `rand` with the number that will be at the upper end of our range (100). Let's try it out a couple times:

```
puts rand(100)
puts rand(100)
```

```
67
25
```

Looks good, but there's one problem: `rand` generates numbers between *zero* and *just below* the maximum value you specify. That means we'll be getting random numbers in the range 0-99, not 1-100 like we need.

That's easy to fix, though, we'll just add `1` to whatever value we get back from `rand`. That will put us back in the range of 1-100!

```
rand(100) + 1
```

```
# Get My Number Game
# Written by: you!

puts "Welcome to 'Get My Number!'"

# Get the player's name, and greet them.
print "What's your name? "
input = gets
name = input.chomp
puts "Welcome, #{name}!"
```

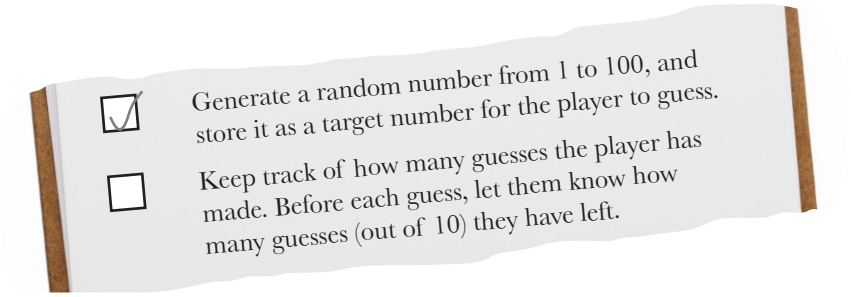
We'll store the result in a new variable, named `target`.

Our new code!

```
# Store a random number for the player to guess.
puts "I've got a random number between 1 and 100."
puts "Can you guess it?"
target = rand(100) + 1
```

Converting to strings

That's another requirement down! Let's look at the next one...



"Keep track of how many guesses the player has made..." Looks like we'll need a variable for the number of guesses. Obviously, when the player first starts, they haven't made any guesses, so we'll create a variable named `num_guesses` that's set to `0` initially.

```
num_guesses = 0
```

Now, the first thing you might attempt to do in order to display the number of guesses remaining is to concatenate (join) the strings together using the + sign, as many other languages do. Something like this *won't work*, however:

```
remaining_guesses = 10 - num_guesses
puts remaining_guesses + " guesses left."
```

Gives an error!

The + operator is used to *add numbers* as well as to *concatenate strings*, and since `remaining_guesses` contains a number, this plus sign looks like an attempt to add numbers.

What's the solution? You need to convert the number to a string. Almost all Ruby objects have a `to_s` method you can call to do this conversion; let's try that now.

```
remaining_guesses = 10 - num_guesses
puts remaining_guesses.to_s + " guesses left."
```

```
10 guesses left.
```

That works! Converting the number to a string first makes it clear to Ruby you're doing concatenation, not addition.

Ruby provides an easier way to handle this, though. Read on...

Ruby makes working with strings easy

Instead of calling `to_s`, we could save ourselves the effort of explicitly converting a number to a string by using string interpolation. As you saw in our code to greet the user, when you include `#{}` in a double-quoted string, code within the curly brackets is evaluated, converted to a string if necessary, and interpolated (substituted) into the longer string.

The automatic string conversion means we can get rid of the `to_s` call.

```
remaining_guesses = 10 - num_guesses
puts "#{remaining_guesses} guesses left."
```

```
10 guesses left.
```

Ruby lets us do operations directly within the curly brackets, so we can also get rid of the `remaining_guesses` variable.

```
puts "#{10 - num_guesses} guesses left."
```

```
10 guesses left.
```

The `#{}` can occur anywhere within the string, so it's easy to make the output a little more user-friendly, too.

```
puts "You've got #{10 - num_guesses} guesses left."
```

```
You've got 10 guesses left.
```

Now the player will know how many guesses they have left. We can check another requirement off our list!

```
# Get My Number Game
# Written by: you!

puts "Welcome to 'Get My Number!'"

# Get the player's name, and greet them.
print "What's your name? "
input = gets
name = input.chomp
puts "Welcome, #{name}!"

# Store a random number for the player to guess.
puts "I've got a random number between 1 and 100."
puts "Can you guess it?"
target = rand(100) + 1

# Track how many guesses the player has made.
num_guesses = 0

puts "You've got #{10 - num_guesses} guesses left."
```

Our new code!

Converting strings to numbers

- [x] Keep track of how many guesses the player has made. Before each guess, let them know how many guesses (out of 10) they have left.
- [ ] Prompt the player to make a guess as to what the target number is.

Our next requirement is to prompt the player to guess the target number. So, we need to print a prompt, then record the user's input as their guess. The `gets` method, as you may recall, retrieves input from the user. (We already used it to get the player's name.) Unfortunately, we can't just use `gets` by itself to get a number from the user, because it returns a string. The problem will arise later, when we try to compare the player's guess with the target number using the > and < operators.

```
print "Make a guess: "
guess = gets
guess < target
guess > target
```

Either of these will result in an error!

We need to convert the string returned from the `gets` method to a number so that we can compare the guess to our target number. No problem! Strings have a `to_i` method to do the conversion for us.

This code will call `to_i` on the string returned from `gets`. We don't even need to put the string in a variable first; we'll just use the dot operator to call the method directly on the return value.

```
guess = gets.to_i
```

If we want to test our changes, we can print out the result of a comparison.

```
puts guess < target
```

```
true
```

Much better - we have a guess that we can compare to the target. That's another requirement done!

Common conversions

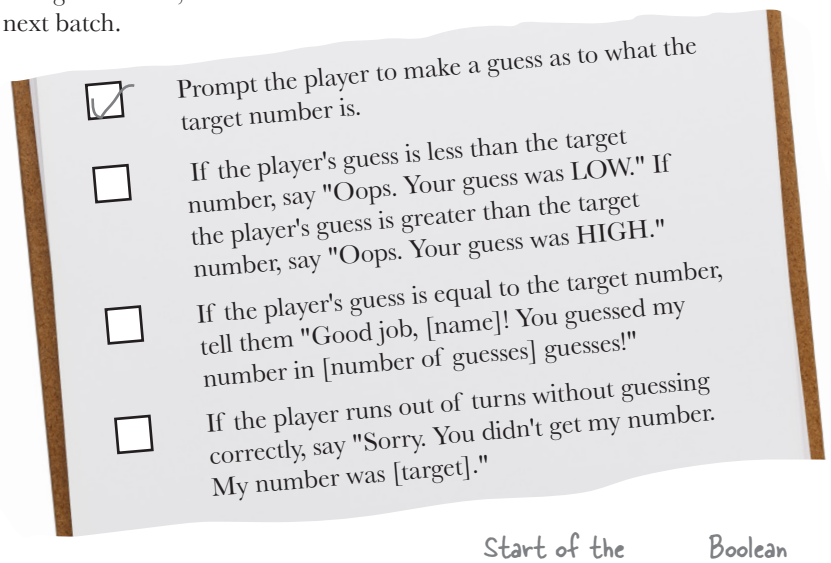
If you call this method on an object...	...you get this kind of object back.
`to_s`	string
`to_i`	integer
`to_f`	floating-point number

Our new code!

```
...

# Store a random number for the player to guess.
puts "I've got a random number between 1 and 100."
puts "Can you guess it?"
target = rand(100) + 1

# Track how many guesses the player has made.
num_guesses = 0

puts "You've got #{10 - num_guesses} guesses left."
print "Make a guess: "
guess = gets.to_i
```

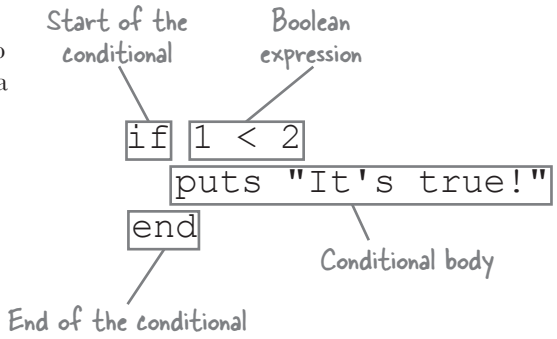
Conditionals

Two more requirements for our game down, four to go! Let's look at the next batch.



Now, we need to compare the player's guess with the target. *If* it's too high, we print a message saying so. *Otherwise, if* it's too low, we print a message to that effect, and so on... Looks like we need the ability to execute portions of our code only under certain *conditions*.

Like most languages, Ruby has **conditional** statements: statements that cause code to be executed only if a condition is met. An expression is evaluated, and if its result is true, the code in the conditional body is executed. If not, it's skipped.



As with most other languages, Ruby supports multiple branches in the condition. These statements take the form `if/elsif/else`.

Note that there's no "e" in the middle of "elsif"!

```
if score == 100
  puts "Perfect!"
elsif score >= 70
  puts "You pass!"
else
  puts "Summer school time!"
end
```

Conditionals rely on a **boolean** expression (one with a true or false value) to decide whether the code they contain should be executed. Ruby has constants representing the two boolean values, `true` and `false`.

```
if true
  puts "I'll be printed!"
end
```

```
if false
  puts "I won't!"
end
```

Conditionals (cont.)

Ruby also has all the comparison operators you're used to.

```
if 1 == 1
  puts "I'll be printed!"
end
```

```
if 1 > 2
  puts "I won't!"
end
```

```
if 1 < 2
  puts "I'll be printed!"
end
```

```
if 1 >= 2
  puts "I won't!"
end
```

```
if 2 <= 2
  puts "I'll be printed!"
end
```

```
if 2 != 2
  puts "I won't!"
end
```

Said aloud as "not equal to".

It has the boolean negation operator, `!`, which lets you take a true value and make it false, or a false value and make it true. It also has the more-readable keyword `not`, which does basically the same thing.

```
if ! true
  puts "I won't be printed!"
end
```

```
if ! false
  puts "I will!"
end
```

```
if not true
  puts "I won't be printed!"
end
```

```
if not false
  puts "I will!"
end
```

If you need to ensure that two conditions are *both* true, you can use the `&&` operator. If you need to ensure that *either* of two conditions are true, you can use the `||` operator.

```
if true && true
  puts "I'll be printed!"
end
```

```
if true && false
  puts "I won't!"
end
```

```
if false || true
  puts "I'll be printed!"
end
```

```
if false || false
  puts "I won't!"
end
```

I notice that you're indenting the code between the `if` and the `end`. Is that required?

Indented 2 spaces!

```
if true
  puts "I'll be printed!"
end
```

Ruby doesn't treat indentation as significant to the meaning of the program, no. (Unlike some other languages, such as Python.)

But indenting code within `if` statements, loops, methods, classes, and the like is just good coding style. It helps make the structure of your code clear to your fellow developers (and even to yourself).

We need to compare the player's guess to the random target number. Let's use everything we've learned about conditionals to implement this batch of requirements.


get_number.rb

```
# Get My Number Game
# Written by: you!

puts "Welcome to 'Get My Number!'"

# Get the player's name, and greet them.
print "What's your name? "
input = gets
name = input.chomp
puts "Welcome, #{name}!"

# Store a random number for the player to guess.
puts "I've got a random number between 1 and 100."
puts "Can you guess it?"
target = rand(100) + 1

# Track how many guesses the player has made.
num_guesses = 0

# Track whether the player has guessed correctly.
guessed_it = false

puts "You've got #{10 - num_guesses} guesses left."
print "Make a guess: "
guess = gets.to_i

# Compare the guess to the target.
# Print the appropriate message.
if guess < target
  puts "Oops. Your guess was LOW."
elsif guess > target
  puts "Oops. Your guess was HIGH."
elsif guess == target
  puts "Good job, #{name}!"
  puts "You guessed my number in #{num_guesses} guesses!"
  guessed_it = true
end

# If player ran out of turns, tell them what the number was.
if not guessed_it
  puts "Sorry. You didn't get my number. (It was #{target}.)"
end
```

We add this variable to track whether we should print the "you lost" message. We'll also use it later to halt the game on a correct guess.

Here are our "if" statements!

We'll see a cleaner way to write this in a moment.

The opposite of "if" is "unless"

This statement works, but it's a little awkward to read:

```
if not guessed_it
  puts "Sorry. You didn't get my number. (It was #{target}.)"
end
```

In most respects, Ruby's conditional statements are just like most other languages. Ruby has an additional keyword, though: `unless`.

Code within an `if` statement executes only if a condition is *true*, but code within an `unless` statement executes only if the condition is *false*.

```
unless true
  puts "I won't be printed!"
end
```

```
unless false
  puts "I will!"
end
```

The `unless` keyword is an example of how Ruby works hard to make your code a little easier to read. You can use `unless` in situations where a negation operator would be awkward. So instead of this:

```
if ! light == "red"
  puts "Go!"
end
```

You can write this:

```
unless light == "red"
  puts "Go!"
end
```

We can use `unless` to clean up that last conditional.

```
unless guessed_it
  puts "Sorry. You didn't get my number. (It was #{target}.)"
end
```

Much more legible! And our conditional statements are working great!

You'll see something like this if you run get_number.rb now...

```
File Edit Window Help
$ ruby get_number.rb
Welcome to 'Get My Number!'
What's your name? Jay
Welcome, Jay!
I've got a random number between 1 and 100.
Can you guess it?
You've got 10 guesses left.
Make a guess: 50
Oops. Your guess was HIGH.
Sorry. You didn't get my number. (It was 34.)
```

As it stands right now, though, the player only gets one guess - they're supposed to get 10. We'll fix that next...

Conventional Wisdom

It's valid to use `else` and `elsif` together with `unless` in Ruby:

```
unless light == "red"
  puts "Go!"
else
  puts "Stop!"
end
```

Confusing!

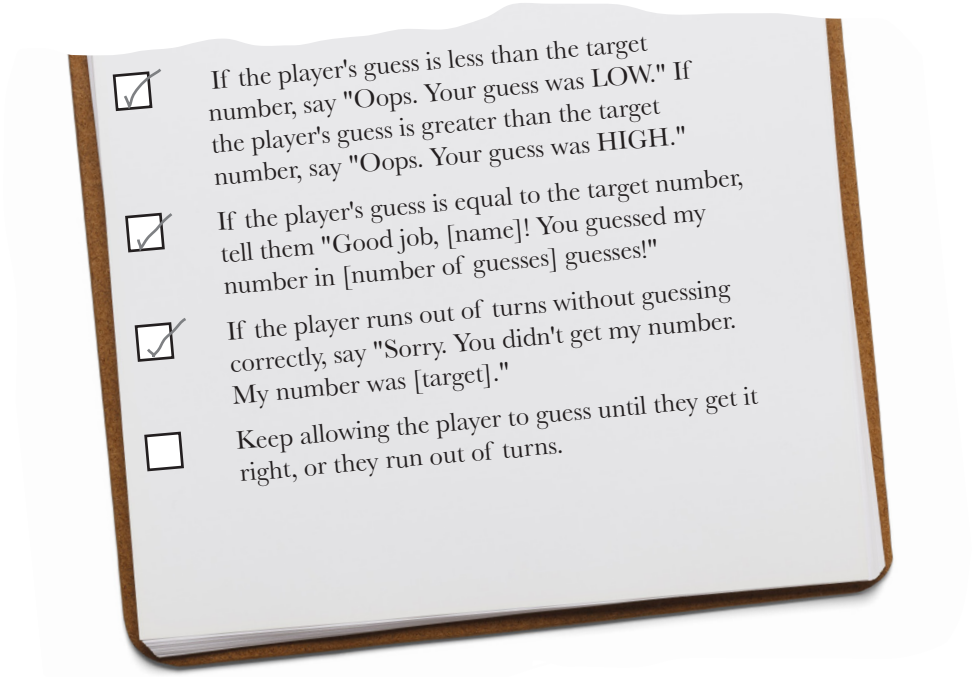
But it's very hard to read. If you need an `else` clause, use `if` for the main clause instead!

```
if light == "red"
  puts "Stop!"
else
  puts "Go!"
end
```

Moved up here.

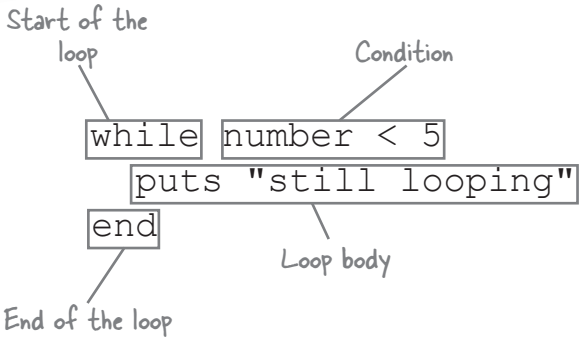
Loops

Great work so far! We have just one more requirement to go for our guessing game!



Currently, the player gets one guess. Since there's 100 possible target numbers, those don't seem like very fair odds. We need to keep asking them 10 times, or until they get the right answer, whichever comes first.

The code to prompt for a guess is already in place, we just need to run it *more than once*. We can use a **loop** to execute a segment of code repeatedly. You've probably encountered loops in other languages. When you need one or more statements to be executed over and over, you place them inside a loop.



A `while` loop consists of the word `while`, a boolean expression (just like in `if` or `unless` statements), the code you want to repeat, and the word `end`. The code within the loop body repeats *while* the condition is true.

Here's a simple example that uses a loop for counting.

```
number = 1
while number <= 5
  puts number
  number += 1
end
```

```
1
2
3
4
5
```

Just as `unless` is the counterpart to `if`, Ruby offers an `until` loop as a counterpart to `while`. An `until` loop repeats *until* the condition is true (that is, it loops while it's false).

Here's a similar example, using `until`.

```
number = 1
until number > 5
  puts number
  number += 1
end
```

```
1
2
3
4
5
```

Here's our conditional code again, updated to run within a `while` loop:

The loop will stop after the player's tenth guess, or when they guess correctly, whichever comes first.

```
# Track how many guesses the player has made.
num_guesses = 0

# Track whether the player has guessed correctly.
guessed_it = false

while num_guesses < 10 && guessed_it == false
```

This code is exactly the same; we've just nested it inside the loop.

```
  puts "You've got #{10 - num_guesses} guesses left."
  print "Make a guess: "
  guess = gets.to_i
```

We need to add 1 to the guess count each loop, so we don't loop forever.

```
  num_guesses += 1
```

No changes here, either.

```
  # Compare the guess to the target.
  # Print the appropriate message.
  if guess < target
    puts "Oops. Your guess was LOW."
  elsif guess > target
    puts "Oops. Your guess was HIGH."
  elsif guess == target
    puts "Good job, #{name}!"
    puts "You guessed my number in #{num_guesses} guesses!"
    guessed_it = true
  end
```

This marks the end of the code that will loop.

```
end

unless guessed_it
  puts "Sorry. You didn't get my number. (It was #{target}.)"
end
```

There's one more readability improvement we can make. As with the `if` statement that we replaced with an `unless`, we can make this `while` loop read more clearly by replacing it with an `until`.

Before:

```
while num_guesses < 10 && guessed_it == false
  ...
end
```

After:

```
until num_guesses == 10 || guessed_it
  ...
end
```

Here's our complete code listing.

get_number.rb

```
# Get My Number Game
# Written by: you!

puts "Welcome to 'Get My Number!'"

# Get the player's name, and greet them.
print "What's your name? "
input = gets
name = input.chomp
puts "Welcome, #{name}!"

# Store a random number for the player to guess.
puts "I've got a random number between 1 and 100."
puts "Can you guess it?"
target = rand(100) + 1

# Track how many guesses the player has made.
num_guesses = 0

# Track whether the player has guessed correctly.
guessed_it = false

until num_guesses == 10 || guessed_it

  puts "You've got #{10 - num_guesses} guesses left."
  print "Make a guess: "
  guess = gets.to_i

  num_guesses += 1

  # Compare the guess to the target.
  # Print the appropriate message.
  if guess < target
    puts "Oops. Your guess was LOW."
  elsif guess > target
    puts "Oops. Your guess was HIGH."
  elsif guess == target
    puts "Good job, #{name}!"
    puts "You guessed my number in #{num_guesses} guesses!"
    guessed_it = true
  end

end

# If the player didn't guess in time, show the target number.
unless guessed_it
  puts "Sorry. You didn't get my number. (It was #{target}.)"
end
```

Let's try running our game!

Our loop is in place - that's the last requirement! Let's open a command prompt, and try running the program!

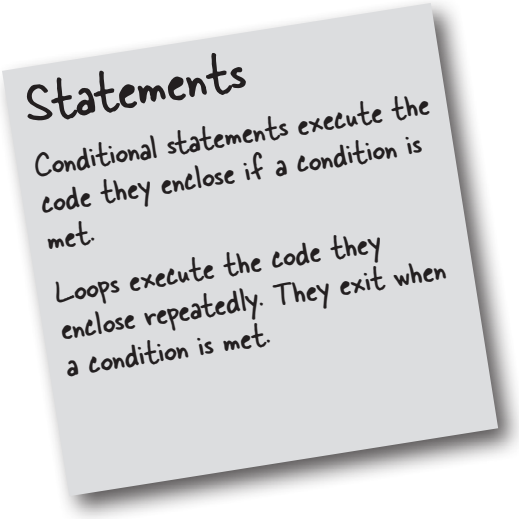
- [x] Keep allowing the player to guess until they get it right, or they run out of turns.

```
File Edit Window Help Cheats
$ ruby get_number.rb
Welcome to 'Get My Number!'
What's your name? Gary
Welcome, Gary!
I've got a random number between 1 and 100.
Can you guess it?
You've got 10 guesses left.
Make a guess: 50
Oops. Your guess was LOW.
You've got 9 guesses left.
Make a guess: 75
Oops. Your guess was HIGH.
You've got 8 guesses left.
Make a guess: 62
Oops. Your guess was HIGH.
You've got 7 guesses left.
Make a guess: 56
Oops. Your guess was HIGH.
You've got 6 guesses left.
Make a guess: 53
Good job, Gary!
You guessed my number in 5 guesses!
$
```

Using variables, strings, method calls, conditionals, and loops, you've written a complete game in Ruby! Better yet, it took less than 30 lines of code! Pour yourself a cold drink - you've earned it!

Your Ruby Toolbox

You've got Chapter 1 under your belt and now you've added method calls, conditionals, and loops to your tool box.



BULLET POINTS

- Ruby is an interpreted language. You don't have to compile Ruby code before executing it.
- You don't need to declare variables before assigning to them. You also don't have to specify a type.
- Ruby treats everything from a `#` to the end of the line as a comment - and ignores it.
- Text within quotation marks is treated as a string - a series of characters.
- If you include #{} in a Ruby string, the expression in the brackets will be interpolated into the string.
- Method calls *may* need one or more arguments, separated by commas.
- Parenthesis are optional around method arguments. Leave them off if you're not passing any arguments.
- Use the `inspect` and `p` methods to view debug output for Ruby objects.
- You can include special characters within double-quoted strings by using escape sequences like `\n` and `\t`.
- You can use the interactive Ruby interpreter, or `irb`, to quickly test out the result of Ruby expressions.
- Call `to_s` on almost any object to convert it to a string. Call `to_i` on a string to convert it to an integer.
- `unless` is the opposite of `if`; its code won't execute *unless* a statement is *false*.
- `until` is the opposite of `while`; it executes repeatedly *until* a condition is true.

2 methods and classes

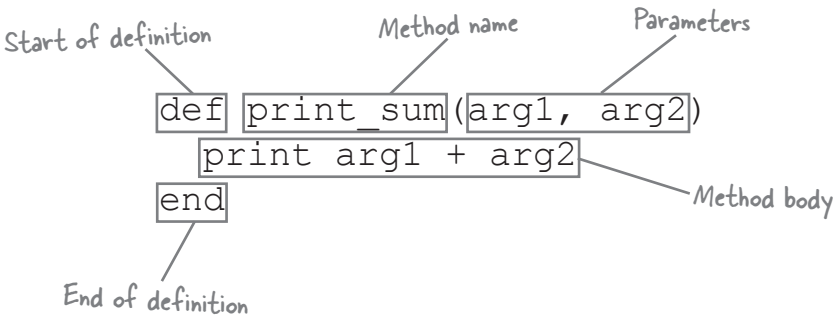
Getting Organized

You've been missing out. You've been calling methods and creating objects like a pro. But the only methods you could call, and the only kinds of objects you could create, were the ones that Ruby defined for you. Now, it's your turn. You're going to learn to create your *own* methods. You'll also create your own **classes** - templates for new objects. *You'll decide* what objects based on your class will be like. You'll use **instance variables** to define what they *know*, and **instance methods** to define what they *do*. And most importantly, you'll discover how defining your own classes can make your code *easier to read and maintain*.

Defining methods

Got-A-Motor, Inc. is working on their "virtual test-drive" app, which lets their customers try vehicles out on their computers without needing to visit a show room. For this first version, they need methods to let users step on the virtual gas, sound the virtual horn, and turn on the virtual headlights in low-beam or high-beam modes.

Method definitions look like this in Ruby:



If you want calls to your method to include arguments, you'll need to add **parameters** to the method definition. Parameters appear after the method name, within parenthesis. (You should leave off the parenthesis if there are no parameters.) Each argument on the method call gets stored in one of the parameters within the method.

The method body consists of one or more Ruby statements that are executed when the method is called.

Let's create our very own methods to represent the actions in the test-drive app.

Here are two methods for accelerating and sounding the horn. They're about as simple as Ruby methods can be; each method body has a pair of statements that print strings.

```
def accelerate                          # Method takes no parameters.
  puts "Stepping on the gas"            # These statements will be run
  puts "Speeding up"                    #  when the method is called.
end

def sound_horn                          # Method takes no parameters.
  puts "Pressing the horn button"       # These statements will be run
  puts "Beep beep!"                     #  when the method is called.
end
```

The `use_headlights` method is only slightly more complex; it takes a single parameter, which is interpolated into one of the output strings.

```
def use_headlights(brightness)          # One method parameter.
  puts "Turning on #{brightness} headlights"
  puts "Watch out for deer!"
end                                     # Parameter is used in the output.
```

That's all it takes! With these method definitions in place, we're ready to make calls to them.

Calling methods you've defined

You can call methods you've defined just like any other. Let's try out our new vehicle simulator methods.

Ruby lets you put calls to your methods anywhere - even within the same source file where you defined them. Since this is such a simple program at this point, we'll do that, just for convenience. We'll just stick the method calls right after the method declarations.

```
def accelerate
  puts "Stepping on the gas"
  puts "Speeding up"
end

def sound_horn
  puts "Pressing the horn button"
  puts "Beep beep!"
end

def use_headlights(brightness)
  puts "Turning on #{brightness} headlights"
  puts "Watch out for deer!"
end

sound_horn
accelerate
use_headlights("hi-beam")
```

Calls without arguments.

This is used as the "brightness" argument.

vehicle_methods.rb

When we run the source file from the command line, we'll see the result of our method calls!

```
File Edit Window Help
$ ruby vehicle_methods.rb
Pressing the horn button
Beep beep!
Stepping on the gas
Speeding up
Turning on hi-beam headlights
Watch out for deer!
$
```

I notice you didn't use the dot operator to specify a receiver for those method calls, just like when we call the `puts` and `print` methods.

That's right. Like `puts` and `print`, these methods are included in the top-level execution environment.

Methods that are defined outside of any class (like these examples) are included in the top-level execution environment. Like we saw back in Chapter 1, you can call them anywhere in your code, *without* using the dot operator to specify a receiver.

Method names

The method name can be one or more lower-case words, separated by underscores. (This is just like the convention for variable names.) Numbers are legal, but rarely used.

It's also legal for a method name to end in a question mark (?) or exclamation point (!). These endings have no special meaning to Ruby, but there are certain conventions around their use, which we'll cover in later chapters.

Lastly, it's legal for a method name to end in an equals sign (=). Methods ending in this character are used as attribute writers, which we'll be looking at in the upcoming section on classes. Ruby *does* treat this ending specially, so don't use it for a regular method, or you may find it acts strangely!

Parameters

If you need to pass data into your method, you can include one or more parameters after the method name, separated by commas. In your method body, parameters can be accessed just like any variable.

```
def print_area(length, width)
  puts length * width
end
```

Optional parameters

Got-A-Motor's developers are happy with our work on the virtual test drive system... mostly.

Do we have to specify an argument on this `use_headlights` method? We almost always use `"low-beam"`, and we're copying that string everywhere in our code!

```
use_headlights("low-beam")
stop_engine
buy_coffee
start_engine
use_headlights("low-beam")
accelerate
create_obstacle("deer")
use_headlights("high-beam")
```

Conventional Wisdom

Method names should be in "snake case": one or more lower-case words, separated by underscores, just like variable names.

```
def bark
end

def wag_tail
end
```

As with method calls, you should leave parenthesis off the method definition if there are no parameters. Please don't do this, even though it's legal:

```
def no_args()
  puts "Bad Rubyist!"
end
```

But if there are parameters, you should always include parenthesis. (Back in Chapter 1, we showed some tasteful exceptions when making method calls, but there are no exceptions when declaring methods.) Leaving them off is legal, but again, don't do it:

```
def with_args first, second
  puts "No! Bad!"
end
```

Optional parameters (cont.)

This scenario is pretty common - you use one particular argument 90% of the time, and you're tired of repeating it everywhere. You can't just take the parameter out, though, because 10% of the time you need a different value.

There's an easy solution, though; *make the parameter optional*. You can provide a default value in the method declaration.

Here's an example of a method that uses default values for some of its parameters:

```
def order_soda(flavor, size = "medium", quantity = 1)
  if quantity == 1
    plural = "soda"
  else
    plural = "sodas"
  end
  puts "#{quantity} #{size} #{flavor} #{plural}, coming right up!"
end
```

Default value for size.

Default value for quantity.

Now, if you want to override the default, just provide an argument with the value you want. And if you're happy with the default, you can skip the argument altogether.

```
order_soda("orange")
order_soda("lemon-lime", "small", 2)
order_soda("grape", "large")
```

Specify flavor, use default for size and quantity.

Specify everything.

Specify flavor and size, use default for quantity.

```
1 medium orange soda, coming right up!
2 small lemon-lime sodas, coming right up!
1 large grape soda, coming right up!
```

There is one caveat to be aware of with optional parameters: they need to appear *after* any other parameters you intend to use. If you make a required parameter following an optional parameter, you won't be able to leave the optional parameter off:

```
def order_soda(flavor, size = "medium", quantity)
  ...
end

order_soda("grape")
```

Don't place an optional parameter before a required one!

Error →

```
wrong number of arguments (1 for 2..3)
```

there are no Dumb Questions

Q: What's the difference between an argument and a parameter?

A: You define and use *parameters* within a method *definition*. You provide *arguments* with method *calls*.

```
def say_hello(name)
  puts "Hello, #{name}!"
end

say_hello("Marcy")
```

Parameter.

Parameter.

Argument.

Each argument you pass with the method call gets stored in a method parameter.

The two terms mostly serve to distinguish whether you're talking about a method *definition*, or a method *call*.

Optional parameters (cont.)

Let's earn some goodwill with the developers using our methods and make that `use_headlights` parameter optional.

```
def use_headlights(brightness = "low-beam")
  puts "Turning on #{brightness} headlights"
  puts "Watch out for deer!"
end
```

Now, they won't have to specify the brightness, unless they want the high-beams.

```
use_headlights                      # Uses the default, "low-beam"
use_headlights("high-beam")         # Overrides the default.
```

```
Turning on low-beam headlights
Watch out for deer!
Turning on high-beam headlights
Watch out for deer!
```

```
use_headlights                      # No argument needed!
stop_engine
start_engine
use_headlights
accelerate
use_headlights("high-beam")
```

We've finished up our methods for Got-A-Motor's virtual test drive app. Let's try loading them up in irb, and take them for a spin.

Step One: Save our method definitions to a file, named "vehicle_methods.rb".

Step Two: Open a system command prompt, and navigate into the directory where you saved your file.

```
def accelerate
  puts "Stepping on the gas"
  puts "Speeding up"
end

def sound_horn
  puts "Pressing the horn button"
  puts "Beep beep!"
end

def use_headlights(brightness = "low-beam")
  puts "Turning on #{brightness} headlights"
  puts "Watch out for deer!"
end
```


vehicle_methods.rb

Exercise (Continued)

Step Three: Since we're loading code from a file into `irb`, we want to be able to load Ruby files from the current directory. So we're going to invoke `irb` a little differently this time.

At the command prompt, type this and press Enter:

```
irb -I .
```

A flag that means "search the current directory for files to load".

The `-I` is a *command line flag*, a string that you add on to a command to change how it operates. In this case, `-I` alters the set of directories that Ruby searches for files to load. And the dot (`.`) represents the current directory.

Step Four: Now, `irb` should be loaded, and we should be able to load the file with our methods. Type this line:

```
require "vehicle_methods"
```

Ruby knows to search in `.rb` files by default, so you can leave the extension off. If you see the result `true`, it means your file was loaded successfully.

Now, you can type in a call to any of our methods, and they'll be run!

Here's a sample session:

File Edit Window Help

```
$ irb -I .
irb(main):001:0> require "vehicle_methods"
 => true
irb(main):002:0> sound_horn
Pressing the horn button
Beep beep!
 => nil
irb(main):003:0> use_headlights
Turning on low-beam headlights
Watch out for deer!
 => nil
irb(main):004:0> use_headlights("high-beam")
Turning on high-beam headlights
Watch out for deer!
 => nil
irb(main):005:0> exit
$
```

Return value

Got-A-Motor wants the test-drive app to highlight how fuel-efficient its cars are. They want to be able to display the mileage a car got on its most recent trip, as well as lifetime average mileage.

In the first scenario, you're dividing the mileage from the car's trip odometer by the number of gallons from your last fillup, and in the second you're dividing the main odometer's value by the car's lifetime fuel use. But in both cases, you're taking a number of miles, and dividing it by a number of gallons of fuel. So, do you still have to write two methods?

Nope! Like in most languages, Ruby methods have a **return value**, a value that they can send back to the code that called them. A Ruby method can return a value to its caller using the `return` keyword.

You can write a single `mileage` method, and use its return value in your output.

```
def mileage(miles_driven, gas_used)
  return miles_driven / gas_used
end
```

Then, you can use the same method to calculate both types of mileage.

```
trip_mileage = mileage(400, 12)
puts "You got #{trip_mileage} MPG on this trip."

lifetime_mileage = mileage(11432, 366)
puts "This car averages #{lifetime_mileage} MPG."
```

```
You got 33 MPG on this trip.
This car averages 31 MPG.
```

Implicit return values

You don't actually need the `return` keyword in the above method. The value of the last expression evaluated within a method automatically becomes that method's return value. So, our `mileage` method could be rewritten without an explicit `return`:

```
def mileage(miles_driven, gas_used)
  miles_driven / gas_used
end
```

It will still work in exactly the same way.

```
puts mileage(400, 12)
```

```
33
```

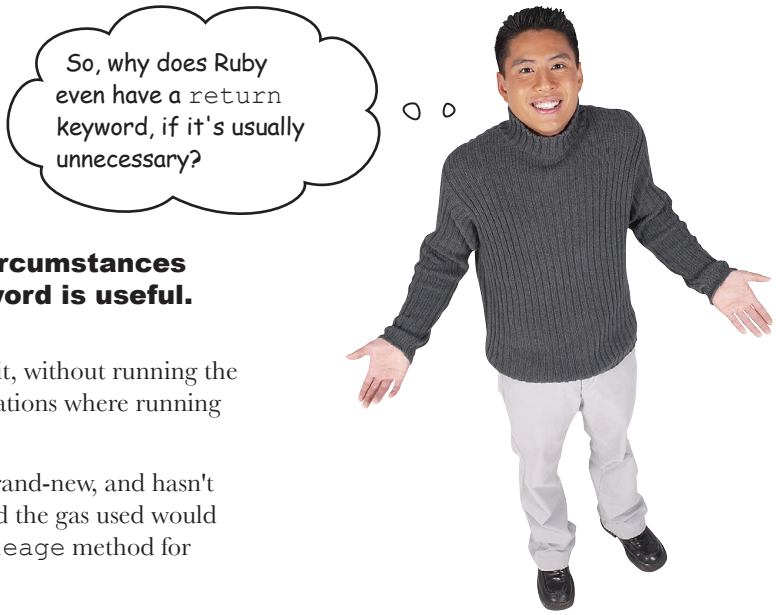
Rubyists generally prefer implicit return values over explicit return values. With a short method, there's no reason to write this:

```
def area(length, width)
  return length * width
end
```

...When you can just write this:

```
def area(length, width)
  length * width
end
```

Returning from a method early



There are still some circumstances where the `return` keyword is useful.

The `return` keyword causes the method to exit, without running the lines of code that follow it. This is useful in situations where running that code would be pointless, or even harmful.

For example, consider the case where a car is brand-new, and hasn't been driven anywhere yet. The miles driven and the gas used would both be zero. What happens if you call the `mileage` method for such a car?

Well, `mileage` works by dividing `miles_driven` by `gas_used`... And as you may have learned in your other programming language, dividing anything by zero is an error!

```
puts mileage(0, 0)
```

Error →

```
in `/': divided by 0 (ZeroDivisionError)
```

We can fix this by testing whether `gas_used` is zero, and if so, returning from the method early.

```
def mileage(miles_driven, gas_used)
  if gas_used == 0
    return 0.0
  end
  miles_driven / gas_used
end
```

← If no gas has been used...
← Return zero.
← This code won't be run if "gas_used" is zero.

If we try the same code again, we'll see that it returns `0.0`, without attempting the division operation. Problem solved!

```
puts mileage(0, 0)
```

```
0.0
```

Methods are a great way to reduce duplication, and keep your code organized. But sometimes, methods by themselves aren't enough. Let's leave our friends at Got-A-Motor for now, to look at a somewhat fuzzier problem...

Some messy methods

Fuzzy Friends Animal Rescue is in the middle of a fundraising drive, and are doing an interactive storybook application to raise awareness. They've approached your company for help. They need many different types of animals, each of which has its own sounds and actions.

They've created some methods that simulate movement and animal noises. Their methods are called by specifying the animal type as the first argument, followed by any additional arguments that are needed.

Here's what they have so far:

```
def talk(animal_type, name)
  if animal_type == "bird"
    puts "#{name} says Chirp! Chirp!"
  elsif animal_type == "dog"
    puts "#{name} says Bark!"
  elsif animal_type == "cat"
    puts "#{name} says Meow!"
  end
end

def move(animal_type, name, destination)
  if animal_type == "bird"
    puts "#{name} flies to the #{destination}."
  elsif animal_type == "dog"
    puts "#{name} runs to the #{destination}."
  elsif animal_type == "cat"
    puts "#{name} runs to the #{destination}."
  end
end

def report_age(name, age)
  puts "#{name} is #{age} years old."
end
```

The animal type parameter is used to select which string is printed.

This method is the same for all animal types, so there's no animal type parameter.

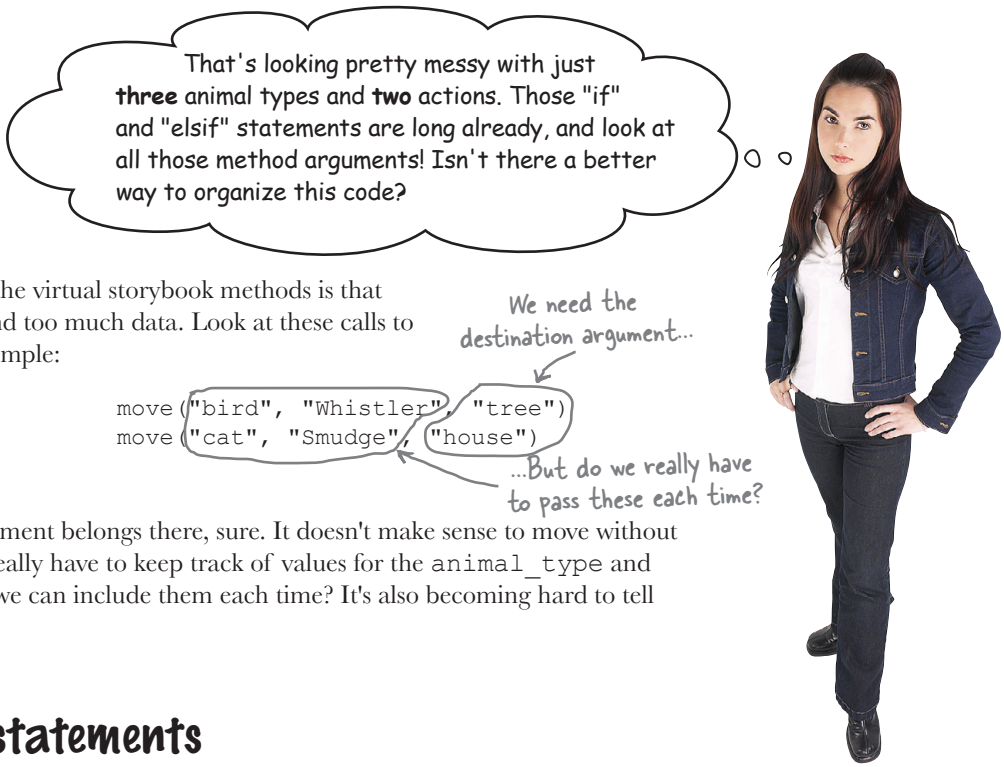
And here are some typical calls to those methods:

```
move("bird", "Whistler", "tree")
talk("dog", "Sadie")
talk("bird", "Whistler")
move("cat", "Smudge", "house")
report_age("Smudge", 6)
```

```
Whistler flies to the tree.
Sadie says Bark!
Whistler says Chirp! Chirp!
Smudge runs to the house.
Smudge is 6 years old.
```

Fuzzy Friends just needs you to add 10 additional animal types and 30 more actions, and version 1.0 will be done!

Too many arguments



Part of the problem with the virtual storybook methods is that we're having to pass around too much data. Look at these calls to the `move` method, for example:

We need the destination argument...

```
move("bird", "Whistler", "tree")
move("cat", "Smudge", "house")
```

...But do we really have to pass these each time?

The `destination` argument belongs there, sure. It doesn't make sense to move without a destination. But do we really have to keep track of values for the `animal_type` and `name` arguments, so that we can include them each time? It's also becoming hard to tell which argument is which!

Too many "if" statements

The problem isn't just with the method arguments, either – things are messy *inside* the methods. Consider what the `talk` method would look like if we added ten more animal types, for example...

Each time you want to change the sound an animal makes (and you *will* be asked to change the sounds, you can count on it), you'll have to search through all those `elsif` clauses to find the right animal type... What happens when the code for `talk` becomes more complex, adding things like animations and sound file playback? What happens when *all* of the action methods are like that?

What we need is a better way to represent which animal type we're working with. We need a better way to break all that code up by animal type, so that we can maintain it more easily. And we need a better way to store the attributes for each individual animal, like their name and their age, so we don't have to pass so many arguments around.

We need to keep the animals' data, and the code that operates on that data, in one place. We need: *classes* and *objects*.

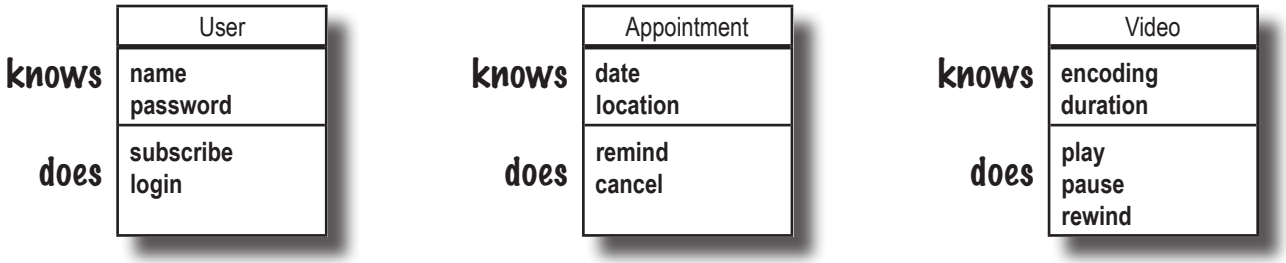
```
def talk(animal_type, name)
  if animal_type == "bird"
    puts "#{name} says Chirp! Chirp!"
  elsif animal_type == "dog"
    puts "#{name} says Bark!"
  elsif animal_type == "cat"
    puts "#{name} says Meow!"
  elsif animal_type == "lion"
    puts "#{name} says Roar!"
  elsif animal_type == "cow"
    puts "#{name} says Moo."
  elsif animal_type == "bob"
    puts "#{name} says Hello."
  elsif animal_type == "duck"
    puts "#{name} says Quack."
  ...
  end
end
```

We don't even have room to print all this...

Designing a class

The benefit of using objects is that they keep a set of data, and the methods that operate on that data, in one place. We want those benefits in the Fuzzy Friends app.

To start creating your own objects, though, you're going to need classes. A **class** is a blueprint for making objects. When you use a class to make an object, the class describes what that object *knows* about itself, as well as what that object *does*.

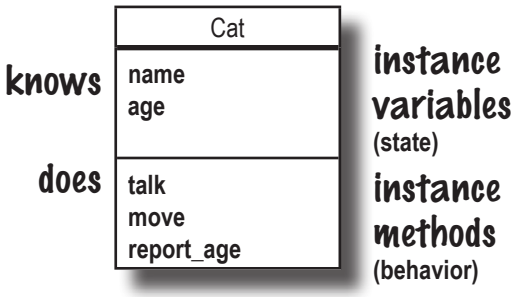


Things an object *knows* about itself are called:

instance variables

Things an object *does* are called:

instance methods



An **instance** of a class is an object that was made using that class. You only have to write *one* class, but you can make *many* instances of that class.

Think of "*instance*" as another way of saying "*object*".

Instance variables are variables that belong to one object. They comprise everything the object **knows** about itself. They represent the object's state (its data), and they can have different values for each instance of the class.

Instance methods are methods that you can call directly on that object. They comprise what the object **does**. They have access to the object's instance variables, and can use them to change their behavior based on the values in those variables.

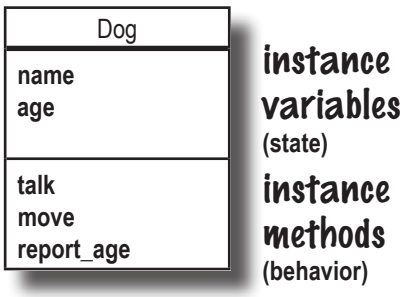
What's the difference between a class and an object?

A class is a blueprint for an object. The class tells Ruby how to make an object of that particular type. Objects have instance variables and instance methods, but those variables and methods are *designed* as part of the class.

If classes are cookie cutters, objects are the cookies they make.

Each instance of a class can have its own values for the instance variables used within that class's methods. For example, you'll only define the `Dog` class once. Within that `Dog` class's methods, you'll only specify once that `Dog` instances should have "name" and "age" instance variables. But each `Dog` *object* will have its own name and age, distinct from all the other `Dog` instances.

Dog class:



Dog instances:

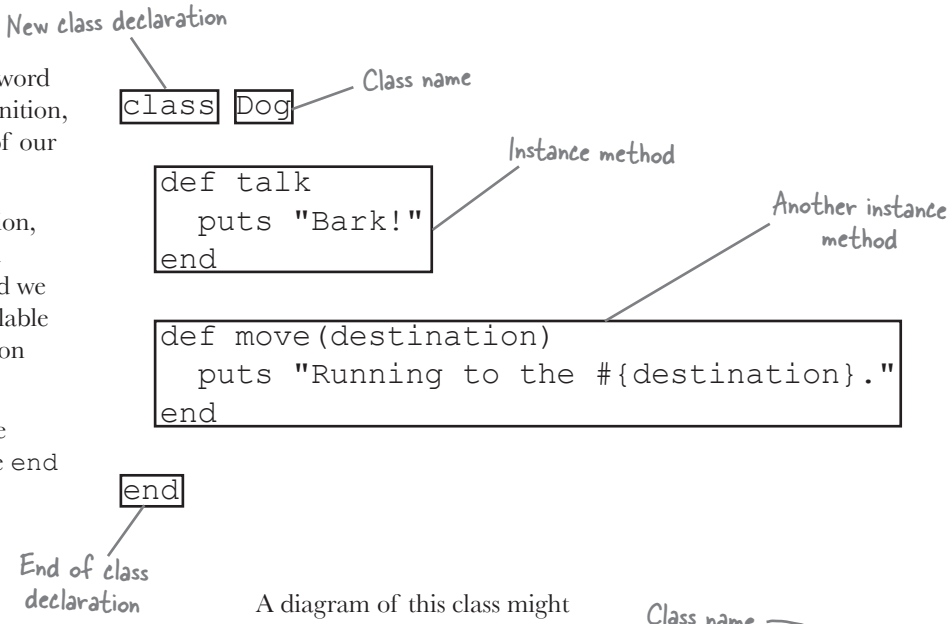
Your first class

Here's an example of a class we could use in our interactive storybook: a `Dog` class.

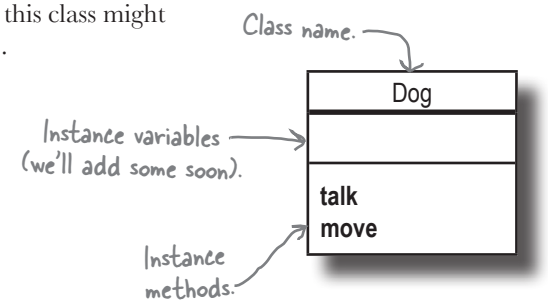
We use the `class` keyword to start a new class definition, followed by the name of our new class.

Within the class definition, we can include method definitions. Any method we define here will be available as an instance method on instances of the class.

We mark the end of the class definition with the `end` keyword.



A diagram of this class might look like this...



Creating new instances (objects)

If we call the `new` method on a class, it will return a new instance of that class. We can then assign that instance to a variable, or whatever else we need to do with it.

```
fido = Dog.new
rex = Dog.new
```

Once we have one or more instances of the class, we can call their instance methods. We do it in the same way we've called all other methods on objects so far: we use the dot operator to specify which instance is the method's reciever.

```
fido.talk
rex.move("food bowl")
```

```
Bark!
Running to the food bowl.
```

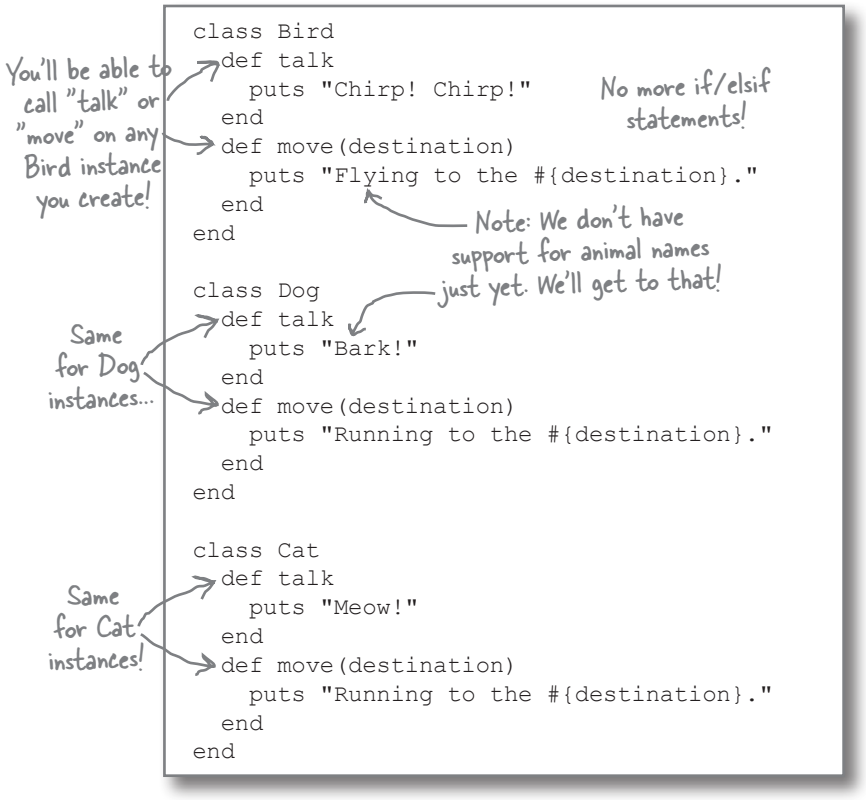
Breaking our giant methods up into classes

The animal rescue's solution uses strings to track what type of animal they're dealing with. Also, all knowledge of the different ways that different animals should respond is embedded in giant `if/else` statements. Their approach is unwieldy, at best.

```
def talk(animal_type, name)
  if animal_type == "bird"
    puts "#{name} says Chirp! Chirp!"
  elsif animal_type == "dog"
    puts "#{name} says Bark!"
  elsif animal_type == "cat"
    puts "#{name} says Meow!"
  end
end
```

The object-oriented approach

Now that you know how to create classes, we can take an *object-oriented* approach to the problem. We can create a *class* to represent each *type* of animal. Then, instead of one *big* method that contains behavior for *all* the animal types, we can put *little* methods in *each* class, methods that define behavior specific to that type of animal.




```
class Bird
  def talk
    puts "Chirp! Chirp!"
  end
  def move(destination)
    puts "Flying to the #{destination}."
  end
end

class Dog
  def talk
    puts "Bark!"
  end
  def move(destination)
    puts "Running to the #{destination}."
  end
end

class Cat
  def talk
    puts "Meow!"
  end
  def move(destination)
    puts "Running to the #{destination}."
  end
end
```

Conventional Wisdom

Ruby class names must begin with a capital letter. Letters after the first should be lower case.

```
class Appointment
  ...
end
```

If there's more than one word in the name, the first letter of each word should also be capitalized.

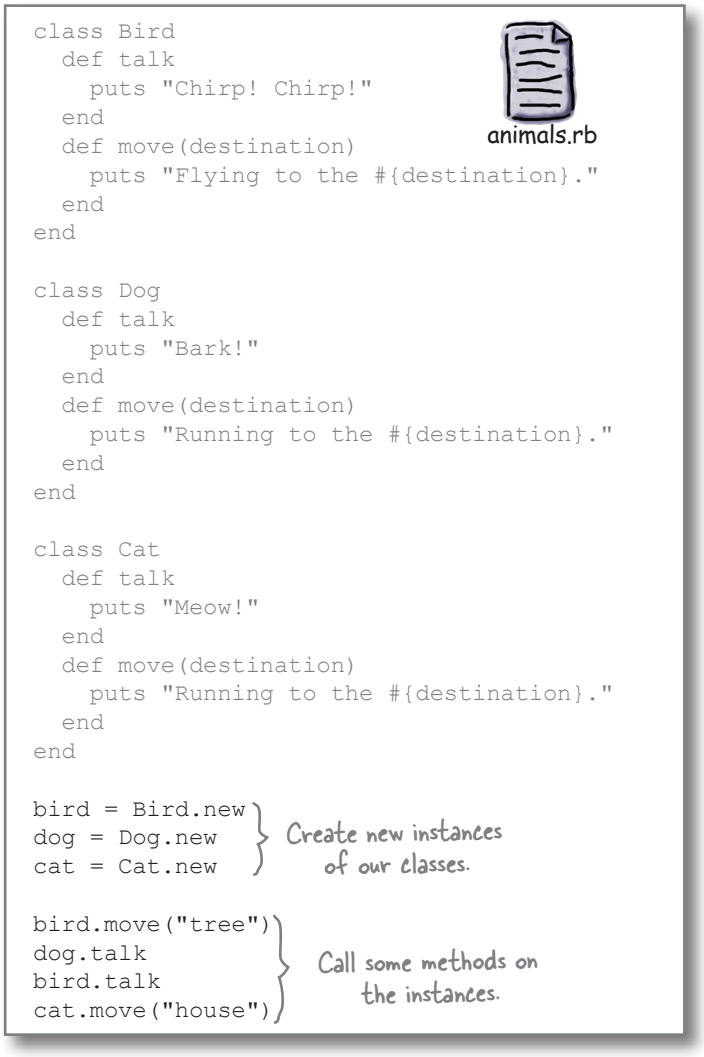
```
class AddressBook
  ...
end

class PhoneNumber
  ...
end
```

Remember how the convention for variable names (with underscores separating words) is called "snake case"? The style for class names is called "camel case", because the capital letters look like the humps on a camel.

Creating instances of our new animal classes

With these classes defined, we can create new instances of them (new objects based on the classes), and call methods on them.

Just as with methods, Ruby lets us create instances of classes right in the same file where we declared them. You probably won't want to organize your code this way in larger applications, but since this is such a simple app right now, we can go ahead and create some new instances right below the class declarations.

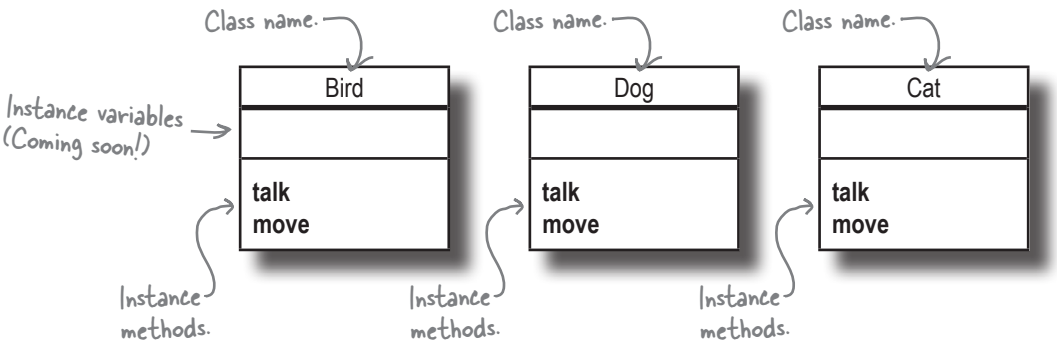


If we save all this to a file named `animals.rb`, then run `ruby animals.rb` at a command prompt, we'll see the output of our instance methods!

```
File Edit Window Help
$ ruby animals.rb
Flying to the tree.
Bark!
Chirp! Chirp!
Running to the house.
$
```

Updating our class diagram with instance methods

If we were to draw a diagram of our new classes, they'd look something like this:



At this point, instances of our classes have two instance methods (things they can *do*): `talk` and `move`. They don't have any instance variables (things they *know*) yet, however. We'll be looking at that next.

Code Magnets

A working Ruby program is scrambled up on the fridge. Some of the code snippets are in the correct places, but others have been moved around randomly. Can you rearrange the code snippets to make a working program that produces the output listed below?

```
class Blender
  def close_lid
  end

(speed)   .blend   ("high")
blender   blender   .close_lid
puts "Sealed tight!"   def   blend
puts "Spinning on #{speed} setting."   end

end

blender = Blender .new
```

Output

```
File Edit Window Help
Sealed tight!
Spinning on high setting.
```

Code Magnets Solution

A working Ruby program is scrambled up on the fridge. Some of the code snippets are in the correct places, but others have been moved around randomly. Can you rearrange the code snippets to make a working program that produces the output listed below?

```
class Blender
  def close_lid
    puts "Sealed tight!"
  end
  def blend (speed)
    puts "Spinning on #{speed} setting."
  end
end

blender = Blender.new
blender.close_lid
blender.blend ("high")
```

Output

```
File Edit Window Help
Sealed tight!
Spinning on high setting.
```

there are no Dumb Questions

Q: Can I call these new `move` and `talk` methods by themselves (without an object)?

A: Not from outside the class, no. Remember, the purpose of specifying a receiver is to tell Ruby which object a method is being called on. The `move` and `talk` methods are *instance methods*; it doesn't make sense to call them without stating which instance of the class you're calling them on. If you try, you'll get an error, like this:

```
move("food bowl")

undefined method `move' for
main:Object (NoMethodError)
```

Q: You say that we have to call the `new` method on a class to create an object. You also said back in chapter 1 that numbers and strings are objects. Why don't we have to call `new` to get a new number or string?

A: Creating new numbers and strings is something developers need to do so frequently that special shorthand notation is built right into the language: string and number *literals*.

```
new_string = "Hello!"
new_float = 4.2
```

Doing the same for other classes would require modifying the Ruby language itself, so most of them just rely on `new` to create new instances. (There are exceptions; we'll get to those in later chapters.)

Our objects don't "know" their names or ages!

The animal rescue's lead developer points out a couple details we forgot to address with our class-based solution:

We're supposed to see the animal's name when we call these methods! And where is the `report_age` method?

```
Flying to the tree.
Bark!
Chirp! Chirp!
Running to the house.
```

She has a point; we're missing a couple of features from the original program.

Let's start by re-adding the `name` parameter to the `talk` and `move` methods:

A name will have to be provided when we call these methods, like before.

```
class Bird
  def talk(name)
    puts "#{name} says Chirp! Chirp!"
  end
  def move(name, destination)
    puts "#{name} flies to the #{destination}."
  end
end

class Dog
  def talk(name)
    puts "#{name} says Bark!"
  end
  def move(name, destination)
    puts "#{name} runs to the #{destination}."
  end
end

class Cat
  def talk(name)
    puts "#{name} says Meow!"
  end
  def move(name, destination)
    puts "#{name} runs to the #{destination}."
  end
end
```

And like before, we'll use the names in the output.

Too many arguments (again)

Now that we've re-added the name parameter to the `talk` and `move` methods, we can once again pass in the animal's name to be printed.

```
dog = Dog.new
dog_name = "Lucy"
dog.talk(dog_name)
dog.move(dog_name, "fence")

cat = Cat.new
cat_name = "Fluffy"
cat.talk(cat_name)
cat.move(cat_name, "litter box")
```

```
Lucy says Bark!
Lucy runs to the fence.
Fluffy says Meow!
Fluffy runs to the litter box.
```

Come on. We already have a variable to hold the animal object. You really want us to pass a **second** variable with the animal's name everywhere? What a pain!

```
dog = Dog.new
dog_name = "Lucy"
cat = Cat.new
cat_name = "Fluffy"
```

Actually, we can do better. We can use instance variables to store data inside the object.

One of the key benefits of object-oriented programming is that it keeps data, and the methods that operate on that data, in the same place. Let's try storing the names *in* the animal objects so that we don't have to pass so many arguments to our instance methods.

Local variables live until the method ends

So far, we've been working with **local variables** - variables that are *local* to the current scope (usually the current method). When the current scope ends, local variables cease to exist, so they *won't* work for storing our animals' names, as you'll see below.

Here's a new version of the `Dog` class with an additional method, `make_up_name`. When we call `make_up_name`, it stores a name for the dog, for later access by the `talk` method.

```
class Dog

  def make_up_name
    name = "Sandy"
  end

  def talk
    puts "#{name} says Bark!"
  end

end
```

Store a name.

Attempt to access the stored name.

The moment we call the `talk` method, however, we get an error, saying the `name` variable doesn't exist:

```
dog = Dog.new
dog.make_up_name
dog.talk
```

Error

```
in `talk': undefined local variable or method `name' for #<Dog:0x007fa3188ae428>
```

What happened? We *did* define a `name` variable, back in the `make_up_name` method!

The problem, though, is that we used a *local* variable. Local variables live only as long as the method in which they were created. In this case, The `name` variable ceases to exist as soon as `make_up_name` ends.

```
class Dog

  def make_up_name
    name = "Sandy"
  end

  def talk
    puts "#{name} says Bark!"
  end

end
```

"name" drops out of scope as soon as the method ends.

This variable no longer exists here!

Trust us, the short life of local variables is a *good* thing. If *any* variable was accessible *anywhere* in your program, you'd be accidentally referencing the wrong variables *all the time*! Like most languages, Ruby limits the scope of variables in order to prevent this sort of mistake.

Just imagine if this local variable...

```
def alert_ceo
  message = "Sell your stock."
  email(ceo, message)
end

email(shareholders, message)
```

...were accessible here...

Whew! Close one.

Error

```
undefined local variable or method `message'
```

Instance variables live as long as the instance does

Any local variable we create disappears as soon as its scope ends. If that's true, though, how can we store a `Dog`'s name together with the object? We're going to need a new kind of variable.

An object can store data in **instance variables** - variables that are tied to a particular object instance. Data written to an object's instance variables stays with that object, getting removed from memory only when the object is removed.

An instance variable looks just like a regular variable, and follows all the same naming conventions. The only difference in syntax is that its name begins with an "at" symbol (`@`).

```
my_variable      @my_variable
```

Local variable **Instance variable**

Here's that `Dog` class again. It's identical to the previous one, except that we added two little `"@"` symbols to convert the *two* local variables to *one* instance variable.

```
class Dog

  def make_up_name
    @name = "Sandy"
  end

  def talk
    puts "#{@name} says Bark!"
  end

end
```

Store a value in an instance variable

Access the instance variable.

Now, we can make the exact same call to `talk` that we did before, and the code will work! The `@name` instance variable that we create in the `make_up_name` method is still accessible in the `talk` method.

```
dog = Dog.new
dog.make_up_name
dog.talk
```

```
Sandy says Bark!
```

Instance variables live as long as the instance does (cont.)

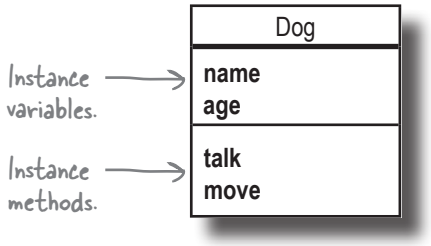
With instance variables at our disposal, it's easy to add the `move` and `report_age` methods back in, as well...

```
class Dog

  def make_up_name
    @name = "Sandy"
  end

  def talk
    puts "#{@name} says Bark!"
  end

  def move(destination)
    puts "#{@name} runs to the #{destination}."
  end

  def make_up_age
    @age = 5
  end

  def report_age
    puts "#{@name} is #{@age} years old."
  end

end

dog = Dog.new
dog.make_up_name
dog.move("yard")
dog.make_up_age
dog.report_age
```

Our new code!

```
Sandy runs to the yard.
Sandy is 5 years old.
```

And now that we have instance variables, we can finally fill in that hole in the class diagram for `Dog`!



That's true. Up next, we'll show you a way to set a dog's name and age to other values.

Encapsulation

Thanks to instance variables, we now have a way to store names and ages for our animals. But our `make_up_name` and `make_up_age` methods only allow us to use hard-coded values (we can't change them when the program's running). We need a way for our program to set any values we want.

```
class Dog

  def make_up_name
    @name = "Sandy"
  end

  def make_up_age
    @age = 5
  end
...
end
```

Code like this *won't* work, though:

```
fido = Dog.new
fido.@age = 3
```

Error

```
syntax error, unexpected tIVAR
```

Ruby never allows us to access instance variables directly from outside our class. This isn't due to some authoritarian agenda; it's to keep other programs and classes from modifying your instance variables willy-nilly.

Let's suppose that you *could* update instance variables directly. What's to prevent other portions of the program from setting the variables to invalid values?

This is invalid code!

```
fido = Dog.new
fido.@name = ""
fido.@age = -1
fido.report_age
```

If you COULD do that, the output would be...

```
is -1 years old.
```

Who is *how* old? This object's data is clearly invalid, and the user can see it in the program output!

Blank names and negative ages are just the start. Imagine someone accidentally replacing the value in an `Appointment` object's `@date` instance variable with a phone number. Or setting the `@sales_tax` on all their `Invoice` objects to zero. All kinds of things could go wrong!

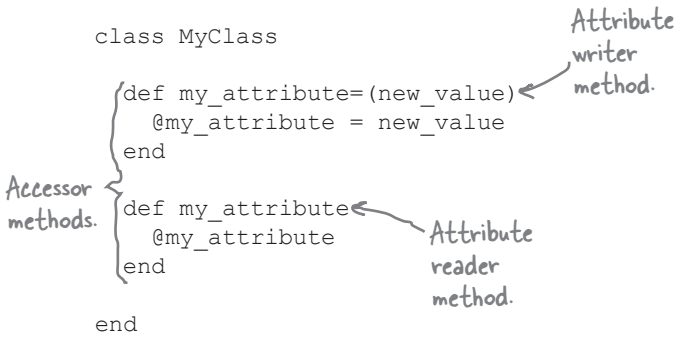
To help avoid exposing an object's data to malicious (or clumsy) users, most object-oriented languages encourage the concept of **encapsulation**: of preventing other parts of the program from directly accessing or changing an object's instance variables.

Attribute accessor methods

To encourage encapsulation and protect your instances from invalid data, Ruby doesn't allow you to access or change instance variables from outside the class. Instead, you can create **accessor methods**, which will write values to the instance variables and read them back out again for you. Once you're accessing your data through accessor methods, it's easy to extend those methods to *validate* your data—to reject any bad values that get passed in.

Ruby has two kinds of accessor methods: *attribute writers* and *attribute readers*. (An "attribute" is another name for a piece of data regarding an object.) Attribute *writer* methods *set* an instance variable, and attribute *reader* methods *get* the value of an instance variable back.

Here's a simple class with writer and reader methods for an attribute named `my_attribute`:



If we create a new instance of the above class... `my_instance = MyClass.new`

...we can set the attribute like this... `my_instance.my_attribute = "a value"`

...and read the attribute like this. `puts my_instance.my_attribute`

Accessor methods are just ordinary instance methods; we only refer to them as "accessor methods" because their primary purpose is to access an instance variable.

Look at the attribute reader method, for example; it's a perfectly ordinary method that simply returns the current value of `@my_attribute`.

Attribute accessor methods (cont.)

Like attribute *reader* methods, an attribute *writer* method is a perfectly ordinary instance method. We just call it an "attribute writer" method because the primary thing it does is to update an instance variable.

```
class MyClass

  def my_attribute=(new_value)
    @my_attribute = new_value
  end

  ...

end
```

Attribute writer method.

It may be a perfectly ordinary method, but *calls* to it are treated somewhat specially.

Remember that earlier in the chapter, we said that Ruby method names could end in "="? Ruby allows that equals-sign ending so that it can be used in the names of attribute writer methods.

```
def my_attribute=(new_value)
  ...
end
```

Part of the method name!

When Ruby sees something like this in your code:

```
my_instance.my_attribute = "a value"
```

…it gets translated into a call to the `my_attribute=` instance method. The value to the right of the "=" is passed as an argument to the method:

```
my_instance.my_attribute=("a value")
```

A method call!

The method argument.

The above code is valid Ruby, and you can try it yourself, if you like:

```
class MyClass
  def my_attribute=(new_value)
    @my_attribute = new_value
  end
  def my_attribute
    @my_attribute
  end
end

my_instance = MyClass.new
my_instance.my_attribute = "assigned via method call"
puts my_instance.my_attribute
my_instance.my_attribute=("same here")
puts my_instance.my_attribute
```

A call to "my_attribute=", disguised as assignment.

A call to "my_attribute=" that actually looks like one!

```
assigned via method call
same here
```

Conventional Wisdom

We only show this alternate way of calling attribute writer methods so that you can understand what's going on behind the scenes. In your actual Ruby programs, you should only use the assignment syntax!

Using accessor methods

Now we're ready to use what we've learned in the Fuzzy Friends application. As a first step, let's update the `Dog` class with methods that will let us read and write `@name` and `@age` instance variables. We'll also use `@name` and `@age` in the `report_age` method. We'll look at adding data validation later.

```
class Dog

  def name=(new_value)
    @name = new_value
  end

  def name
    @name
  end

  def age=(new_value)
    @age = new_value
  end

  def age
    @age
  end

  def report_age
    puts "#{@name} is #{@age} years old."
  end

end
```

Write a new value to @name

Read the value from @name

Write a new value to @age

Read the value from @age

With accessor methods in place, we can (indirectly) set and use the `@name` and `@age` instance variables from outside the `Dog` class!

```
fido = Dog.new
fido.name = "Fido"
fido.age = 2
rex = Dog.new
rex.name = "Rex"
rex.age = 3
fido.report_age
rex.report_age
```

Set @name for Fido.

Set @age for Fido.

Set @name for Rex.

Set @age for Rex.

```
Fido is 2 years old.
Rex is 3 years old.
```

Writing a reader and writer method by hand for each attribute can get tedious, though. Next, we'll look at an easier way...

Conventional Wisdom

The name of an attribute reader method should usually match the name of the instance variable it reads from (without the `@` symbol, of course).

```
def tail_length
  @tail_length
end
```

The same is true for attribute writer methods, but you should add an = symbol on to the end of the name.

```
def tail_length=(value)
  @tail_length = value
end
```

Attribute writers and readers

Creating this pair of accessor methods for an attribute is so common that Ruby offers us shortcuts - methods named: `attr_writer`, `attr_reader`, and `attr_accessor`. Calling these three methods within your class definition will automatically define new accessor methods for you:

Write this within your class definition...	...and Ruby will automatically define these methods:

`attr_writer :name`	`def name=(new_value)`
	`  @name = new_value`
	`end`

`attr_reader :name`	`def name`
	`  @name`
	`end`

`attr_accessor :name`	`def name=(new_value)`
	`  @name = new_value`
	`end`
	
	`def name`
	`  @name`
	`end`

Just like our old definition!

Just like our old definition!

Defines two methods at once!

All three of these methods can take multiple arguments, specifying multiple attributes that you want to define accessors for.

```
attr_accessor :name, :age
```

Defines FOUR methods at once!

Symbols

In case you're wondering, those `:name` and `:age` things are *symbols*. A Ruby **symbol** is a series of characters, like a string. Unlike a string, its value can't be changed later. That makes them perfect for use inside Ruby programs, to refer to anything whose name doesn't (usually) change, like a method. For example, if you call the method named `methods` on an object in `irb`, you'll see that it returns a list of symbols.

```
:hello
Ruby symbols. --> :over_easy
:east
```

```
> Object.new.methods
=> [:class, :singleton_class, :clone, ...]
```

A symbol reference in Ruby code always begins with a colon character (`:`). A symbol should be in all lower-case, with words separated by underscores, just like a variable name.

Attribute writers and readers in action

The Dog class currently devotes 12 lines of code to accessor methods. With the `attr_accessor` method, we can shrink that down to 1 line!

It will let us reduce our Dog class's size...

from this...

```
class Dog

  def name=(new_value)
    @name = new_value
  end

  def name
    @name
  end

  def age=(new_value)
    @age = new_value
  end

  def age
    @age
  end

  def report_age
    puts "#{@name} is #{@age} years old."
  end

  def talk
    puts "#{@name} says Bark!"
  end

  def move(destination)
    puts "#{@name} runs to the #{destination}."
  end

end
```

...to this!

```
class Dog

  attr_accessor :name, :age

  def report_age
    puts "#{@name} is #{@age} years old."
  end

  def talk
    puts "#{@name} says Bark!"
  end

  def move(destination)
    puts "#{@name} runs to the #{destination}."
  end

end
```

Equivalent!

Equivalent!

...how's *that* for efficiency? It's a lot easier to read, too!

Let's not forget why we're writing accessor methods in the first place, though. We need to *protect* our instance variables from invalid data. Right now, these methods don't do that... We'll see how to fix this in a few pages!

We haven't really gotten to play around with classes and objects much yet. Let's try another `irb` session. We'll load up a simple class so we can create some instances of it interactively.

Step One:

Save this class definition to a file, named "mage.rb".

```
class Mage

  attr_accessor :name, :spell

  def enchant(target)
    puts "#{@name} casts #{@spell} on #{target.name}!"
  end

end
```

Step Two:

From a system command prompt, navigate into the directory where you saved your file.

Step Three:

We want to be able to load Ruby files from the current directory, so as in the previous exercise, type the following to launch `irb`:

```
irb -I .
```

Step Four:

As before, we need to load the file with our saved Ruby code. Type this line:

```
require "mage"
```

Exercise (Continued)

With our `Mage` class's code loaded, you can try creating as many instances as you like, set their attributes, and have them cast spells at each other! Try the following for starters:

```
merlin = Mage.new
merlin.name = "Merlin"
morgana = Mage.new
morgana.name = "Morgana"
morgana.spell = "Shrink"
morgana.enchant(merlin)
```

Here's a sample session:

```
File Edit Window Help
$ irb -I .
irb(main):001:0> require 'mage'
 => true
irb(main):002:0> merlin = Mage.new
 => #<Mage:0x007fd432082308>
irb(main):003:0> merlin.name = "Merlin"
 => "Merlin"
irb(main):004:0> morgana = Mage.new
 => #<Mage:0x007fd43206b310>
irb(main):005:0> morgana.name = "Morgana"
 => "Morgana"
irb(main):006:0> morgana.spell = "Shrink"
 => "Shrink"
irb(main):007:0> morgana.enchant(merlin)
Morgana casts Shrink on Merlin!
 => nil
irb(main):008:0>
```

Who am I?

A bunch of Ruby concepts, in full costume, are playing a party game, "Who am I?" They'll give you a clue — you try to guess who they are based on what they say. Assume they always tell the truth about themselves. Fill in the blanks to the right to identify the attendees. (We've done the first one for you.)

Tonight's attendees: Any of the terms related to storing data within an object just might show up!

	Name
I stay within an object instance, and store data about that object.	instance variable
I'm another name for a piece of data about an object. I get stored in an instance variable.	
I store data within a method. As soon as the method returns, I disappear.	
I'm a kind of instance method. My main purpose is to read or write an instance variable.	
I'm used in Ruby programs to refer to things whose names don't change (like methods).	

Who am I? Solution

Name	
I stay within an object instance, and store data about that object.	instance variable
I'm another name for a piece of data about an object. I get stored in an instance variable.	attribute
I store data within a method. As soon as the method returns, I disappear.	local variable
I'm a kind of instance method. My main purpose is to read or write an instance variable.	accessor method
I'm used in Ruby programs to refer to things whose names don't change (like methods).	symbol

there are no Dumb Questions

Q: What's the difference between an accessor method and an instance method?

A: "Accessor method" is just a way of describing one particular *kind* of instance method, one whose primary purpose is to get or set the value of an instance variable. In all other respects, accessor methods are ordinary instance methods.

Q: I set up an instance variable outside an instance method, but it's not there when I try to access it. Why?

```
class Widget
  @size = 'large'
  def show_size
    puts "Size: #{@size}"
  end
end

widget = Widget.new
widget.show_size
```

Empty!

```
Size:
```

A: When you use instance variables outside of an instance method, you're actually creating an instance variable *on the class object*. (That's right, even classes are themselves objects in Ruby.)

While there are potential uses for this, they're beyond the scope of this book. For now, this is almost certainly not what you want. Instead, set up the instance variable within an instance method:

```
class Widget
  def set_size
    @size = 'large'
  end
  ...
end
```

Pool Puzzle

Your **job** is to take code snippets from the pool and place them into the blank lines in the code. **Don't** use the same snippet more than once, and you won't need to use all the snippets. Your **goal** is to make code that will run and produce the output shown.

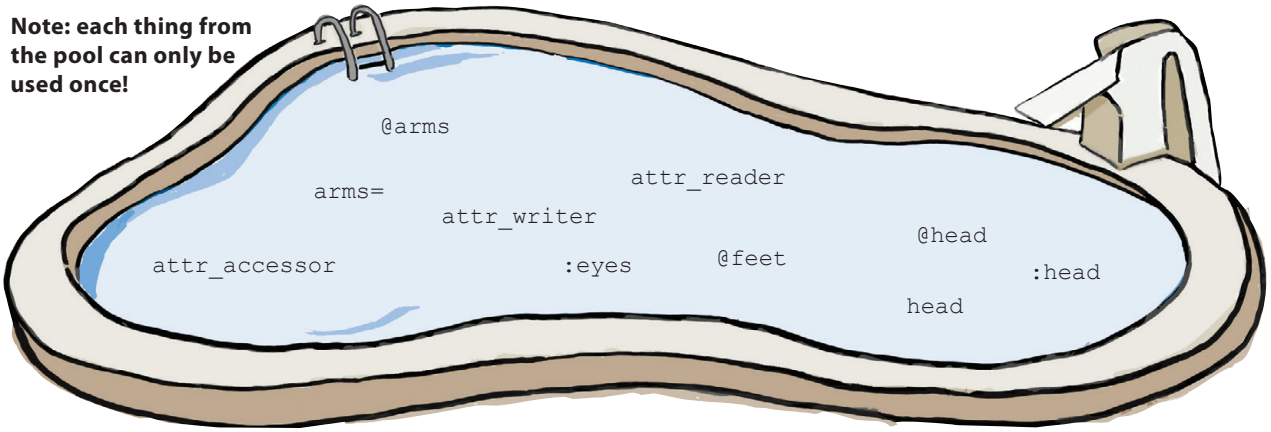
```
class Robot

  def ____
    @head
  end

  def _____(value)
    @arms = value
  end

  ___________ :legs, :body

  attr_writer _____

  _____________ :feet

  def assemble
    @legs = "RubyTek Walkers"
    @body = "BurlyBot Frame"
    _____ = "SuperAI 9000"
  end

  def diagnostic
    puts _____
    puts @eyes
  end

end
```

```
robot = Robot.new

robot.assemble

robot.arms = "MagGrip Claws"
robot.eyes = "X-Ray Scopes"
robot.feet = "MagGrip Boots"

puts robot.head
puts robot.legs
puts robot.body
puts robot.feet
robot.diagnostic
```

Output

```
File Edit Window Help
SuperAI 9000
RubyTek Walkers
BurlyBot Frame
MagGrip Boots
MagGrip Claws
X-Ray Scopes
```

Note: each thing from the pool can only be used once!



Pool Puzzle Solution

Your **job** is to take code snippets from the pool and place them into the blank lines in the code. **Don't** use the same snippet more than once, and you won't need to use all the snippets. Your **goal** is to make code that will run and produce the output shown.

```
class Robot

  def head
    @head
  end

  def arms=(value)
    @arms = value
  end

  attr_reader :legs, :body

  attr_writer :eyes

  attr_accessor :feet

  def assemble
    @legs = "RubyTek Walkers"
    @body = "BurlyBot Frame"
    @head = "SuperAI 9000"
  end

  def diagnostic
    puts @arms
    puts @eyes
  end

end
```

```
robot = Robot.new

robot.assemble

robot.arms = "MagGrip Claws"
robot.eyes = "X-Ray Scopes"
robot.feet = "MagGrip Boots"

puts robot.head
puts robot.legs
puts robot.body
puts robot.feet
robot.diagnostic
```

Output

```
File Edit Window Help Lasers
SuperAI 9000
RubyTek Walkers
BurlyBot Frame
MagGrip Boots
MagGrip Claws
X-Ray Scopes
```

Ensuring data is valid with accessors

Remember our scenario from a nightmare world where Ruby let programs access instance variables directly, and someone gave your `Dog` instances *blank* names and *negative* ages? Bad news: now that you've added attribute writer methods to your `Dog` class, they actually *can*!

```
joey = Dog.new
joey.name = ""
joey.age = -1
joey.report_age
```

```
 is -1 years old.
```

Don't panic! Those same writer methods are going to help us prevent this from happening in the future. We're going to add some simple data *validation* to the methods, which will give an error any time an invalid value is passed in.

Since `name=` and `age=` are just ordinary Ruby methods, adding the validation is really easy; we'll use ordinary `if` statements to look for an empty string (for `name=`) or a negative number (for `age=`). If we encounter an invalid value, we'll print an error message. Only if the value is valid will we actually set the `@name` or `@age` instance variables.

We only define the reader methods automatically, since we're defining writer methods ourselves.

```
class Dog

  attr_reader :name, :age

  def name=(value)
    if value == ""
      puts "Name can't be blank!"
    else
      @name = value
    end
  end

  def age=(value)
    if value < 0
      puts "An age of #{value} isn't valid!"
    else
      @age = value
    end
  end

  def report_age
    puts "#{@name} is #{@age} years old."
  end

end
```

If the name is blank, print an error message.

Set the instance variable only if the name is valid.

If the age is negative, print an error message.

Set the instance variable only if the age is valid.

Errors - the "emergency stop" button

So now, we get a warning if an invalid name or age are set. Great. But then the program goes right on to call `report_age` anyway, and the name and age are blank!

```
glitch = Dog.new
glitch.name = ""
glitch.age = -256
glitch.report_age
```

```
Name can't be blank!
An age of -256 isn't valid!
 is  years old.
```

Blank!

Instead of just *printing* a message, we need to deal with invalid parameters in the `name=` and `age=` accessor methods in a more meaningful way. Let's change the validation code in our `name=` and `age=` methods to Ruby's built-in `raise` method to report any errors.

```
raise "Something bad happened!"
```

That's `raise` as in "raise an issue". Your program is bringing a problem to your attention.

You call `raise` with a string describing what's wrong. When Ruby encounters the call, it stops what it's doing, and prints your error message. Since this program doesn't do anything to handle the error, it will exit immediately.

Using "raise" in our attribute writer methods

Since we're using `raise` in both of our writer methods, we don't need to use an `else` clause on the `if` statements. If the new value is invalid and the `raise` statement is executed, the program will halt. The statement that assigns to the instance variable will never be reached.

```
class Dog

  attr_reader :name, :age

  def name=(value)
    if value == ""
      raise "Name can't be blank!"
    end
    @name = value
  end

  def age=(value)
    if value < 0
      raise "An age of #{value} isn't valid!"
    end
    @age = value
  end

  def report_age
    puts "#{@name} is #{@age} years old."
  end

end
```

If "value" is invalid... → `if value == ""`

...execution will halt here. → `raise "Name can't be blank!"`

This statement won't be reached if "raise" is called. → `@name = value`

If "value" is invalid... → `if value < 0`

...execution will halt here. → `raise "An age of #{value} isn't valid!"`

This statement won't be reached if "raise" is called. → `@age = value`

Now, if a blank name is passed in to `name=`, Ruby will report an error, and the entire program will exit.

```
anonymous = Dog.new
anonymous.name = ""
```

Error →

```
in `name=': Name can't be blank! (RuntimeError)
```

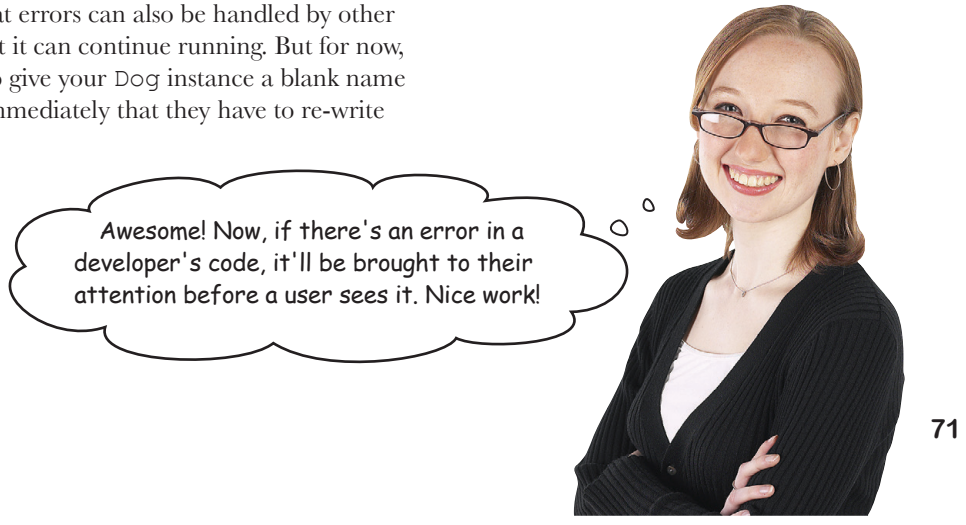
You'll get another error message if someone tries to set the age to a number less than zero.

```
joey = Dog.new
joey.age = -1
```

Error →

```
in `age=': An age of -1 isn't valid! (RuntimeError)
```

In a later chapter, we'll see that errors can also be handled by other parts of your program, so that it can continue running. But for now, naughty developers that try to give your `Dog` instance a blank name or a negative age will know immediately that they have to re-write their code.



Our complete Dog class

Here's a file with our complete Dog class, plus some code to create a Dog instance.

```
class Dog

  attr_reader :name, :age

  def name=(value)
    if value == ""
      raise "Name can't be blank!"
    end
    @name = value
  end

  def age=(value)
    if value < 0
      raise "An age of #{value} isn't valid!"
    end
    @age = value
  end

  def move(destination)
    puts "#{@name} runs to the #{destination}."
  end

  def talk
    puts "#{@name} says Bark!"
  end

  def report_age
    puts "#{@name} is #{@age} years old."
  end

end

dog = Dog.new
dog.name = "Daisy"
dog.age = 3
dog.report_age
dog.talk
dog.move("bed")
```

Sets up "name" and "age" attribute reader methods

Attribute writer method for "@name".

Data validation.

Attribute writer method for "@age".

Data validation.

Instance method.

Using an instance variable.

Instance method.

Using an instance variable.

Instance method.

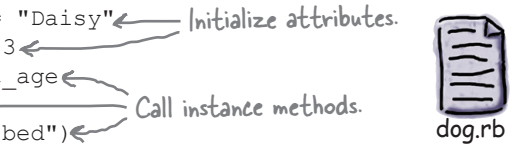
Using instance variables.

Create a new Dog instance.

Initialize attributes.

Call instance methods.

dog.rb



We have instance methods that act as *attribute accessors*, letting us get and set the contents of our instance variables.

```
puts dog.name
dog.age = 3
puts dog.age
```

```
Daisy
3
```

We have instance methods that let our dog object do things, like move, make noise, and report its age. The instance methods can make use of the data in the object's instance variables.

```
dog.report_age
dog.talk
dog.move("bed")
```

```
Daisy is 3 years old.
Daisy says Bark!
Daisy runs to the bed.
```

And we've set up our attribute writer methods to *validate* the data passed to them, raising an error if the values are invalid.

```
dog.name = ""
```

Error →

```
in `name=': Name
can't be blank!
(RuntimeError)
```

Do this!

Type the above code into a file named "dog.rb". Try adding more Dog instances! Then run ruby dog.rb from a command line.

Now, we just need to do the same for the Cat and Bird classes!

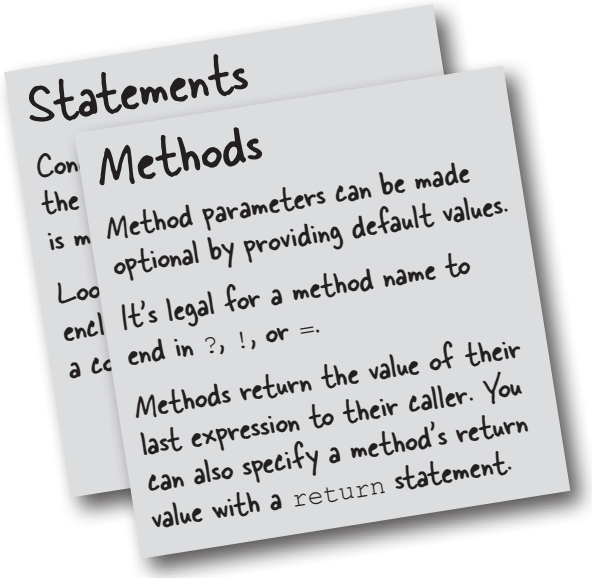
Not excited by the prospect of duplicating all that code? Don't worry! The next chapter is all about inheritance, which will make the task easy!

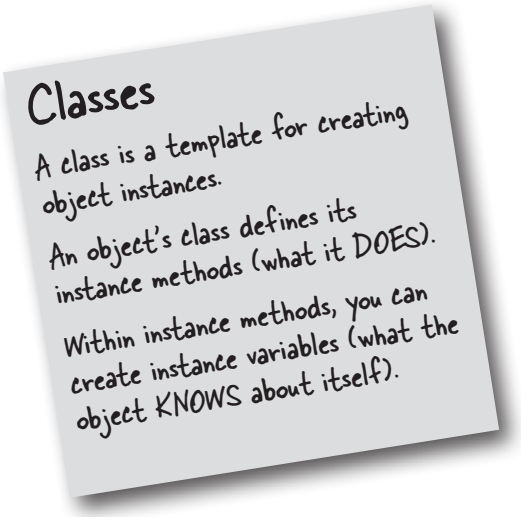
Your Ruby Toolbox

That's it for Chapter 2! You've added methods and classes to your tool box.

BULLET POINTS

- A method body consists of one or more Ruby statements that will be executed when the method is called.
- Parenthesis should be left off of a method definition if (and only if) you're not defining any parameters.
- If you don't specify a return value, methods will return the value of the last expression evaluated.
- Method definitions that appear within a class definition are treated as instance methods for that class.
- Outside a class definition, instance variables can only be accessed via accessor methods.
- You can call the `attr_writer`, `attr_reader`, and `attr_accessor` methods within your class definition as a shortcut for defining accessor methods.
- Accessor methods can be used to ensure data is valid before it's stored in instance variables.
- The `raise` method can be called to report an error in your program.





3 inheritance

Relying on Your Parents

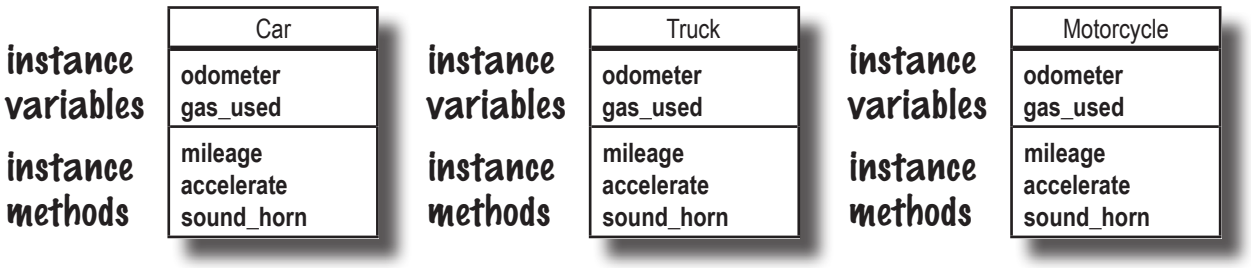
So much repetition! Your new classes representing the different types of vehicles and animals are awesome, it's true. But you're having to *copy instance methods from class to class*. And the copies are starting to fall out of sync - some are fine, and others have bugs. Weren't classes supposed to make code *easier* to maintain?

In this chapter, we'll learn how to use **inheritance** to let your classes *share* methods. Fewer copies means fewer maintenance headaches!

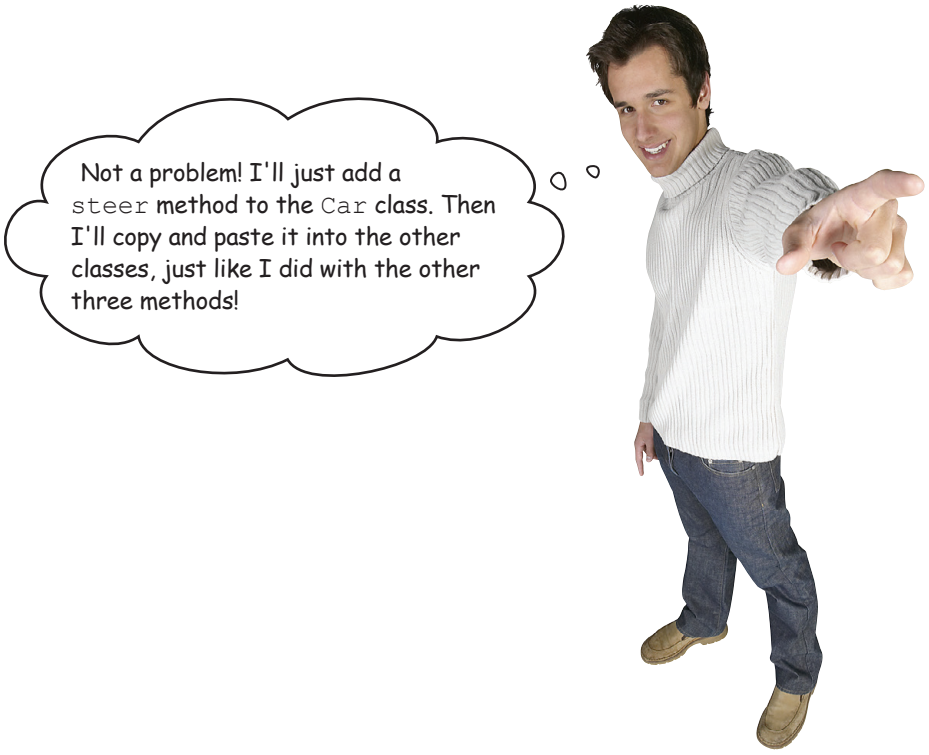
Copy, paste... Such a waste...

Back at Got-A-Motor, Inc., the development team wants to try this "object-oriented programming" thing out for themselves. They've converted their old virtual test drive app to use classes for each vehicle type. They have classes representing cars, trucks, and motorcycles.

Here's what their class structure looks like right now:



Thanks to customer demand, management has asked that steering be added to all vehicle types. Mike, Got-A-Motor's rookie developer, thinks he has this requirement covered.



Mike's code for the Virtual Test Drive classes

```
class Car

  attr_accessor :odometer
  attr_accessor :gas_used

  def mileage
    @odometer / @gas_used
  end

  def accelerate
    puts "Floor it!"
  end

  def sound_horn
    puts "Beep! Beep!"
  end

  def steer
    puts "Turn front 2 wheels."
  end

end
```

Copy!

```
class Truck

  attr_accessor :odometer
  attr_accessor :gas_used

  def mileage
    @odometer / @gas_used
  end

  def accelerate
    puts "Floor it!"
  end

  def sound_horn
    puts "Beep! Beep!"
  end

  def steer
    puts "Turn front 2 wheels."
  end

end
```

Paste!

```
class Motorcycle

  attr_accessor :odometer
  attr_accessor :gas_used

  def mileage
    @odometer / @gas_used
  end

  def accelerate
    puts "Floor it!"
  end

  def sound_horn
    puts "Beep! Beep!"
  end

  def steer
    puts "Turn front 2 wheels."
  end

end
```

Paste!

But Marcy, the team's experienced object-oriented developer, has some reservations about this approach.

Marcy is right; this is a maintenance nightmare waiting to happen. First, let's figure out how to address the duplication. Then we'll fix the `steer` instance method for `Motorcycle` objects.

Inheritance to the rescue!

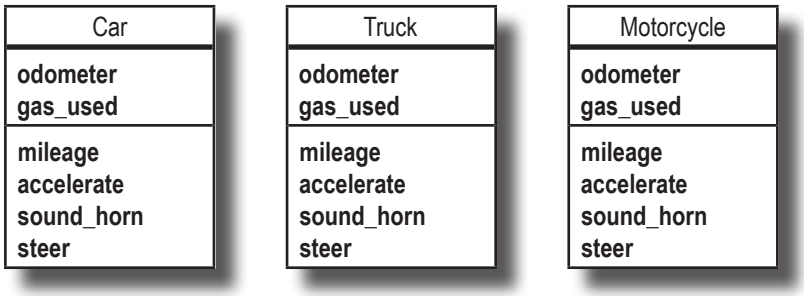
Fortunately, like most object-oriented languages, Ruby has the concept of **inheritance**, which allows classes to inherit methods from one another. If one class has some functionality, classes that inherit from it can get that functionality *automatically*.

Instead of repeating method definitions across many similar classes, inheritance lets you move the common methods to a single class. You can then specify that other classes inherit from this class. The class with the common methods is referred to as the **superclass**, and the classes that inherit those methods are known as **subclasses**.

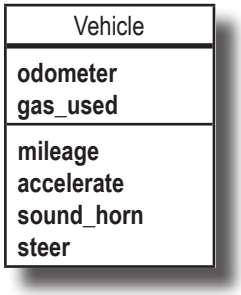
If a superclass has instance methods, then its subclasses automatically inherit those methods. You can get access to all the methods you need from the superclass, without having to duplicate the methods' code in each subclass.

Here's how we might use inheritance to get rid of the repetition in the virtual test drive app...

1. We see that the `Car`, `Truck`, and `Motorcycle` classes have several instance methods and attributes in common.

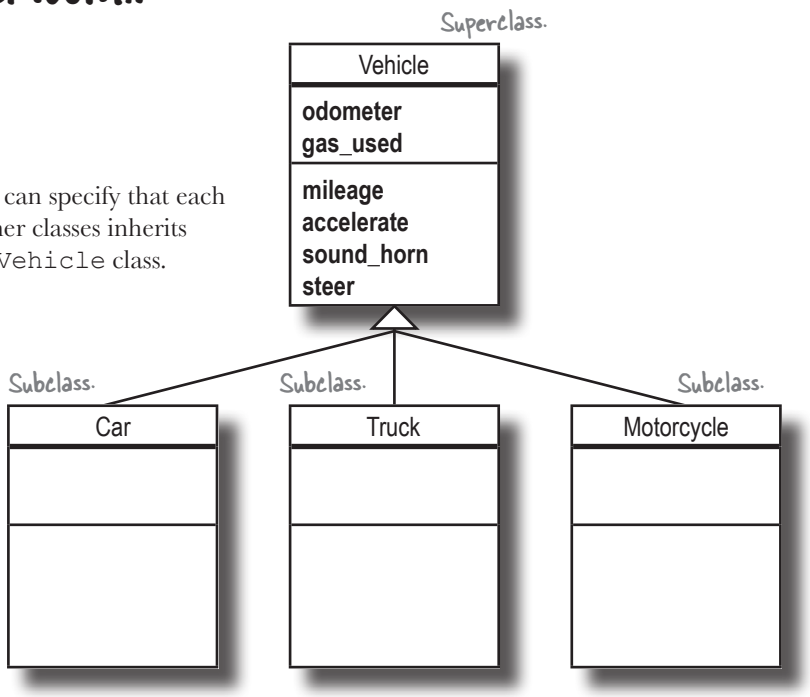


2. Each one of these classes is a type of vehicle. So we can create a new class, which we'll choose to call `Vehicle`, and move the common methods and attributes there.



Inheritance to the rescue! (cont.)

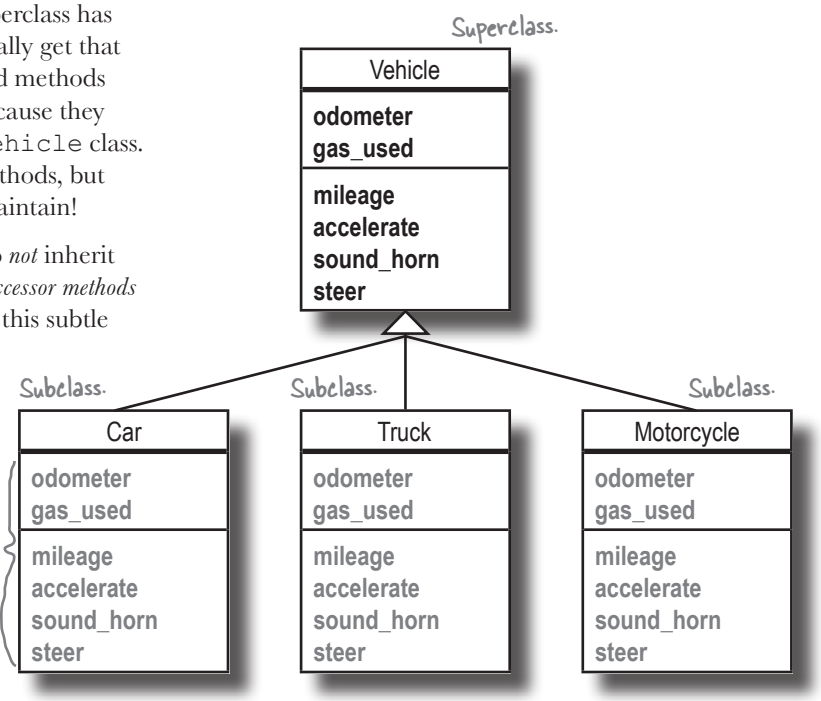
❸ Then, we can specify that each of the other classes inherits from the `Vehicle` class.



The `Vehicle` class is called the *superclass* of the other three classes. `Car`, `Truck`, and `Motorcycle` are called *subclasses* of `Vehicle`.

The subclasses *inherit* all the methods and attributes of the superclass. In other words, if the superclass has some functionality, its subclasses automatically get that functionality. We can remove the duplicated methods from `Car`, `Truck`, and `Motorcycle`, because they will automatically inherit them from the `Vehicle` class. All of the classes will still have the same methods, but there's only one copy of each method to maintain!

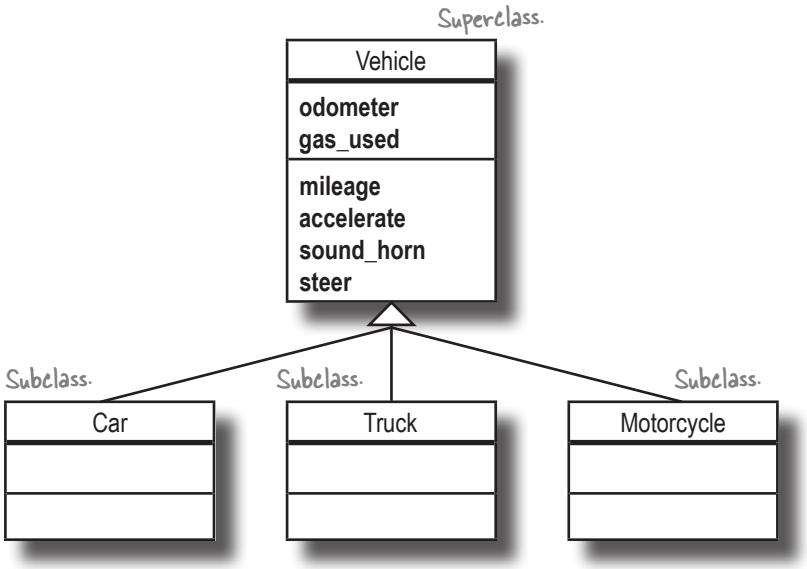
Note that in Ruby, subclasses technically do *not* inherit instance *variables*; they inherit the *attribute accessor methods* that create those variables. We'll talk about this subtle distinction in a few pages.



You can still call all these inherited methods and attribute accessors on instances of the subclasses, just as if the subclasses declared them directly!

Defining a superclass (requires nothing special)

To eliminate the repeated methods and attributes in our `Car`, `Truck`, and `Motorcycle` classes, Marcy has created this design. It moves the shared methods and attributes to a `Vehicle` *superclass*. `Car`, `Truck`, and `Motorcycle` are all *subclasses* of `Vehicle`, and they *inherit* all of `Vehicle`'s methods.



There's actually no special syntax to define a superclass in Ruby; it's just an ordinary class. (Most object-oriented languages are like this.)

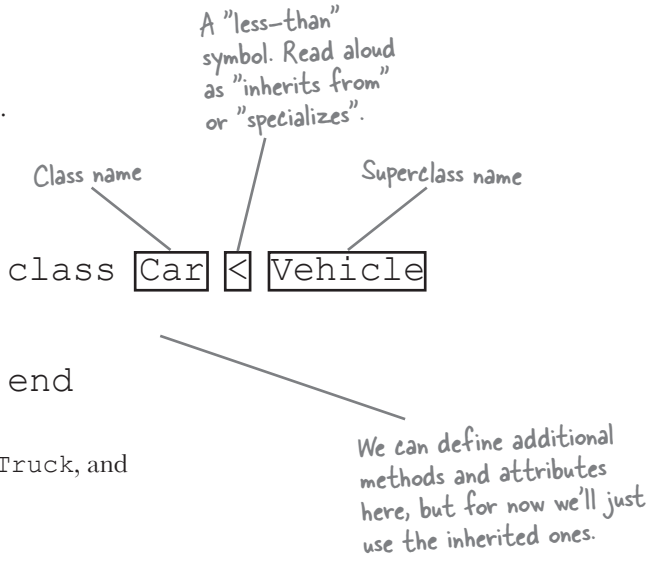
```
class Vehicle

  attr_accessor :odometer
  attr_accessor :gas_used

  def accelerate
    puts "Floor it!"
  end

  def sound_horn
    puts "Beep! Beep!"
  end

  def steer
    puts "Turn front 2 wheels."
  end

  def mileage
    return @odometer / @gas_used
  end

end
```

All attributes will be inherited when we declare a subclass.

So will all instance methods.

Defining a subclass (is really easy)

The syntax for subclasses isn't much more complicated. A subclass definition looks just like an ordinary class definition, except that you specify the superclass it will inherit from.



Ruby uses a less-than (<) symbol because the subclass is a *subset* of the superclass. (All cars are vehicles, but not all vehicles are cars.) You can think of the subclass as being *lesser than* the superclass.

So here's all we have to write in order to specify that `Car`, `Truck`, and `Motorcycle` are subclasses of `Vehicle`:

```
class Car < Vehicle
end

class Truck < Vehicle
end

class Motorcycle < Vehicle
end
```

As soon as you define them as subclasses, `Car`, `Truck`, and `Motorcycle` inherit all the attributes and instance methods of `Vehicle`. Even though the subclasses don't contain any code of their own, any instances we create will have access to all of the superclass's functionality!

```
truck = Truck.new
truck.accelerate
truck.steer

car = Car.new
car.odometer = 11432
car.gas_used = 366

puts "Lifetime MPG:"
puts car.mileage
```

```
Floor it!
Turn front 2 wheels.
Lifetime MPG:
31
```

Our `Car`, `Truck`, and `Motorcycle` classes have all the same functionality they used to, without all the duplicated code. Using inheritance will save us a lot of maintenance headaches!

Adding methods to subclasses

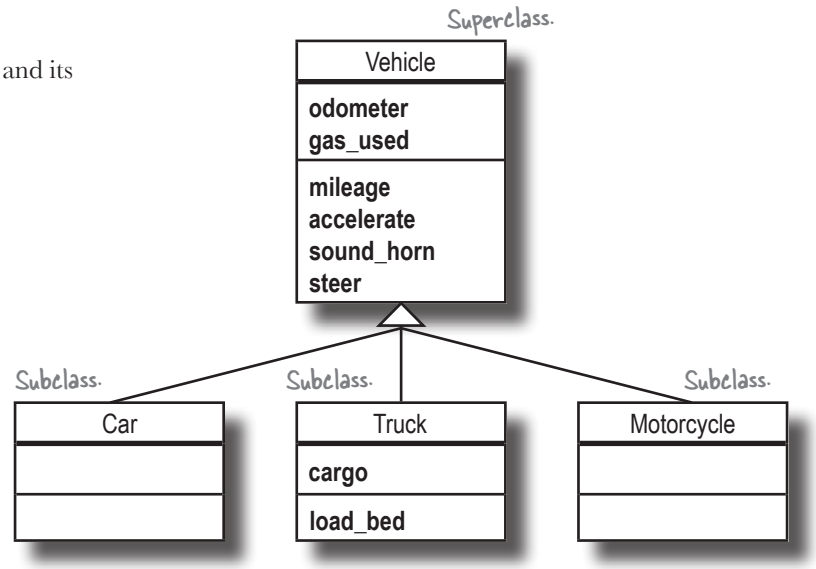
As it stands, there's no difference between our `Truck` class and the `Car` or `Motorcycle` classes. But what good is a truck, if not for hauling cargo? Got-A-Motor wants to add a `load_bed` method for `Truck` instances, as well as a `cargo` attribute to access the bed contents.

It won't do to add `cargo` and `load_bed` to the `Vehicle` class, though. The `Truck` class would inherit them, yes, but so would `Car` and `Motorcycle`. Cars and motorcycles don't *have* cargo beds!

So instead, we can define a `cargo` attribute and a `load_bed` method *directly on the* `Truck` *class*.

```
class Truck < Vehicle

  attr_accessor :cargo

  def load_bed(contents)
    puts "Securing #{contents} in the truck bed."
    @cargo = contents
  end

end
```

If we were to draw the diagram of `Vehicle` and its subclasses again now, it would look like this:



With these code changes in place, we can create a new `Truck` instance, then load and access its cargo.

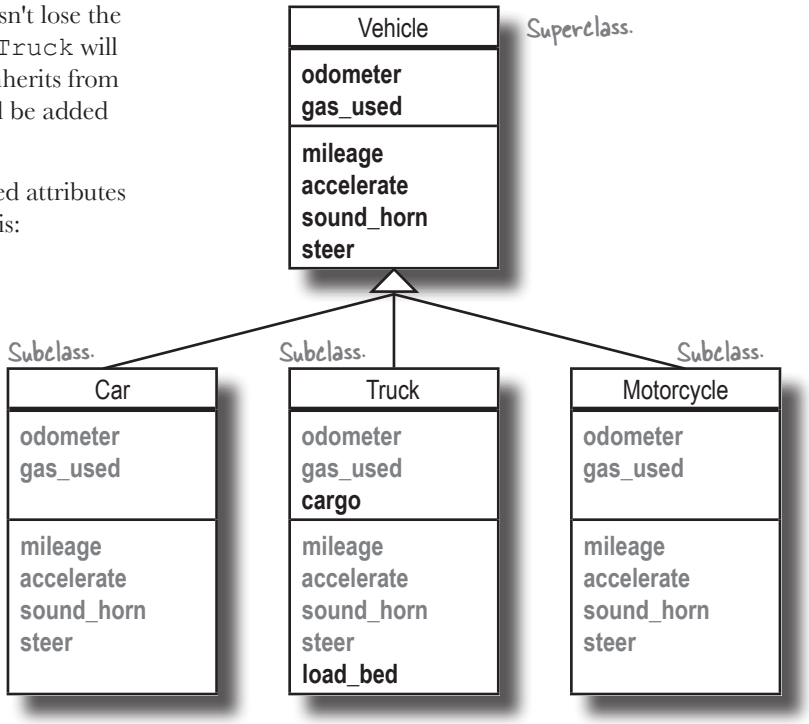
```
truck = Truck.new
truck.load_bed("259 bouncy balls")
puts "The truck is carrying #{truck.cargo}."
```

```
Securing 259 bouncy balls in the truck bed.
The truck is carrying 259 bouncy balls.
```

Subclasses keep inherited methods alongside new ones

A subclass that defines its own methods doesn't lose the ones it inherits from its superclass, though. `Truck` will still have all the attributes and methods it inherits from `Vehicle`, but `cargo` and `load_bed` will be added alongside them.

If we re-drew our diagram with the inherited attributes and methods included, it would look like this:



So in addition to the `cargo` attribute and `load_bed` method, our `Truck` instance can also access all the old inherited attributes and methods it used to.

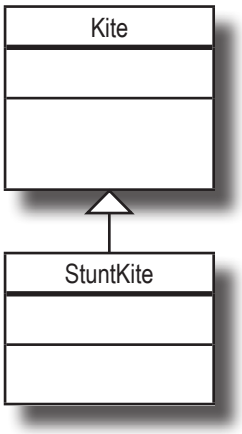
```
truck.odometer = 11432
truck.gas_used = 366
puts "Average MPG:"
puts truck.mileage
```

```
Average MPG:
31
```

So, a subclass inherits instance methods from its superclass. Does it also inherit instance variables?

Surprisingly, the answer is no! Bear with us, we need to take a 2-page detour to explain...

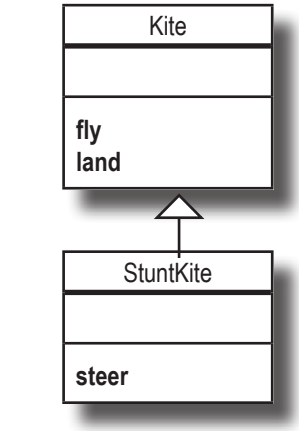
Sharpen your pencil



We need two classes, `Kite` and `StuntKite`. Both `Kite` and `StuntKite` instances will need `fly` and `land` methods. **Only** `StuntKite` instances should have a `steer` method, however. Place the class names and method definitions at the appropriate places in this class diagram.

fly **steer** **land**

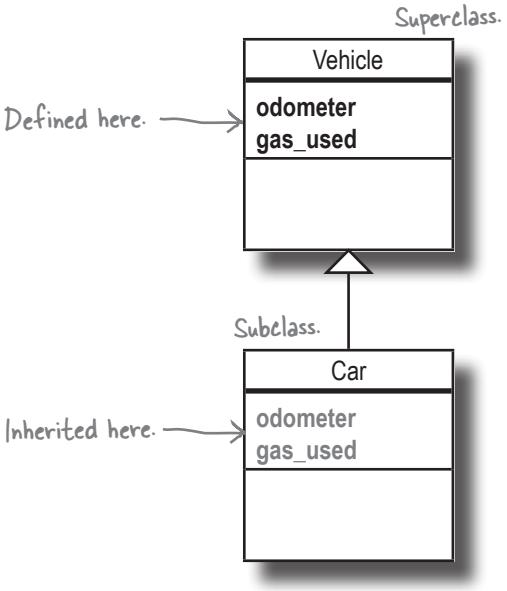
Sharpen your pencil Solution



Instance variables are NOT inherited!

A Ruby Detour

It's easy to form the (incorrect) impression that instance variables are inherited from the superclass. Let's take another look at our class diagram, focusing on the attributes of the `Vehicle` and `Car` classes...



All Ruby objects have a method called `instance_variables` that we can call to see what instance variables are defined for that object. So if we create a new `Car` and assign values to its `odometer` and `gas_used` attributes...

```
car = Car.new
car.odometer = 22914
car.gas_used = 728
```

...then call the `instance_variables` method to see what instance variables it has...

```
puts car.instance_variables
```

```
@odometer
@gas_used
```

...it sure *looks* like the `@odometer` and `@gas_used` instance variables got inherited from the `Vehicle` superclass.

But what *actually* gets inherited are the `odometer` and `gas_used` *instance methods* (the attribute accessor methods). These methods just *happen* to assign to instance variables named `@odometer` and `@gas_used` (because that's the Ruby convention). The variables are *created* on the `car` object *at the time a value is assigned to them*.

The only thing that Ruby subclasses ever inherit are instance methods. Instance variables usually come along for the ride, though.

Instance variables are NOT inherited! (cont.)

To prove that it's the `odometer` and `gas_used` instance *methods* that are inherited from `Vehicle`, and not the `@odometer` and `@gas_used` instance *variables*, let's try breaking the convention. We'll override the `Car` subclass's attribute accessor methods to write to and read from totally different instance variables.

```
class Car < Vehicle
  def odometer=(new_value)
    @banana = new_value
  end
  def odometer
    @banana
  end
  def gas_used=(new_value)
    @apple = new_value
  end
  def gas_used
    @apple
  end
end
```

Now, we can run the very same code to create a `Car` instance:

```
car = Car.new
car.odometer = 22914
car.gas_used = 728
```

...But the `odometer=` and `gas_used=` methods will assign to different instance variables:

```
puts car.instance_variables
```

```
@banana
@apple
```

Note the complete absence of @odometer and @gas_used!

So, why worry about the fact that instance variables aren't inherited? As long as you follow the convention of ensuring your instance variable names match your accessor method names, you won't have to. But if you deviate from that convention, look out! You may find that a subclass can interfere with it's superclass's functionality by *overwriting* its instance variables.

```
class Person
  def name=(new_value)
    @storage = new_value
  end
  def name
    @storage
  end
end
```

NOT a good choice of variable names.

```
class Employee < Person
  def salary=(new_value)
    @storage = new_value
  end
  def salary
    @storage
  end
end
```

...But we'll use the same name here. (Hey, why not?)

When we try to actually use the `Employee` subclass, we'll find that any time we assign to the `salary` attribute, we overwrite the `name` attribute, because both are using the *same* instance variable.

```
employee = Employee.new
employee.name = "John Smith"
employee.salary = 80000
puts employee.name
```

```
80000
```

What an unusual name!

What's the lesson here? Ensure you're using sensible variable names that match your attribute accessor names. That simple practice should be enough to keep you out of trouble!

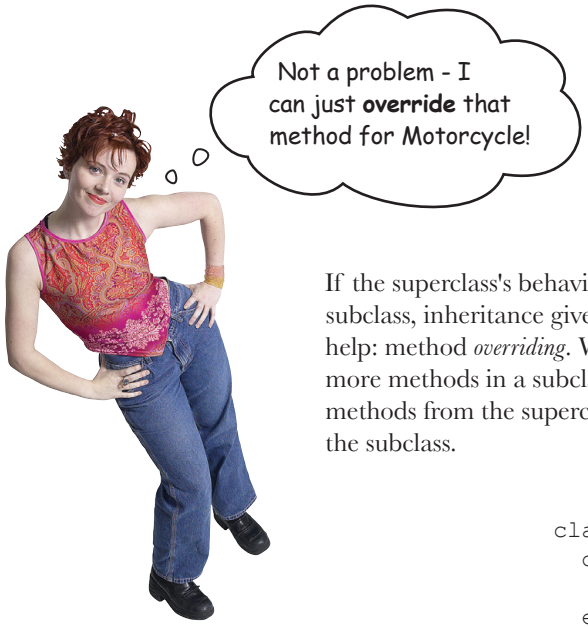
Overriding methods

Marcy, the team's experienced object-oriented developer, has re-written our `Car`, `Truck`, and `Motorcycle` classes as subclasses of `Vehicle`. They don't need any methods or attributes of their own - they inherit everything from the superclass! But Mike points out an issue with this design...


```
motorcycle = Motorcycle.new
motorcycle.steer
```

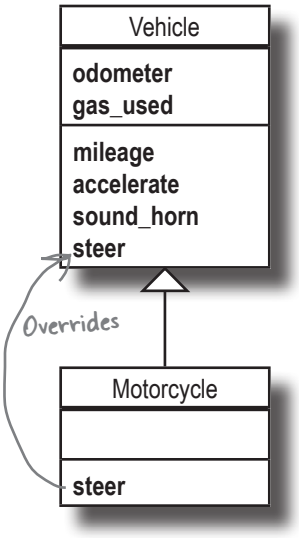
```
Turn front 2 wheels.
```

One wheel too many, for a motorcycle!



If the superclass's behavior isn't what you need in the subclass, inheritance gives you another mechanism to help: method *overriding*. When you **override** one or more methods in a subclass, you replace the inherited methods from the superclass with methods specific to the subclass.

```
class Motorcycle < Vehicle
  def steer
    puts "Turn front wheel."
  end
end
```



Now, if we call `steer` on a `Motorcycle` instance, we'll get the overriding method. That is, we'll get the version of `steer` defined within the `Motorcycle` class, not the version from `Vehicle`.

```
motorcycle.steer
```

```
Turn front wheel.
```

Overriding methods (continued)

If we call any other methods on a `Motorcycle` instance, though, we'll get the inherited method.

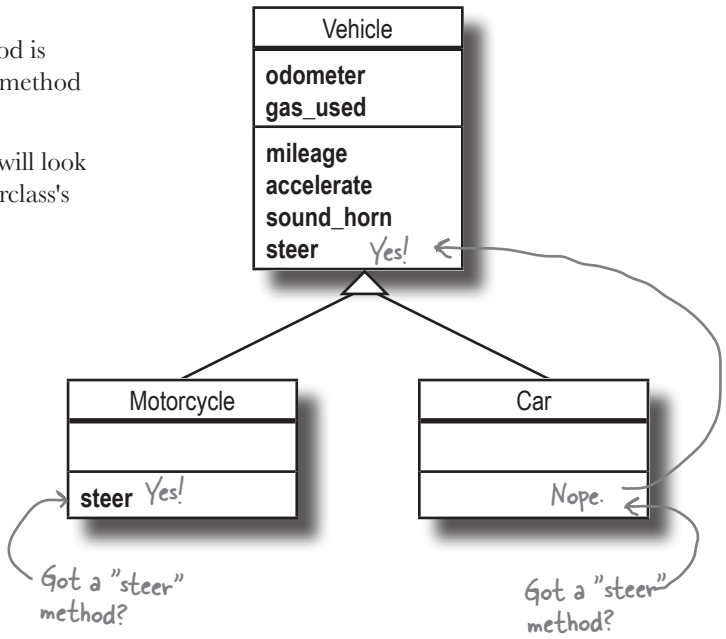
```
motorcycle.accelerate
```

```
Floor it!
```

How does this work?

If Ruby sees that the requested method is defined on a subclass, it will call that method and stop there.

But if the method's not found, Ruby will look for it on the superclass, then the superclass's superclass, and so on, up the chain.



Everything seems to be working again! When changes are needed, they can be made in the `Vehicle` class, and they'll propagate to the subclasses automatically, meaning everyone gets the benefit of updates sooner. If a subclass needs specialized behavior, it can simply override the method it inherited from the superclass.

Nice work cleaning up Got-A-Motor's code! Up next, we have a couple exercises where you can practice working with superclasses and subclasses.

Then, we'll take another look at the Fuzzy Friends code. They still have a lot of redundant methods in their application's classes. We'll see if inheritance and method overriding can help them out.

there are no Dumb Questions

Q: Can you have more than one level of inheritance? That is, can a subclass have its own subclasses?

A: Yes! If you need to override methods on some of your subclass's instances, but not others, you might consider making a subclass of the subclass.

```
class Car < Vehicle
end

class DragRacer < Car
  def accelerate
    puts "Inject nitrous!"
  end
end
```

Don't overdo it, though! This kind of design can rapidly become very complex. Ruby doesn't place a limit on the number of levels of inheritance, but most Ruby developers don't go more than one or two levels deep.

Q: You said that if a method is called on an instance of a class and Ruby doesn't find the method, it will look on the superclass, then the superclass's superclass... What happens if it runs out of superclasses without finding the method?

A: After searching the last superclass, Ruby gives up the search. That's when you get one of those "`undefined method`" errors we've been seeing.

```
Car.new.fly
```

```
undefined method
`fly' for
#<Car:0x007ffec48c>
```

Q: When designing an inheritance hierarchy, which should I design first, the subclass or the superclass?

A: Either! You might not even realize you need to use inheritance until after you've started coding your application.

When you discover that two related classes need similar or identical methods, though, just make those classes into subclasses of a new superclass. Then move those shared methods into the superclass. There: you've designed the subclasses first.

Likewise, when you discover that only some instances of a class are using a method, create a new subclass of the existing class, and move the method there. You've just designed the superclass first!

Code Magnets

A Ruby program is all scrambled up on the fridge. Can you reconstruct the code snippets to make a working superclass and subclass, so the sample code below can execute and produce the given output?

```
class Camera
class DigitalCamera < Camera
  def load
  def load
  def take_picture
    puts "Winding film."
    puts "Triggering shutter."
  end
  def load
    puts "Inserting memory card."
    puts "Triggering shutter."
  end
end
```

Sample code:

```
camera = Camera.new
camera.load
camera.take_picture

camera2 = DigitalCamera.new
camera2.load
camera2.take_picture
```

Output:

```
File Edit Window Help
Winding film.
Triggering shutter.
Inserting memory card.
Triggering shutter.
```

WHAT'S MY PURPOSE?

Match each of the concepts on the left to a definition on the right.

Subclass	Replaces a method inherited from a superclass with new functionality.
Overriding	Allows a single method or attribute to be shared by multiple classes.
Inheritance	A class that holds the code for methods that are shared by one or more other classes.
Superclass	A class that inherits one or more methods or attributes from a superclass.

Code Magnets Solution

A Ruby program is all scrambled up on the fridge. Can you reconstruct the code snippets to make a working superclass and subclass, so the sample code below can execute and produce the given output?

```
class Camera
  def take_picture
    puts "Triggering shutter."
  end
  def load
    puts "Winding film."
  end
end
```

```
class DigitalCamera < Camera
  def load
    puts "Inserting memory card."
  end
end
```

Sample code:

```
camera = Camera.new
camera.load
camera.take_picture

camera2 = DigitalCamera.new
camera2.load
camera2.take_picture
```

Output:

```
File Edit Window Help
Winding film.
Triggering shutter.
Inserting memory card.
Triggering shutter.
```

WHAT'S MY PURPOSE? SOLUTION

Match each of the concepts on the left to a definition on the right.

Subclass	A class that inherits one or more methods or attributes from a superclass.
Overriding	Replaces a method inherited from a superclass with new functionality.
Inheritance	Allows a single method or attribute to be shared by multiple classes.
Superclass	A class that holds the code for methods that are shared by one or more other classes.

Bringing our animal classes up to date with inheritance

Remember the Fuzzy Friends virtual storybook application from last chapter? We did a lot of excellent work on the `Dog` class. We added `name` and `age` attribute accessor methods (with validation), and updated the `talk`, `move`, and `report_age` methods to use the `@name` and `@age` instance variables.

Here's a recap of the code we have so far:

Creates methods to get current values of @name and @age.

We create our own attribute writer methods, so we can check that the new values are valid.

Other instance methods for our Dog objects.

```
class Dog

  attr_reader :name, :age

  def name=(value)
    if value == ""
      raise "Name can't be blank!"
    end
    @name = value
  end

  def age=(value)
    if value < 0
      raise "An age of #{value} isn't valid!"
    end
    @age = value
  end

  def talk
    puts "#{@name} says Bark!"
  end

  def move(destination)
    puts "#{@name} runs to the #{destination}."
  end

  def report_age
    puts "#{@name} is #{@age} years old."
  end

end
```

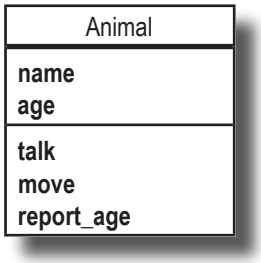
The `Bird` and `Cat` classes have been completely left behind, however, even though they need almost identical functionality.

Let's use this new concept of inheritance to create a design that will bring all our classes up to date at once (and keep them updated in the future).

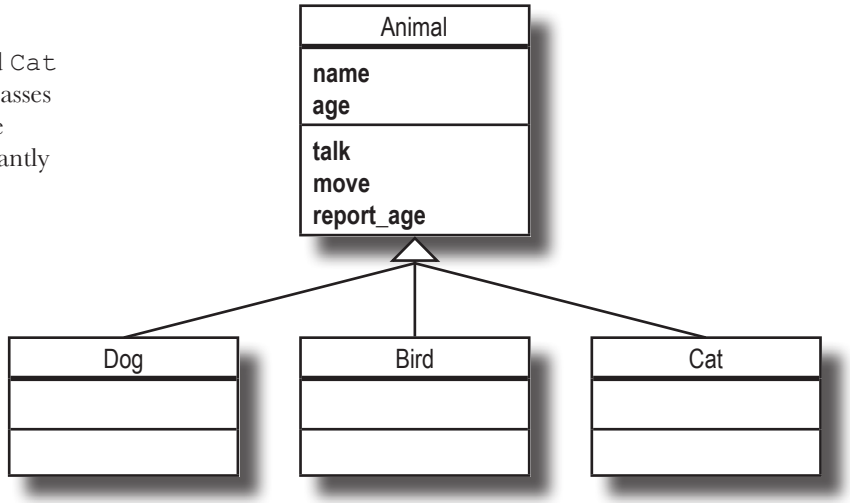
Designing the animal class hierarchy

We've added lots of new functionality to our `Dog` class, and now we want it in the `Cat` and `Bird` classes as well...

We want all the classes to have `name` and `age` attributes, as well as `talk`, `move`, and `report_age` methods. Let's move all of these attributes and methods up to a new class, which we'll call `Animal`.



Then, we'll declare that `Dog`, `Bird`, and `Cat` are *subclasses* of `Animal`. All three subclasses will inherit all the attributes and instance methods from their superclass. We'll instantly be caught up!



Code for the Animal class and its subclasses

Here's code for the `Animal` superclass, with all the old methods from `Dog` moved into it…

```
class Animal

  attr_reader :name, :age

  def name=(value)
    if value == ""
      raise "Name can't be blank!"
    end
    @name = value
  end

  def age=(value)
    if value < 0
      raise "An age of #{value} isn't valid!"
    end
    @age = value
  end

  def talk
    puts "#{@name} says Bark!"
  end

  def move(destination)
    puts "#{@name} runs to the #{destination}."
  end

  def report_age
    puts "#{@name} is #{@age} years old."
  end

end
```

The exact same code that was in the Dog class!

And here are the other classes, rewritten as subclasses of `Animal`.

```
class Dog < Animal
end

class Bird < Animal
end

class Cat < Animal
end
```

We don't have to write any methods here; these classes will inherit all the methods from the Animal class above!

Overriding a method in the Animal subclasses

With our Dog, Bird, and Cat classes re-written as subclasses of Animal, they don't need any methods or attributes of their own - they inherit everything from the superclass!

```
whiskers = Cat.new("Whiskers")
fido = Dog.new("Fido")
polly = Bird.new("Polly")

polly.age = 2
polly.report_age
fido.move("yard")
whiskers.talk
```

```
Polly is 2 years old.
Fido runs to the yard.
Whiskers says Bark!
```

Wait... Whiskers is a Cat...

Looks good, except for one problem... our Cat instance is barking.

The subclasses inherited this method from Animal:

```
def talk
  puts "#{@name} says Bark!"
end
```

That's appropriate behavior for a Dog, but not so much for a Cat or a Bird.

```
whiskers = Cat.new("Whiskers")
polly = Bird.new("Polly")

whiskers.talk
polly.talk
```

```
Whiskers says Bark!
Polly says Bark!
```

This code will override the talk method that was inherited from Animal:

```
class Cat < Animal
  def talk
    puts "#{@name} says Meow!"
  end
end

class Bird < Animal
  def talk
    puts "#{@name} says Chirp! Chirp!"
  end
end
```

Overrides the inherited method.

Overrides the inherited method.

Now, when you call talk on Cat or Bird instances, you'll get the overridden methods.

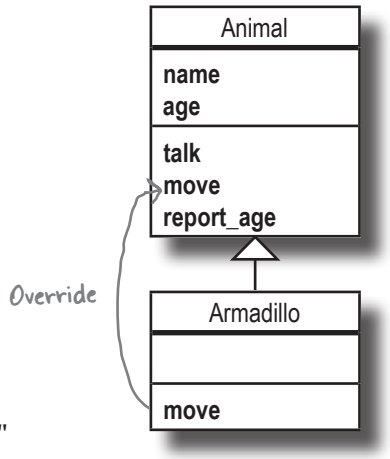
```
whiskers.talk
polly.talk
```

```
Whiskers says Meow!
Polly says Chirp! Chirp!
```

We need to get at the overridden method!

Next up, Fuzzy Friends wants to add armadillos to their interactive storybook. (Yeah, the little anteater-like critters that can roll into an armored ball to protect themselves from predators and overly-playful dogs.) We can simply add `Armadillo` as a subclass of `Animal`.

There's a catch, though; before they can run anywhere, they have to unroll.The `move` method will have to be overridden to reflect this fact.




```
class Animal
  ...
  def move(destination)
    puts "#{@name} runs to the #{destination}."
  end
  ...
end
```

The method we're overriding.

```
class Armadillo < Animal

  def move(destination)
    puts "#{@name} unrolls!"
    puts "#{@name} runs to the #{destination}."
  end

end
```

Our subclass.

Overrides the "move" method from the superclass.

The new functionality.

This code is duplicated from the superclass's method. (OK, it's just one line, but in a real-world app there would be many more!)

This works, but it's unfortunate that we have to replicate the code from the `move` method of the `Animal` class.

What if we could override the `move` method with new code, *and* still harness the code from the superclass? Ruby has a mechanism to do just that…

The "super" keyword

When you use the `super` keyword within a method, it makes a call to a method of the same name on the superclass.

```
class Person

  def greeting
    puts "Hello!"
  end

end


class Friend < Person

  def greeting
    super
    puts "Glad to see you!"
  end

end
```

If we make a call to the *overriding* method on the *subclass*, we'll see that the `super` keyword makes a call to the *overridden* method on the *superclass*:

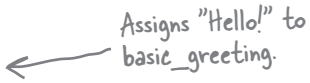
```
Friend.new.greeting
```

```
Hello!
Glad to see you!
```

The `super` keyword works like an ordinary method call in almost every respect.

For example, the superclass method's return value becomes the value of the `super` expression:

```
class Person

  def greeting
    "Hello!"
  end

end

class Friend < Person

  def greeting
    basic_greeting = super
    "#{basic_greeting} Glad to see you!"
  end

end

puts Friend.new.greeting
```




```
Hello! Glad to see you!
```

The "super" keyword (continued)

Another way in which using the `super` keyword is like a regular method call: you can pass it arguments, and those arguments will be passed to the superclass's method.

```
class Person

  def greet_by_name(name)
    "Hello, #{name}!"
  end

end

class Friend < Person

  def greet_by_name(name)
    basic_greeting = super(name)
    "#{basic_greeting} Glad to see you!"
  end

end

puts Friend.new.greet_by_name("Meghan")
```

Includes the argument in the method call.

```
Hello, Meghan! Glad to see you!
```

But here's a way that `super` *differs* from a regular method call: if you leave the arguments *off*, the superclass method will automatically be called with the same arguments that were passed to the subclass method.

```
class Friend < Person

  def greet_by_name(name)
    basic_greeting = super
    "#{basic_greeting} Glad to see you!"
  end

end

puts Friend.new.greet_by_name("Bert")
```

Friend's greet_by_name method has to be called with a "name" argument...

So the "name" argument will be forwarded on to Person's greet_by_name method as well.

```
Hello, Bert! Glad to see you!
```

Watch it!

The calls `super` and `super()` are not the same.

By itself, `super` calls the overridden method with the same arguments the overriding method received. But `super()` calls the overridden method with no arguments, even if the overriding method did receive arguments.

A super-powered subclass

Now, let's use our new understanding of `super` to eliminate a little duplicated code from the `move` method in our `Armadillo` class.

Here's the method we're inheriting from the `Animal` superclass:

```
class Animal
  ...
  def move(destination)
    puts "#{@name} runs to the #{destination}."
  end
  ...
end
```

Here's that duplicated line.

And here's the overridden version in the `Armadillo` subclass:

```
class Armadillo < Animal

  def move(destination)
    puts "#{@name} unrolls!"
    puts "#{@name} runs to the #{destination}."
  end

end
```

We can replace the duplicated code in the subclass's `move` method with a call to `super`, and rely on the superclass's `move` method to provide that functionality.

Here, we explicitly pass on the `destination` parameter for `Animal`'s `move` method to use:

```
class Armadillo < Animal

  def move(destination)
    puts "#{@name} unrolls!"
    super(destination)
  end

end
```

Explicitly specify the argument...

OR...

But we could instead leave off the arguments to `super`, and allow the `destination` parameter to be forwarded to the superclass's `move` method automatically:

```
class Armadillo < Animal

  def move(destination)
    puts "#{@name} unrolls!"
    super
  end

end
```

Auto-forward the same argument(s) "move" was called with.

Either way, the code still works great!

```
dillon = Armadillo.new
dillon.name = "Dillon"
dillon.move("burrow")
```

```
Dillon unrolls!
Dillon runs to the burrow.
```

Your mastery of class inheritance has wrung the repetition out of your code like water from a sponge. And your co-workers will thank you - less code means less bugs! Great job!

Below you'll find code for three Ruby classes. The code snippets on the right use those classes, either directly or through inheritance. Fill in the blanks below each snippet with what you think its output will be. Don't forget to take method overriding and the "super" keyword into account!

(We've filled in the first one for you.)

```
class Robot

  attr_accessor :name

  def activate
    puts "#{@name} is powering up"
  end

  def move(destination)
    puts "#{@name} walks to #{destination}"
  end

end

class TankBot < Robot

  attr_accessor :weapon

  def attack
    puts "#{@name} fires #{@weapon}"
  end

  def move(destination)
    puts "#{@name} rolls to #{destination}"
  end

end

class SolarBot < Robot

  def activate
    puts "#{@name} deploys solar panel"
    super
  end

end
```

Your answers:

```
tank = TankBot.new
tank.name = "Hugo"
tank.weapon = "laser"
tank.activate
tank.move("test dummy")
tank.attack
```

Hugo is powering up

.....

.....

.....

```
sunny = SolarBot.new
sunny.name = "Sunny"
sunny.activate
sunny.move("tanning bed")
```

.....

.....

.....

Below you'll find code for three Ruby classes. The code snippets on the right use those classes, either directly or through inheritance. Fill in the blanks below each snippet with what you think its output will be. Don't forget to take method overriding and the "super" keyword into account!

```
class Robot

  attr_accessor :name

  def activate
    puts "#{@name} is powering up"
  end

  def move(destination)
    puts "#{@name} walks to #{destination}"
  end

end

class TankBot < Robot

  attr_accessor :weapon

  def attack
    puts "#{@name} fires #{@weapon}"
  end

  def move(destination)
    puts "#{@name} rolls to #{destination}"
  end

end

class SolarBot < Robot

  def activate
    puts "#{@name} deploys solar panel"
    super
  end

end
```

```
tank = TankBot.new
tank.name = "Hugo"
tank.weapon = "laser"
tank.activate
tank.move("test dummy")
tank.attack
```

Hugo is powering up

Hugo rolls to test dummy

Hugo fires laser

```
sunny = SolarBot.new
sunny.name = "Sunny"
sunny.activate
sunny.move("tanning bed")
```

Sunny deploys solar panel

Sunny is powering up

Sunny walks to tanning bed

Difficulties displaying Dogs

Let's make one more improvement to our `Dog` class, before we declare it finished. Right now, if we pass a `Dog` instance to the `print` or `puts` methods, the output isn't too useful:

```
lucy = Dog.new
lucy.name = "Lucy"
lucy.age = 4

rex = Dog.new
rex.name = "Rex"
rex.age = 2

puts lucy, rex
```

The output we get:

```
#<Dog:0x007fb2b50c4468>
#<Dog:0x007fb2b3902000>
```

We can tell that they're `Dog` objects, but beyond that it's very hard to tell one `Dog` from another. It would be far nicer if we got output like this:

```
Lucy the dog, age 4
Rex the dog, age 2
```

The output we WISH we had...

When you pass an object to the `puts` method, Ruby calls the `to_s` instance method on it to convert it to a string for printing. We can call `to_s` explicitly, and get the same result:

```
puts lucy.to_s, rex.to_s
```

```
#<Dog:0x007fb2b50c4468>
#<Dog:0x007fb2b3902000>
```

Now, here's a question: where did that `to_s` instance method come from?

Indeed, where did *most* of these instance methods on `Dog` objects come from? If you call the method named `methods` on a `Dog` instance, only the first few instance methods will look familiar...

```
puts rex.methods
```

```
name
age
name=
age=
talk
move
report_age
eql?
hash
class
clone
to_s
inspect
methods
object_id
...
```

These are inherited from Animal...

But where did these come from?

There are more than we have room to print!

Instance methods named `clone`, `hash`, `inspect`... We didn't define them ourselves; they're not on the `Dog` class. They weren't inherited from the `Animal` superclass, either.

But - and here's the part you may find surprising - they *were* inherited from *somewhere*.

The Object class

Where could our `Dog` instances have inherited all these instance methods from? We don't define them in the `Animal` superclass. And we didn't specify a superclass for `Animal`...

```
class Dog < Animal
end

class Animal
  ...
end
```

The superclass for Dog is Animal.

No superclass specified!

Ruby classes have a `superclass` method that you can call to get their superclass. The result of using it on `Dog` isn't suprising:

```
puts Dog.superclass
```

```
Animal
```

...But what happens if we call `superclass` on `Animal`?

```
puts Animal.superclass
```

```
Object
```

Woah! Where did *that* come from?

When you define a new class, Ruby implicitly sets a class called `Object` as its superclass (unless you specify a superclass yourself).

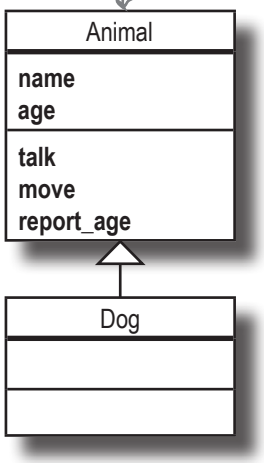
So writing this:

```
class Animal
  ...
end
```

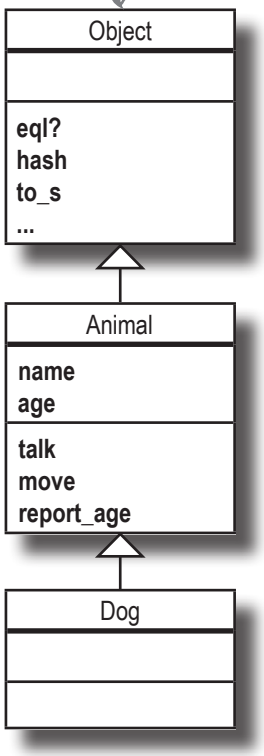
...is equivalent to writing this:

```
class Animal < Object
  ...
end
```

The inheritance diagram for Dog (that we've seen so far):



The actual inheritance diagram for Dog:



Why everything inherits from the Object class

If you don't explicitly specify a superclass for a class you define, Ruby implicitly sets a class named `Object` as the superclass...

```
class Animal < Object
  ...
end

class Dog < Animal
end
```

Implicitly inserted by Ruby.

Inherits from Animal, which means it inherits from Object!

Even if you *do* specify a superclass for your class, that superclass probably inherits from `Object`. That means almost every Ruby object, directly or indirectly, has `Object` as a superclass!

Ruby does this because the `Object` class defines dozens of useful methods that almost all Ruby objects need. This includes a lot of the methods that we've been calling on objects so far:

- The `to_s` method converts an object to a string for printing
- The `inspect` method converts an object to a debug string
- The `class` method tells you which class an object is an instance of
- The `methods` method tells you what instance methods an object has
- The `instance_variables` method gives you a list of an object's instance variables

...And there are many others. The methods inherited from the `Object` class are fundamental to the way Ruby works with objects.

We hope you've found this little tangent informative, but it doesn't help us with our original problem: our `Dog` objects are still printing in a gibberish format.

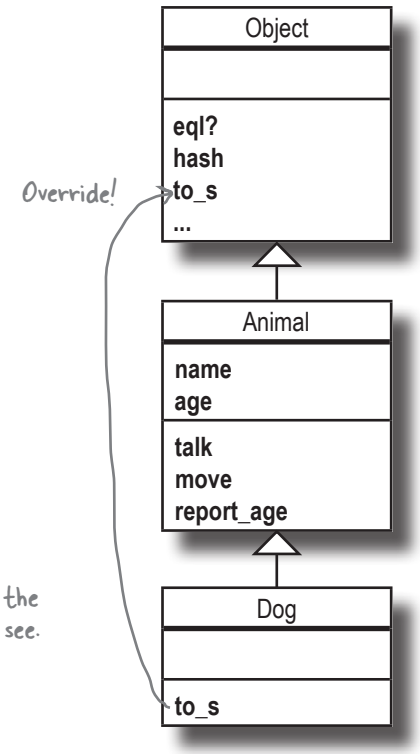
Or *does* it?

Overriding the inherited method

We specified that the superclass of the `Dog` class is the `Animal` class. And we learned that because we *didn't* specify a superclass for `Animal`, Ruby automatically set the `Object` class as its superclass.

That means that `Animal` instances inherit a `to_s` method from `Object`. `Dog` instances, in turn, inherit `to_s` from `Animal`. When we pass a `Dog` object to `puts` or `print`, its `to_s` method is called, to convert it to a string.

Do you see where we're headed? If the `to_s` method is the source of the gibberish strings being printed for `Dog` instances, and `to_s` is an *inherited* method, all we have to do is *override* `to_s` *on the* `Dog` *class*!




```
class Dog < Animal

  def to_s
    "#{@name} the dog, age #{age}"
  end

end
```

This return value is the format we'd like to see.

Are you ready? Let's try it.

```
lucy = Dog.new
lucy.name = "Lucy"
lucy.age = 4

rex = Dog.new
rex.name = "Rex"
rex.age = 2

puts lucy.to_s, rex.to_s
```

```
Lucy the dog, age 4
Rex the dog, age 2
```

It works! No more "#<Dog:0x007fb2b50c4468>". This is actually readable!

One more tweak: the `to_s` method is already called when printing objects, so we can leave that off:

```
puts lucy, rex
```

```
Lucy the dog, age 4
Rex the dog, age 2
```

This new output format will make debugging the virtual storybook much easier. And you've gained a key insight into how Ruby objects work - inheritance plays a vital role!

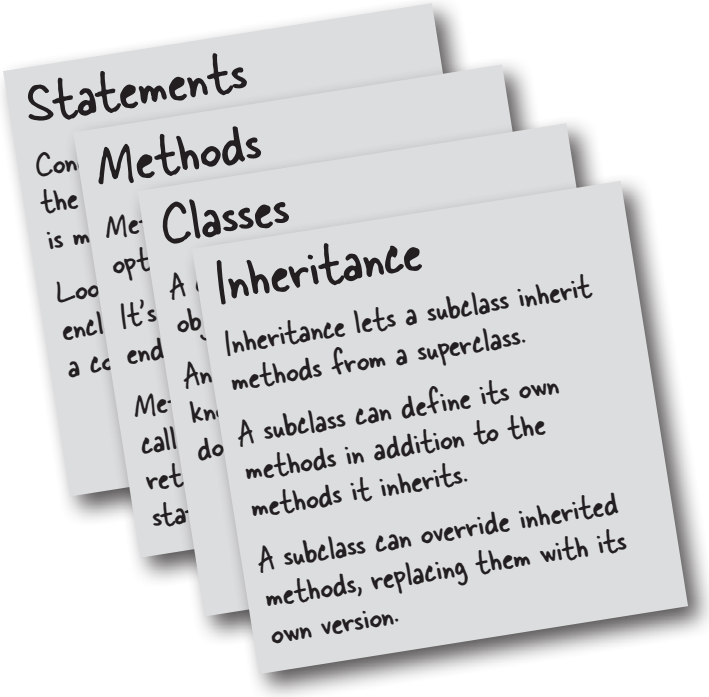
there are no Dumb Questions

Q: **I tried this code in `irb` instead of using the `ruby` command. After I override `to_s`, if I type `lucy = Dog.new` into `irb`, I still see something like "#<Dog:0x007fb2b50c4468>". Why don't I see the dog's name and age?**

A: The values that `irb` shows you are the result of calling `inspect` on an object, not `to_s`. You won't see the results of `to_s` until you set the name and age, and pass the object to `puts`.

Your Ruby Toolbox

That's it for Chapter 3! You've added inheritance to your tool box.



BULLET POINTS

- Any ordinary Ruby class can be used as a superclass.
- To define a subclass, simply specify a superclass in the class definition.
- Instance variables are *not* inherited from a superclass, but the methods that create and access instance variables *are* inherited.
- The `super` keyword can be used within a subclass method to call the overridden method of the same name on the superclass.
- If you don't specify arguments to the `super` keyword, it takes all arguments that the subclass method was called with, and passes them on to the superclass method.
- The expression value of the `super` keyword is the return value of the superclass method it calls.
- When defining a class, Ruby implicitly sets the `Object` class as the superclass, unless you specify one.
- Almost every Ruby object has instance methods from the `Object` class, inherited either directly, or through another superclass.
- The `to_s`, `methods`, `instance_variables`, and `class` methods are all inherited from the `Object` class.

4 initializing instances

Off to a Great Start

Right now, your class is a time bomb. Every instance you create starts out as a clean slate. If you call certain instance methods before adding data, an error will be raised that will bring your whole program to a screeching halt.

We're going to show you a couple ways to create objects that are safe to use right away. We'll start with the `initialize` method, which lets you pass in a bunch of arguments to set up an object's data *at the time you create it*. Then we'll show you how to write **class methods**, which you can use to create and set up an object even **more** easily.

Payroll at Chargemore

You've been tasked with creating a payroll system for Chargemore, a new chain of department stores. They need a system that will print pay stubs for their employees.

Chargemore employees are paid for two-week pay periods. Some employees are paid a two-week portion of their annual salary, and some are paid for the number of hours they work within a two-week period. For starters, though, we're just going to focus on the salaried employees.

A pay stub needs to include the following information:

- The employee name
- The amount of pay an employee received during a two-week pay period

So… here's what the system will need to *know* for each employee:

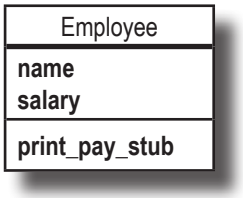
- Employee name
- Employee salary

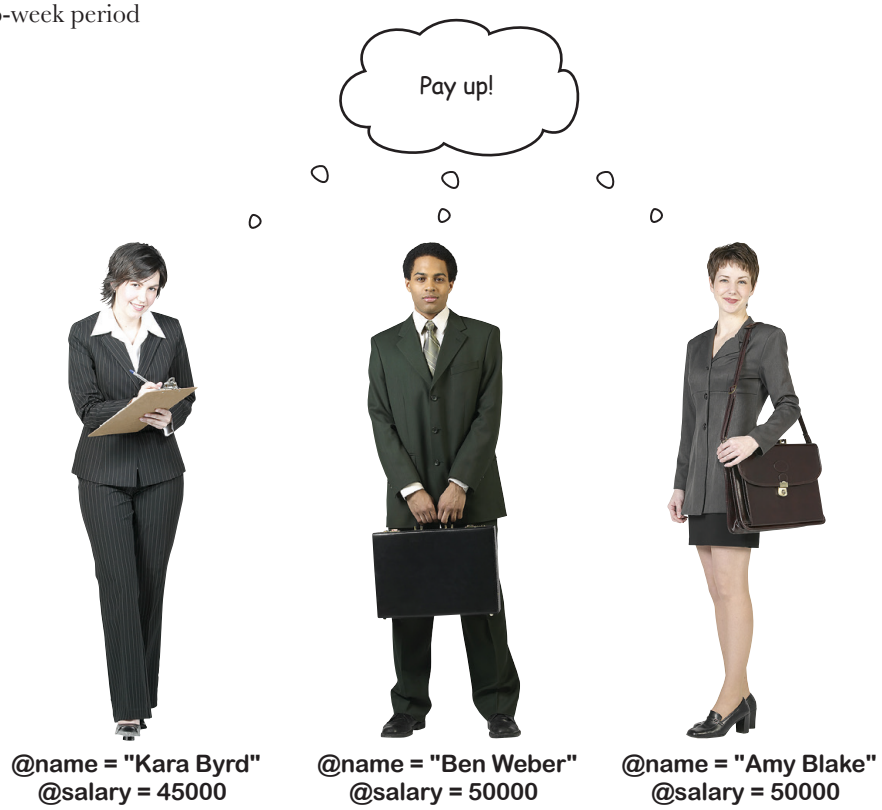
And here's what it will need to *do*:

- Calculate and print pay for a two-week period

This sounds like the ideal place to create an `Employee` class! Let's try it, using the same techniques that we covered back in Chapter 2.

We'll set up attribute reader methods for `@name` and `@salary` instance variables, then add writer methods (with validation). Then we'll add a `print_pay_stub` instance method that prints the employee's name, and their pay for the period.





An Employee class

Here's some code to implement our `Employee` class...

```
class Employee

  attr_reader :name, :salary

  def name=(name)
    if name == ""
      raise "Name can't be blank!"
    end
    @name = name
  end

  def salary=(salary)
    if salary < 0
      raise "A salary of #{salary} isn't valid!"
    end
    @salary = salary
  end

  def print_pay_stub
    puts "Name: #{@name}"
    pay_for_period = (@salary / 365) * 14
    puts "Pay This Period: $#{pay_for_period}"
  end

end
```

We need to create attribute writer methods manually, so we can validate the data. We can create reader methods automatically, though.

Report an error if the name is blank.

Store the name in an instance variable.

Report an error if the salary is negative.

Store the salary in an instance variable.

Print the employee name.

Calculate a 14-day portion of the employee's salary.

Print the amount paid.

(Yes, we realize that this doesn't account for leap years and holidays and a host of other things that real payroll apps must consider. But we wanted a `print_pay_stub` method that fits on one page.)

Creating new Employee instances

Now that we've defined an `Employee` class, we can create new instances, and assign to their `name` and `salary` attributes.

```
amy = Employee.new
amy.name = "Amy Blake"
amy.salary = 50000
```

Thanks to validation code in our `name=` method, we have protection against the accidental assignment of blank names.

```
kara = Employee.new
kara.name = ""
```

Error: → `in name=: Name can't be blank! (RuntimeError)`

Our `salary=` method has validation to ensure negative numbers aren't assigned as a salary.

```
ben = Employee.new
ben.salary = -246
```

Error: → `in salary=: A salary of -246 isn't valid! (RuntimeError)`

And when an `Employee` instance is properly set up, we can use the stored name and salary to print a summary of the employee's pay period.

```
amy.print_pay_stub
```

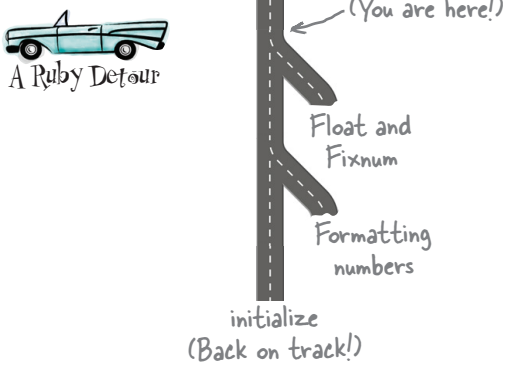
```
Name: Amy Blake
Pay This Period: $1904
```

← Close, but where are the cents?

Hmmm… It's typical to display two decimal places when showing currency, though. And did that calculation really come out to an even dollar amount?

Before we go on to perfect our `Employee` class, it looks like we have a bug to fix. And that will require us to go on a couple brief detours. (But you'll learn some number formatting skills that you'll need later, promise!)

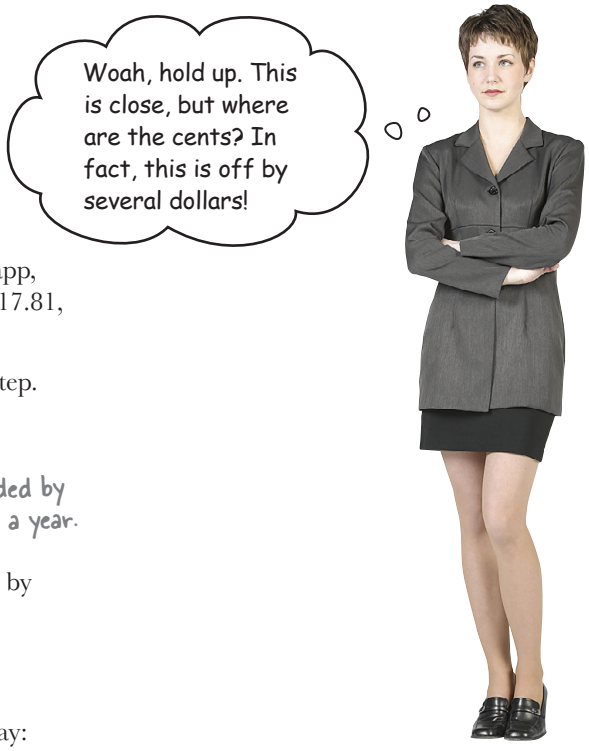
1. Our employee pay is getting its decimal places chopped off. To fix this, we'll need to look at the difference between Ruby's `Float` and `Fixnum` numeric classes.
2. We don't want to display too *many* decimal places, either, so we'll need to look at the `format` method to format our numbers properly.



A division problem

We're working to make the perfect `Employee` class to help us calculate payroll for the Chargemore department store. But there's a little detail we have to take care of, first…

```
Name: Amy Blake
Pay This Period: $1904
```



That's true. Doing the math on paper (or launching a calculator app, if that's your thing) can confirm that Amy should be earning $1917.81, rounded to the nearest cent. So where did that other $13.81 go?

To find out, let's launch `irb` and do the math ourselves, step by step.

First, let's calculate a day's pay.

In irb:

```
>> 50000 / 365
=> 136
```

← Annual salary, divided by number of days in a year.

That's nearly a dollar a day missing, compared to doing the math by hand:

50,000 ÷ 365 = 136.9863...

This error is then compounded when we calculate *fourteen* days' pay:

```
>> 136 * 14
=> 1904
```

Compare that to the answer we'd get if we multiplied the *full* daily pay...

136.9863 x 14 = 1917.8082...

So, we're nearly $14 off. Multiply *that* by many paychecks and many employees, and you've got yourself an angry workforce. We're going to have to fix this, and soon...

Division with Ruby's Fixnum class

The result of our Ruby expression to calculate 2 weeks of an employee's pay doesn't match up with doing the math by hand...

```
>> 50000 / 365 * 14
=> 1904
```

50,000 ÷ 365 x 14 = 1917.8082...

The problem here is that when dividing instances of the `Fixnum` class (a Ruby class that represents integers), Ruby rounds fractional numbers *down* to the nearest whole number.

```
>> 1 / 2
=> 0
```

It rounds the number because `Fixnum` instances aren't *meant* to store numbers with decimal places. They're intended for use in places where only whole numbers make sense, like counting employees in a department or the number of items in a shopping cart. When you create a `Fixnum`, you're telling Ruby: "I expect to only be working with whole numbers here. If anyone does math with you that results in a fraction, I want you to throw those pesky decimal places away."

How can we know whether we're working with Fixnums? We can call the `class` instance method on them. (Remember we talked about the `Object` class back in Chapter 3? The `class` method is one of the instance methods inherited from `Object`.)

```
>> salary = 50000
=> 50000
>> salary.class
=> Fixnum
```

Or, if you'd rather save yourself the trouble, just remember that any number in your code that *doesn't* have a decimal point in it will be treated as a `Fixnum` by Ruby.

Any number in your code that *does* have a decimal point in it gets treated as a `Float` (the Ruby class that represents floating-point decimal numbers):

```
>> salary = 50000.0
=> 50000.0
>> salary.class
=> Float
```

If it's got a decimal point, it's a `Float`.
If it doesn't, it's a `Fixnum`.

`273` **Fixnum** `273.4` **Float**

Division with Ruby's Float class

We loaded up `irb`, and saw that if we divide one `Fixnum` (integer) instance by another `Fixnum`, Ruby rounds the result *down*.

Should be 136.9863...

```
>> 50000 / 365
=> 136
```

The solution, then, is to use `Float` instances in the operation, which we can get by including a decimal point in our numbers. If you do, Ruby will give you a `Float` instance back:

```
>> 50000.0 / 365.0
=> 136.986301369863
>> (50000.0 / 365.0).class
=> Float
```

It doesn't even matter whether both the dividend and divisor are `Float` instances; Ruby will give you a `Float` back as long as *either* operand is a `Float`.

```
>> 50000.0 / 365
=> 136.986301369863
```

It holds true for addition, subtraction, and multiplication as well: Ruby will give you a `Float` if *either* operand is a `Float`:

```
>> 50000 + 1.5
=> 50001.5
>> 50000 - 1.5
=> 49998.5
>> 50000 * 1.5
=> 75000.0
```

When the first operand is a...	And the second operand is a...	The result is a...
Fixnum	Fixnum	Fixnum
Fixnum	Float	Float
Float	Fixnum	Float
Float	Float	Float

And of course, with addition, subtraction, and multiplication, it doesn't matter whether both operands are `Fixnum` instances, because there's no fractional number to lose in the result. The only operation where it really matters is division. So, remember this rule:

When doing division, make sure at least one operand is a Float.

Let's see if we can use this hard-won knowledge to fix our `Employee` class.

Fixing the salary rounding error in Employee

As long as one of the operands is a `Float`, Ruby won't truncate the decimals from our division operation.

```
>> 50000 / 365.0
=> 136.986301369863
```

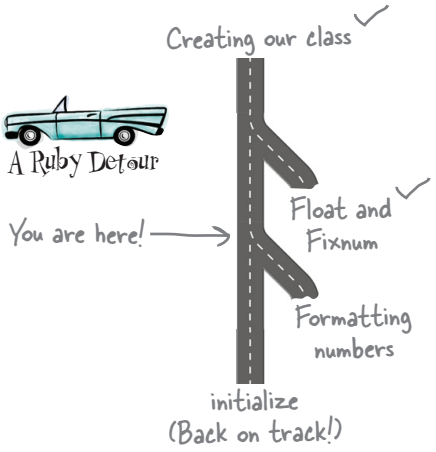
With this rule in mind, we can revise our `Employee` class to stop truncating the decimals from employees' pay:

```
class Employee
  ...   # We're omitting the attribute reader/writer code for brevity.

  def print_pay_stub
    puts "Name: #{@name}"
    pay_for_period = (@salary / 365.0) * 14   # Now, whether or not @salary is a Float, we'll get a Float result.
    puts "Pay This Period: $#{pay_for_period}"   # Print the amount paid.
  end

end

employee = Employee.new
employee.name = "Jane Doe"
employee.salary = 50000   # Using a Fixnum here is just fine!
employee.print_pay_stub
```

Now we have a new problem, though: look what happens to the output!

```
Name: Jane Doe
Pay This Period: $1917.8082191780823
```

We're showing a little *too much* precision! Currency is generally expected to be shown with just two decimal places, after all. So, before we can go back to building the perfect `Employee` class, we need to go on one more detour…



Formatting Numbers for Printing

Our `print_pay_stub` method is displaying too many decimal places. We need to figure out how to round the displayed pay to the nearest penny (2 decimal places).

```
Name: Jane Doe
Pay This Period: $1917.8082191780823
```

To deal with these sort of formatting issues, Ruby provides the `format` method.

Here's a sample of what this method can do. It may look a little confusing, but we'll explain it all on the next few pages!

```
result = format("Rounded to two decimal places: %0.2f", 3.14159265)
puts result
```

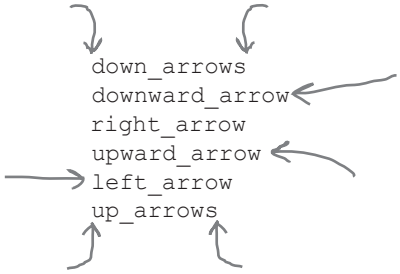
```
Rounded to two decimal places: 3.14
```

So, it looks like `format` *can* help us limit our displayed employee pay to the correct number of places. The question is, *how*? To be able to use this method effectively, we'll need to learn about two features of `format`:

1. Format sequences (the little `%0.2f` above is a format sequence)
2. Format sequence widths (that's the `0.2` in the middle of the format sequence)

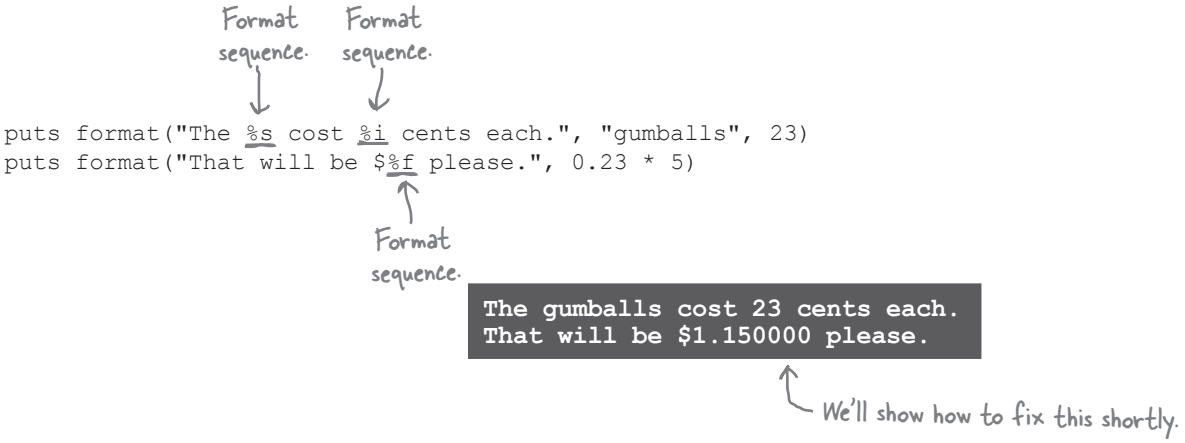
We'll explain exactly what those arguments to `format` mean on the next few pages.

We know, those method calls look a little confusing. We have a ton of examples that should clear that confusion up. We're going to focus on formatting decimal numbers, because it's likely that will be the main thing you use `format` for in your Ruby career.



Format sequences

The first argument to `format` is a string that will be used to format the output. Most of it is formatted exactly as it appears in the string. Any percent signs (`%`), however, will be treated as the start of a **format sequence**, a section of the string that will be substituted with a value in a particular format. The remaining arguments are used as values for those format sequences.



Format sequence types

The letter following the percent sign indicates the type of value that's expected. The most common types are:

`%s`	string
`%i`	integer
`%f`	floating-point decimal

```
puts format("A string: %s", "hello")
puts format("An integer: %i", 15)
puts format("A float: %f", 3.1415)
```

```
A string: hello
An integer: 15
A float: 3.141500
```

So `%f` is for floating-point decimal numbers... We can use that sequence type to format the currency in our pay stubs.

By itself, though, the `%f` sequence type won't help us. The results still show too many decimal places.

```
puts format("$%f", 1917.8082191780823)
```

```
$1917.808219
```

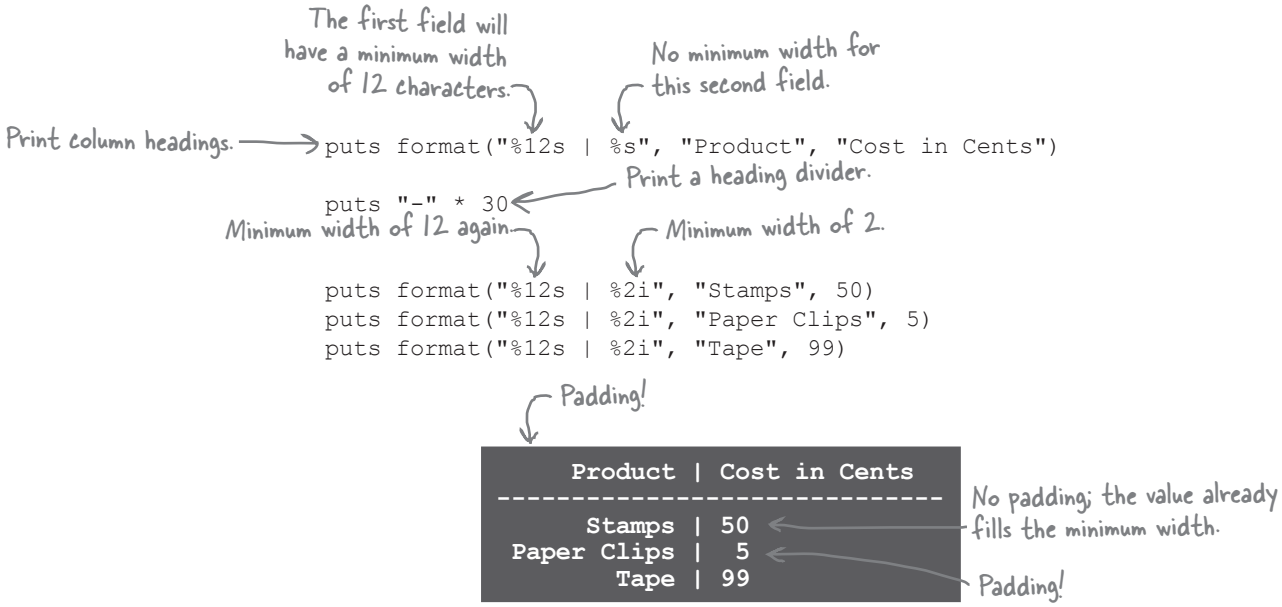
Up next, we'll look at a fix for that situation: the format sequence *width*.

Format sequence width

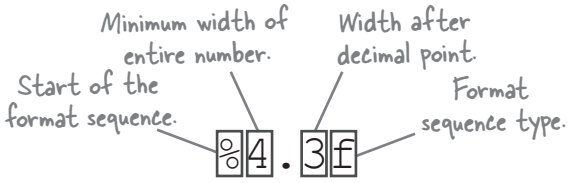
Here's the useful part of format sequences: they let you specify the *width* of the resulting field.

Let's say we want to format some data in a plain-text table. We need to ensure the formatted value fills a minimum number of spaces, so that the columns align properly.

You can specify the minimum width after the percent sign in a format sequence. If the argument for that format sequence is shorter than the minimum width, it will be padded with spaces until the minimum width is reached.



And now we come to the part that's important for today's task: you can use format sequence widths to specify the precision (the number of displayed digits) for floating point numbers. Here's the format:



The minimum width of the entire number includes decimal places. If it's included, shorter numbers will be padded with spaces at the start until this width is reached. If it's omitted, no spaces will ever be added.

The width after the decimal point is the maximum number of digits to show. If a more precise number is given, it will be rounded (up or down) to fit in the given number of decimal places.

Format sequence width with floating-point numbers

So when working with floating-point numbers, format sequence widths let us specify the number of digits displayed before *and* after the decimal point. Could this be the key to fixing our pay stubs?

Here's a quick demonstration of various width values in action:

```
def test_format(format_string)
  print "Testing '#{format_string}': "
  puts format(format_string, 12.3456)
end

test_format "%7.3f"
test_format "%7.2f"
test_format "%7.1f"
test_format "%.1f"
test_format "%.2f"
```

```
Testing '%7.3f':  12.346
Testing '%7.2f':   12.35
Testing '%7.1f':    12.3
Testing '%.1f': 12.3
Testing '%.2f': 12.35
```

Rounded to 3 places.
Rounded to 2 places.
Rounded to 1 place.
Rounded to 1 place, no padding.
Rounded to 2 places, no padding.

That last format, `"%.2f"`, will let us take floating-point numbers of any precision and round them to two decimal places. (It also won't do any unnecessary padding.) This format is ideal for showing currency, and it's just what we need for our `print_pay_stub` method!

```
puts format("$%.2f", 1917.8082191780823)
puts format("$%.2f", 1150.6849315068494)
puts format("$%.2f", 3068.4931506849316)
```

```
$1917.81
$1150.68
$3068.49
```

All rounded to 2 places!

Previously, our calculated pay for our `Employee` class's `print_pay_stub` method was displayed with excess decimal places:

```
salary = 50000
puts "$#{(salary / 365.0) * 14}"
```

```
$1917.8082191780823
```

But now, we finally have a format sequence that will round a floating-point number to two decimal places:

```
puts format("$%.2f", (salary / 365.0) * 14 )
```

```
$1917.81
```

Let's try using `format` in the `print_pay_stub` method.

```
class Employee
  ...
  def print_pay_stub
    puts "Name: #{@name}"
    pay_for_period = (@salary / 365.0) * 14
    formatted_pay = format("%.2f", pay_for_period)
    puts "Pay This Period: $#{formatted_pay}"
  end
end
```

Get a string with the pay amount rounded to 2 decimal places.

Print the formatted amount string.

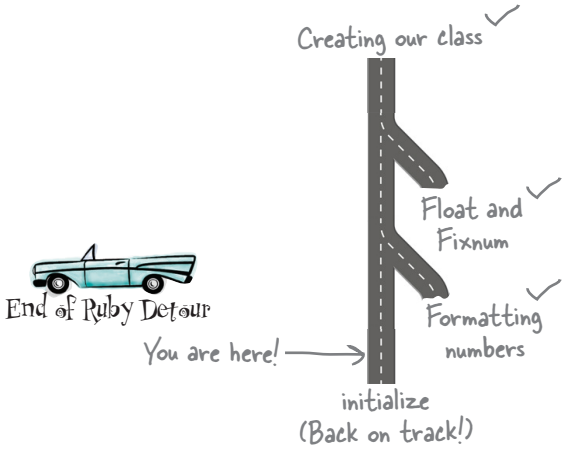
Using "format" to fix our pay stubs

We can test our revised `print_pay_stub` using the same values as before:

```
amy = Employee.new
amy.name = "Amy Blake"
amy.salary = 50000
amy.print_pay_stub
```

```
Name: Amy Blake
Pay This Period: $1917.81
```

We had to make a couple of detours, but we've finally got our `Employee` class printing pay stubs as it should! Let's do a quick exercise to review what we've learned, and then we can get back to the business of perfecting our class...



Look at each of these Ruby statements, and write down what you think the result will be. Consider the result of the division operation, as well as the formatting that will be applied to it. We've done the first one for you.

```
format "%.2f", 3 / 4.0
```

0.75

```
format "%.1f", 3 / 4.0
```

.....

```
format "$%.2f", 3 / 4.0
```

.....

```
format "%i", 3 / 4.0
```

.....

```
format "%.2f", 3 / 4
```

.....

Exercise Solution

Look at each of these Ruby statements, and write down what you think the result will be. Consider the result of the division operation, as well as the formatting that will be applied to it.

```
format "%.2f", 3 / 4.0
```
0.75 ← The format sequence specifies to display two decimal places.

```
format "%.1f", 3 / 4.0
```
0.8 ← Value won't fit into specified number of decimal places, so it gets rounded.

```
format "$%.2f", 3 / 4.0
```
$0.75 ← Parts of the string not part of a format sequence are output literally.

```
format "%i", 3 / 4.0
```
0 ← %i format sequence prints an integer, so the argument gets rounded down.

```
format "%.2f", 3 / 4
```
0.00 ← Both division operands are integers. Result gets rounded DOWN to an integer (0).

When we forget to set an object's attributes

Now that you have the employee pay printing in the correct format, you're puttering along, happily using your new `Employee` class to process payroll. Until, that is, you create a new `Employee` instance, and forget to set the `name` and `salary` attributes before calling `print_pay_stub`:

```
employee = Employee.new
employee.print_pay_stub
```

Not an error, but it's blank!

```
Name:
in `print_pay_stub': undefined method
`/' for nil:NilClass
```
← Error!

Woah! What happened? It's only natural that the name is empty; we forgot to set it. But what's this "undefined method for nil" error? What the heck is this `nil` thing?

This sort of error is pretty common in Ruby, so let's take a few pages to understand it.

Let's alter the `print_pay_stub` method to print the values of `@name` and `@salary`, so we can figure out what's going on.

```
class Employee

  ...

  def print_pay_stub
    puts @name, @salary
  end

end
```

Print the values.

We'll restore the rest of the code later.

"nil" stands for nothing

Now, let's create a new `Employee` instance, and call the revised method:

```
employee = Employee.new
employee.print_pay_stub
```

Two empty lines!

Well, *that* wasn't very helpful. Maybe we're missing something, though.

Back in Chapter 1, we learned that the `inspect` and `p` methods can reveal information that doesn't show up in ordinary output. Let's try again, using `p`:

```
class Employee
  ...
  def print_pay_stub
    p @name, @salary
  end
end
```

Print the values in debug format.

We create another new instance, make another call to the instance method, and...

```
employee = Employee.new
employee.print_pay_stub
```

```
nil
nil
```

Ah-HA!

Ruby has a special value, `nil`, that represents *nothing*. That is, it represents the *absence* of a value.

Just because `nil` *represents* nothing doesn't mean it's *actually* nothing, though. Like everything else in Ruby, it's an object, and it has its own class:

```
puts nil.class
```

```
NilClass
```

But if there's actually something there, how come we didn't see anything in the output?

It's because the `to_s` instance method from `NilClass` always returns an empty string.

```
puts nil.to_s
```

Empty string!

The `puts` and `print` methods automatically call `to_s` on an object to convert it to a string for printing. That's why we got two blank lines when we tried to use `puts` to print the values of `@name` and `@salary`; both were set to `nil`, so we wound up printing two empty strings.

Unlike `to_s`, the `inspect` instance method from `NilClass` always returns the string `"nil"`.

```
puts nil.inspect
```

```
nil
```

You may recall that the `p` method calls `inspect` on each object before printing it. That's why the `nil` values in `@name` and `@salary` appeared in the output once we called `p` on them.

"/" is a method

So, when you first create an instance of the `Employee` class, its `@name` and `@salary` instance variables have a value of `nil`. The `@salary` variable, in particular, causes problems if you call the `print_pay_stub` method without setting it first:

Error: →
```
in `print_pay_stub': undefined method `/' for nil:NilClass
```
"nil" value!

It's obvious from the error that the problem is related to the `nil` value. But it says `undefined method '/'`… Is division really a method?

In Ruby, the answer is yes; most mathematical operators are implemented as methods. When Ruby sees something like this in your code:

```
6 + 2
```

…It converts it to a call to a method named + on the `Fixnum` object 6, with the object on the right of the + (that is, 2) as an argument:

A method call! The other operand is passed as an argument.

```
6.+(2)
```

Both forms are perfectly valid Ruby, and you can try running them yourself:

```
puts 6 + 2
puts 6.+(2)
```
```
8
8
```

The same is true for most of the other mathematical operators.

```
puts 7 - 3
puts 7.-(3)
puts 3.0 * 2
puts 3.0.*(2)
puts 8.0 / 4.0
puts 8.0./(4.0)
```
```
4
4
6.0
6.0
2.0
2.0
```

Even comparison operators are implemented as methods.

```
puts 9 < 7
puts 9.<(7)
puts 9 > 7
puts 9.>(7)
```
```
false
false
true
true
```

But while the `Fixnum` and `Float` classes define these operator methods, `NilClass` does *not*.

```
puts nil./(365.0)
```
Error: →
```
undefined method `/' for nil:NilClass
```

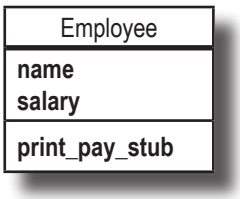
In fact, `nil` doesn't define *most* of the instance methods you see on other Ruby objects.

And why should it? If you're doing mathematical operations with `nil`, it's almost certainly because you forgot to assign a value to one of the operands. You *want* an error to be raised, to bring your attention to the problem.

It was a mistake when we forgot to set a `salary` for an `Employee`, for example. And now that we understand the source of this error, it's time to prevent it from happening again.

The "initialize" method

We tried to call `print_pay_stub` on an instance of our `Employee` class, but we got `nil` when we tried to access the `@name` and `@salary` instance variables.




```
employee = Employee.new
employee.print_pay_stub
```

Chaos ensued.

Not an error, but it's blank!

```
Name:
in `print_pay_stub': undefined method
`/' for nil:NilClass
```

Error!

Here's the method where the `nil` values caused so much trouble:

Results in call to to_s on @name. Since it's nil, prints an empty string.

Results in call to "/" (actually an instance method) on @salary. Since it's nil, raises an error.

```
def print_pay_stub
  puts "Name: #{@name}"
  pay_for_period = (@salary / 365.0) * 14
  formatted_pay = format("$%.2f", pay_for_period)
  puts "Pay This Period: #{formatted_pay}"
end
```

Here's the key problem… At the time we create an `Employee` instance, it's in an invalid state; it's not safe to call `print_pay_stub` until you set its `@name` and `@salary` instance variables.

If we could set `@name` and `@salary` *at the same time* as we create an `Employee` instance, it would reduce the potential for errors.

Ruby provides a mechanism to help with this situation: the `initialize` method. The `initialize` method is your chance to step in and make the object safe to use, before anyone else attempts to call methods on it.

```
class MyClass
  def initialize
    puts "Setting up new instance!"
  end
end
```

When you call `MyClass.new`, Ruby allocates some memory to hold a new `MyClass` object, then calls the `initialize` instance method on that new object.

```
MyClass.new
```

```
Setting up new instance!
```

Employee safety with "initialize"

Let's add an `initialize` method that will set up `@name` and `@salary` for new `Employee` instances before any other instance methods are called.

```
class Employee

  attr_reader :name, :salary

  def name=(name)
    if name == ""
      raise "Name can't be blank!"
    end
    @name = name
  end

  def salary=(salary)
    if salary < 0
      raise "A salary of #{salary} isn't valid!"
    end
    @salary = salary
  end

  def initialize
    @name = "Anonymous"
    @salary = 0.0
  end

  def print_pay_stub
    puts "Name: #{@name}"
    pay_for_period = (@salary / 365.0) * 14
    formatted_pay = format("$%.2f", pay_for_period)
    puts "Pay This Period: #{formatted_pay}"
  end

end
```

Our new method.

Set the @name instance variable.

Set the @salary instance variable.

Now that we've set up an `initialize` method, `@name` and `@salary` will already be set for any new `Employee` instance. It'll be safe to call `print_pay_stub` on them immediately!

```
employee = Employee.new
employee.print_pay_stub
```

```
Name: Anonymous
Pay This Period: $0.00
```

Arguments to "initialize"

Our `initialize` method now sets a default `@name` of `"Anonymous"` and a default `@salary` of `0.0`. It would be better if we could supply a value other than these defaults.

It's for situations like this that any arguments to the `new` method are passed on to `initialize`.

```
class MyClass
  def initialize(my_param)
    puts "Got a parameter from 'new': #{my_param}"
  end
end

MyClass.new("hello")
```

Forwarded to "initialize"!

```
Got a parameter from 'new': hello
```

We can use this feature to let the caller of `Employee.new` specify what the initial name and salary should be. All we have to do is take `name` and `salary` parameters, and use them to set the `@name` and `@salary` instance variables.

```
class Employee

  ...

  def initialize(name, salary)
    @name = name
    @salary = salary
  end

  ...

end
```

Use the "name" parameter to set the "@name" instance variable.

Use the "salary" parameter to set the "@salary" instance variable.

And just like that, we can set `@name` and `@salary` via arguments to `Employee.new`!

```
employee = Employee.new("Amy Blake", 50000)
employee.print_pay_stub
```

Forwarded to "initialize"!

```
Name: Amy Blake
Pay This Period: $1917.81
```

Of course, once you set it up this way, you'll need to be careful. If you don't pass any arguments to `new`, there will be no arguments to forward on to `initialize`. At that point, you'll get the same result that happens any time you call a Ruby method with the wrong number of arguments: an error.

```
employee = Employee.new
```

Error:

```
in `initialize': wrong number
of arguments (0 for 2)
```

We'll look at a solution for this in a moment.

Using optional parameters with "initialize"

We started with an `initialize` method that set default values for our instance variables, but didn't let you specify your own…

```
class Employee
  ...
  def initialize
    @name = "Anonymous"
    @salary = 0.0
  end
  ...
end
```

Set the @name instance variable.

Set the @salary instance variable.

Then we added parameters to `initialize`, which meant that you *had* to specify your own name and salary values, and couldn't rely on the defaults…

```
class Employee
  ...
  def initialize(name, salary)
    @name = name
    @salary = salary
  end
  ...
end
```

Use the "name" parameter to set the "@name" instance variable.

Use the "salary" parameter to set the "@salary" instance variable.

Can we have the best of both worlds?

Yes! Since `initialize` is an ordinary method, it can utilize all the features of ordinary methods. And that includes optional parameters. (Remember those from Chapter 2?)

We can specify default values when declaring the parameters. When we omit an argument, we'll get the default value. Then, we just assign those parameters to the instance variables normally.

```
class Employee
  ...
  def initialize(name = "Anonymous", salary = 0.0)
    @name = name
    @salary = salary
  end
  ...
end
```

With this change in place, we can omit one or both arguments, and get the appropriate defaults!

```
Employee.new("Jane Doe", 50000).print_pay_stub
Employee.new("Jane Doe").print_pay_stub
Employee.new.print_pay_stub
```

```
Name: Jane Doe
Pay This Period: $1917.81
Name: Jane Doe
Pay This Period: $0.00
Name: Anonymous
Pay This Period: $0.00
```

Pool Puzzle

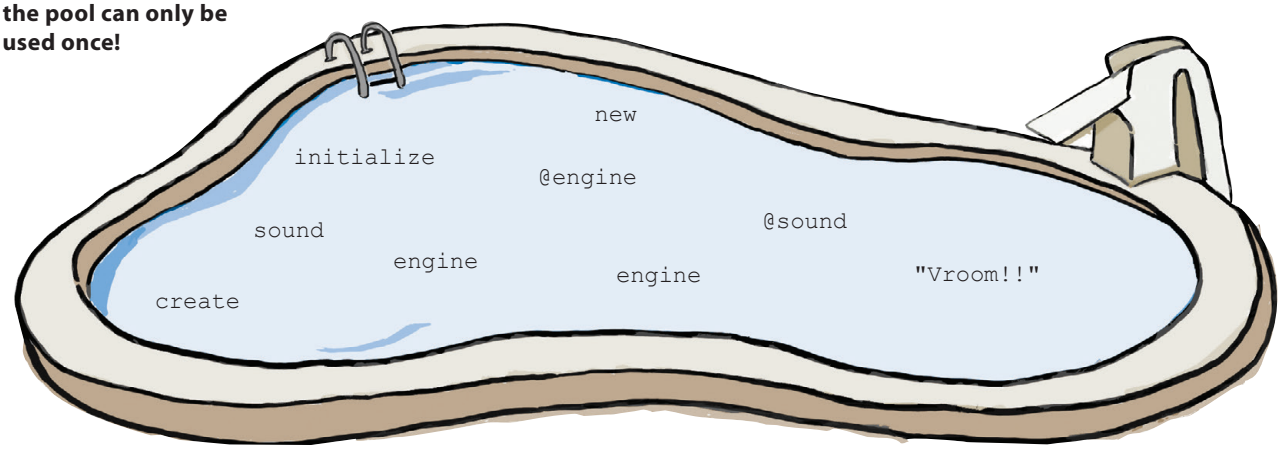
Your **job** is to take code snippets from the pool and place them into the blank lines in the code. **Don't** use the same snippet more than once, and you won't need to use all the snippets. Your **goal** is to make code that will run and produce the output shown.

```
class Car

  def __________(______)
    _______ = engine
  end

  def rev_engine
    @engine.make_sound
  end

end

class Engine

  def initialize(_____ = _________)
    @sound = sound
  end

  def make_sound
    puts @sound
  end

end

engine = Engine.___
car = Car.new(______)
car.rev_engine
```

Output:

```
File Edit Window Help
Vroom!!
```

Note: each thing from the pool can only be used once!



Pool Puzzle Solution

```
class Car

  def initialize(engine)
    @engine = engine
  end

  def rev_engine
    @engine.make_sound
  end

end

engine = Engine.new
car = Car.new(engine)
car.rev_engine
```

```
class Engine

  def initialize(sound = "Vroom!!")
    @sound = sound
  end

  def make_sound
    puts @sound
  end

end
```

Output:

```
File Edit Window Help
Vroom!!
```

there are no Dumb Questions

Q: What's the difference between `initialize` methods in Ruby and *constructors* from other object-oriented languages?

A: They both serve the same basic purpose - to let the class prepare new instances for use. Whereas constructors are a special structure in most other languages, though, Ruby's `initialize` is just an ordinary instance method.

Q: Why do I have to call `MyClass.new`? Can't I just call `initialize` directly?

A: The `new` method is needed to actually *create* the object; `initialize` just sets up the new object's instance variables. Without `new`, there would be no object to initialize! For this reason, Ruby doesn't allow you to call the `initialize` method directly from outside an instance. (So, we oversimplified a little bit; `initialize` *does* differ from an ordinary instance method in one respect.)

Q: Does `MyClass.new` *always* call `initialize` on the new object?

A: Yes, always.

Q: Then how have we been calling `new` on the classes we've made so far? They didn't have `initialize` methods!

A: Actually, they *did* have one... All Ruby classes inherit an `initialize` method from the `Object` superclass.

Q: But if `Employee` inherited an `initialize` method, why did we have to write our own?

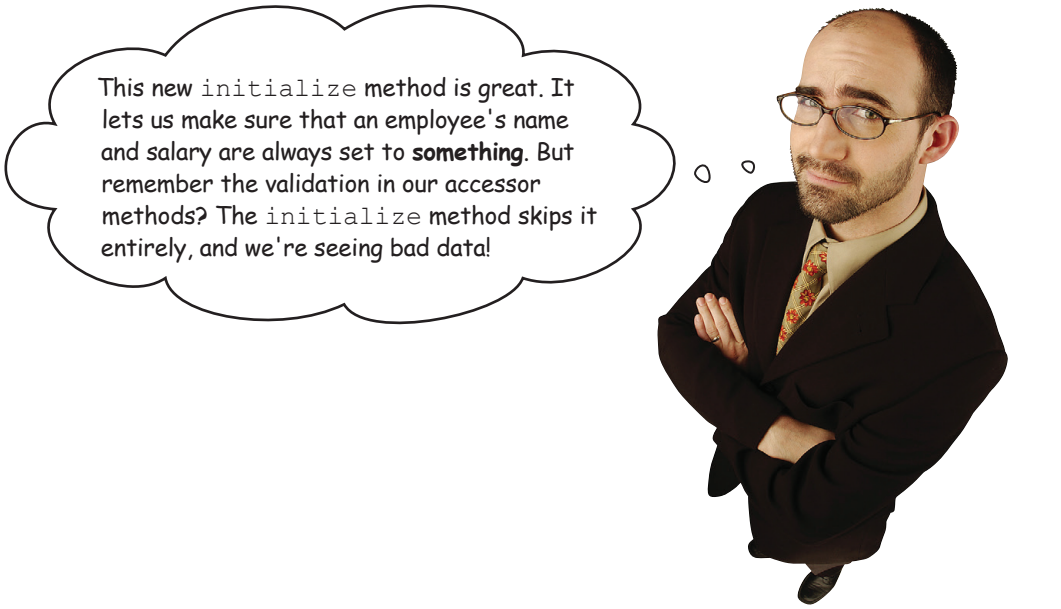
A: The `initialize` from `Object` takes no arguments, and basically does nothing. It won't set up any instance variables for you; we had to override it with our own version in order to do that.

Q: Can I return a value from an `initialize` method?

A: You can, but Ruby will ignore it. The `initialize` method is intended solely for setting up new instances of your class, so if you need a return value, you should do that elsewhere in your code.

The `new` method is needed to actually create the object; `initialize` just sets up the new object's instance variables.

"initialize" does an end-run around our validation



You remember our `name=` attribute writer method, which prevents the assignment of an empty string as an `Employee` name:

```
ben = Employee.new
ben.name = ""
```

Error: → `in `name=': Name can't be blank! (RuntimeError)`

There's also our `salary=` attribute writer method, which ensures that negative numbers aren't assigned as a salary:

```
kara = Employee.new
kara.salary = -246
```

Error: → `in `salary=': A salary of -246 isn't valid! (RuntimeError)`

We have bad news for you… Since your `initialize` method assigns directly to the `@name` and `@salary` instance variables, bad data has a new way to sneak in!

```
employee = Employee.new("", -246)
employee.print_pay_stub
```

Blank name in your output!

```
Name:
Pay This Period: $-9.44
```

← Negative paycheck!

"initialize" and validation

We *could* get our `initialize` method to validate its parameters by adding the same validation code to the `initialize` method...

```
class Employee
  ...
  def name=(name)
    if name == ""
      raise "Name can't be blank!"
    end
    @name = name
  end

  def salary=(salary)
    if salary < 0
      raise "A salary of #{salary} isn't valid!"
    end
    @salary = salary
  end

  def initialize(name = "Anonymous", salary = 0.0)
    if name == ""
      raise "Name can't be blank!"
    end
    @name = name
    if salary < 0
      raise "A salary of #{salary} isn't valid!"
    end
    @salary = salary
  end
  ...
end
```

Duplicated code!

Duplicated code!

But duplicating code like that is a problem. What if we changed the `initialize` validation code later, but forgot to update the `name=` method? Rubyists try to follow the *DRY principle*, where DRY stands for Don't Repeat Yourself. It means that you should avoid duplicating code wherever possible, as it's likely to result in bugs.

What if we called the `name=` and `salary=` methods from *within* the `initialize` method? That would let us set the `@name` and `@salary` instance variables. It would also let us run the validation code, *without* duplicating it!

Calls between methods on the same instance with "self"

We need to call the `name=` and `salary=` attribute writer methods from within the `initialize` method *of the same object*. That will let us run the writer methods' validation code before we set the `@name` and `@salary` instance variables.

Unfortunately, code like this *won't* work…

```
class Employee
  ...
  def initialize(name = "Anonymous", salary = 0.0)
    name = name
    salary = salary
  end
  ...
end

amy = Employee.new("Amy Blake", 50000)
amy.print_pay_stub
```

Doesn't work – Ruby thinks you're assigning to a variable!

@name and @salary are nil again!

```
Name:
in `print_pay_stub': undefined method
`/' for nil:NilClass (NoMethodError)
```

The code in the `initialize` method treats `name=` and `salary=` *not* as calls to the attribute writer methods, but as re-setting the `name` and `salary` local variables to the same values they already contain! (If that sounds like a useless and nonsensical thing to do, that's because it is.)

What we *need* to do is make it clear to Ruby that we intend to call the `name=` and `salary=` instance methods. And to call an instance method, we usually use the dot operator.

But we're inside the `initialize` instance method… what would we put to the left of the dot operator?

We can't use the `amy` variable; it would be silly to refer to one instance of the class within the class itself. Besides, `amy` is out of scope within the `initialize` method.

```
class Employee
  ...
  def initialize(name = "Anonymous", salary = 0.0)
    amy.name = name
    amy.salary = salary
  end
  ...
end

amy = Employee.new("Amy Blake", 50000)
```

Not in scope here!

Error:

```
in `initialize': undefined local variable or method `amy'
```

Calls between methods on the same instance with "self" (cont.)

We need something to put to the left of the dot operator, so that we can call our `Employee` class's `name=` and `salary=` attribute accessor methods within our `initialize` method. The problem is, what do we put there? How do you refer to the current instance from *inside* an instance method?

```
class Employee
  ...
  def initialize(name = "Anonymous", salary = 0.0)
    amy.name = name
    amy.salary = salary
  end
  ...
end

amy = Employee.new("Amy Blake", 50000)
```

Not in scope here!

Ruby has an answer: the `self` keyword. Within instance methods, `self` always refers to the current object.

We can demonstrate this with a simple class:

```
class MyClass
  def first_method
    puts "Current instance within first_method: #{self}"
  end
end
```

If we create an instance and call `first_method` on it, we'll see that inside the instance method, `self` refers to the object the method is being called on.

```
my_object = MyClass.new
puts "my_object refers to this object: #{my_object}"
my_object.first_method
```

```
my_object refers to this object: #<MyClass:0x007f91fb0ae508>
Current instance within first_method: #<MyClass:0x007f91fb0ae508>
```

Same object!

The string representations of `my_object` and `self` include a unique identifier for the object. (We'll learn more about this much later, in the chapter on references.) The identifiers are the same, so it's the same object!

Calls between methods on the same instance with "self" (cont.)

We can also use `self` with the dot operator to call a second instance method from inside the first one.

```
class MyClass
  def first_method
    puts "Current instance within first_method: #{self}"
    self.second_method
  end

  def second_method
    puts "Current instance within second_method: #{self}"
  end
end

my_object = MyClass.new
my_object.first_method
```

Calls here!

```
Current instance within first_method: #<MyClass:0x007ffd4b077510>
Current instance within second_method: #<MyClass:0x007ffd4b077510>
```

Same object!

Now that we have `self` to use the dot operator on, we can make it clear to Ruby that we want to call the `name=` and `salary=` instance methods, not to set the `name` and `salary` variables…

```
class Employee
  ...
  def initialize(name = "Anonymous", salary = 0.0)
    self.name = name
    self.salary = salary
  end
  ...
end
```

DEFINITELY a call to the "name=" method.

DEFINITELY a call to the "salary=" method.

Let's try calling our new constructor and see if it worked!

```
amy = Employee.new("Amy Blake", 50000)
amy.print_pay_stub
```

```
Name: Amy Blake
Pay This Period: $1917.81
```

Calls between methods on the same instance with "self" (cont.)

Success! Thanks to `self` and the dot operator, it's now clear to Ruby (and everyone else) that we're making calls to the attribute writer methods, not assigning to variables.

And since we're going through the accessor methods, that means the validation works, without any duplicated code!

```
employee = Employee.new("", 50000)
```

Error: → `in `name=': Name can't be blank!`

```
employee = Employee.new("Jane Doe", -99999)
```

Error: → `in `salary=': A salary of -99999 isn't valid!`

When "self" is optional

Right now, our `print_pay_stub` method accesses the `@name` and `@salary` instance variables directly:

```
class Employee

  def print_pay_stub
    puts "Name: #{@name}"
    pay_for_period = (@salary / 365.0) * 14
    formatted_pay = format("$%.2f", pay_for_period)
    puts "Pay This Period: #{formatted_pay}"
  end

end
```

But we defined `name` and `salary` attribute reader methods in our `Employee` class; we could use those instead of accessing the instance variables directly. (That way, if you ever change the `name` method to display last name first, or change the `salary` method to calculate salary according to an algorithm, the `print_pay_stub` code won't need to be updated.)

We *can* use the `self` keyword and the dot operator when calling `name` and `salary`, and it will work just fine:

```
class Employee

  attr_reader :name, :salary

  ...

  def print_pay_stub
    puts "Name: #{self.name}"
    pay_for_period = (self.salary / 365.0) * 14
    formatted_pay = format("$%.2f", pay_for_period)
    puts "Pay This Period: #{formatted_pay}"
  end

end

Employee.new("Amy Blake", 50000).print_pay_stub
```

```
Name: Amy Blake
Pay This Period: $1917.81
```

When "self" is optional (cont.)

But Ruby has a rule that can save us a little typing when calling from one instance method to another... If you don't specify a receiver using the dot operator, the receiver defaults to the current object, `self`.

```
class Employee
  ...
  def print_pay_stub
    puts "Name: #{name}"
    pay_for_period = (salary / 365.0) * 14
    formatted_pay = format("$%.2f", pay_for_period)
    puts "Pay This Period: #{formatted_pay}"
  end
  ...
end

Employee.new("Amy Blake", 50000).print_pay_stub
```

"self" omitted, still works!

"self" omitted, still works!

Still works!

```
Name: Amy Blake
Pay This Period: $1917.81
```

As we saw in the previous section, you *have* to include the `self` keyword when calling attribute writer methods, or Ruby will mistake the = for a variable assignment. But for any other kind of instance method call, you can leave `self` off, if you want.

Implementing hourly employees through inheritance

The `Employee` class you've created for Chargemore is working great! It prints accurate pay stubs that are formatted properly, and thanks to the `initialize` method you wrote, it's really easy to create new `Employee` instances.

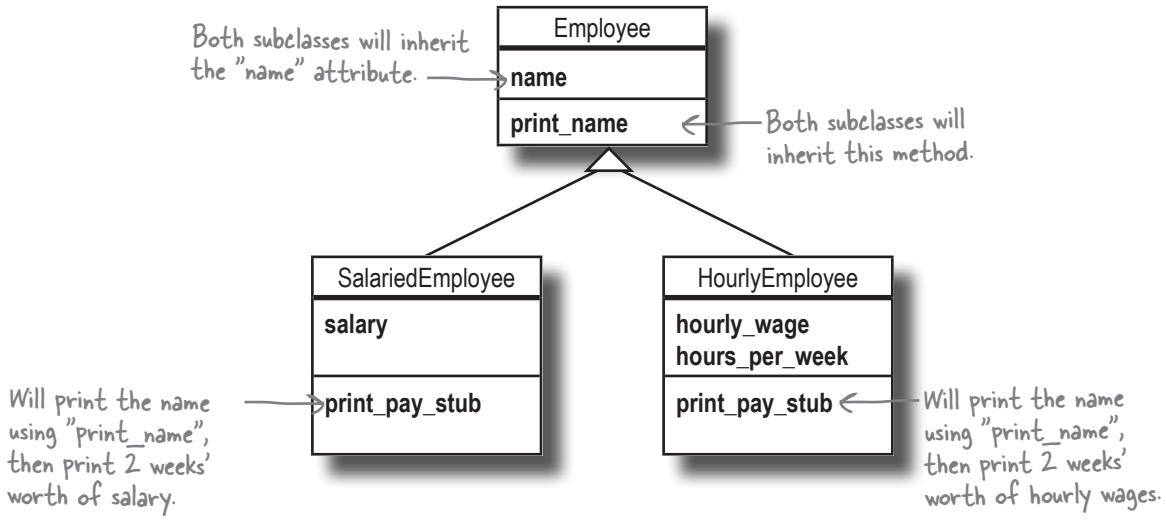
But, at this point, it only handles salaried employees. It's time to look at adding support for employees that are paid by the hour.

The requirements for hourly employees are basically the same as for salaried ones; we need to be able to print pay stubs that include their name and the amount paid. The only difference is the way that we calculate their pay. For hourly employees, we multiply their hourly wage by the number of hours they work per week, then double that amount to get two weeks' worth.

```
(salary / 365.0) * 14
```
Salaried employee pay calculation formula

```
hourly_wage * hours_per_week * 2
```
Hourly employee pay calculation formula

Since salaried and hourly employees are so similar, it makes sense to put the shared functionality in a superclass. Then, we'll make two subclasses that hold the different pay calculation logic.



Implementing hourly employees through inheritance (cont.)

Let's start by ensuring the common logic between `SalariedEmployee` and `HourlyEmployee` stays in the `Employee` superclass.

Since pay stubs for both salaried and hourly employees need to include their names, we'll leave the `name` attribute in the superclass, for the subclasses to share. We'll move the code that prints the name into the `print_name` method in the superclass.

```
class Employee

  attr_reader :name

  def name=(name)
    # Code to validate and set @name
  end

  def print_name
    puts "Name: #{name}"
  end

end
```

We'll be omitting all attribute accessor code for brevity.

Remember, this is the same as a call to self.name.

We'll move the logic to calculate pay for salaried employees to the `SalariedEmployee` class, but we'll call the inherited `print_name` method to print the employee name.

```
class SalariedEmployee < Employee

  attr_reader :salary

  def salary=(salary)
    # Code to validate and set @salary
  end

  def print_pay_stub
    print_name
    pay_for_period = (salary / 365.0) * 14
    formatted_pay = format("$%.2f", pay_for_period)
    puts "Pay This Period: #{formatted_pay}"
  end

end
```

Calls print_name method inherited from superclass.

This code is the same as we had in the old Employee print_pay_stub method.

With those changes in place, we can create a new `SalariedEmployee` instance, set its name and salary, and print a pay stub as before:

```
salaried_employee = SalariedEmployee.new
salaried_employee.name = "Jane Doe"
salaried_employee.salary = 50000
salaried_employee.print_pay_stub
```

```
Name: Jane Doe
Pay This Period: $1917.81
```

Implementing hourly employees through inheritance (cont.)

Now, we'll build a new `HourlyEmployee` class. It's just like `SalariedEmployee`, except that it holds an hourly wage and number of hours worked per week, and uses those to calculate pay for a two-week period. As with `SalariedEmployee`, storing and printing the employee name is left up to the `Employee` superclass.

```
class HourlyEmployee < Employee

  attr_reader :hourly_wage, :hours_per_week

  def hourly_wage=(hourly_wage)
    # Code to validate and set @hourly_wage
  end

  def hours_per_week=(hours_per_week)
    # Code to validate and set @hours_per_week
  end

  def print_pay_stub
    print_name
    pay_for_period = hourly_wage * hours_per_week * 2
    formatted_pay = format("$%.2f", pay_for_period)
    puts "Pay This Period: #{formatted_pay}"
  end

end
```

And now we can create an `HourlyEmployee` instance. Instead of setting a salary, we set an hourly wage and number of hours per week. Those values are then used to calculate the pay stub amount.

```
hourly_employee = HourlyEmployee.new
hourly_employee.name = "John Smith"
hourly_employee.hourly_wage = 14.97
hourly_employee.hours_per_week = 30
hourly_employee.print_pay_stub
```

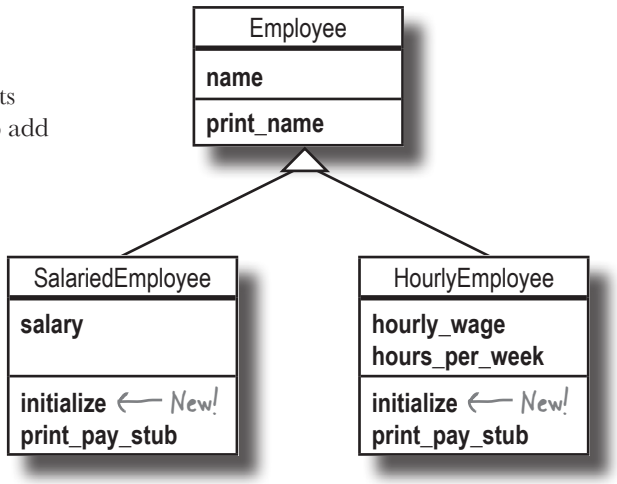
```
Name: John Smith
Pay This Period: $898.20
```

That wasn't bad at all! Through use of inheritance, we've implemented pay stubs for hourly employees, kept pay stubs for salaried employees, and minimized code duplication between the two.

We've lost something in the shuffle, though—our `initialize` method. We used to be able to set up an `Employee` object's data at the time we created it, and these new classes won't let us do that. We'll have to add `initialize` methods back in.

Restoring "initialize" methods

To make `SalariedEmployee` and `HourlyEmployee` objects that are safe to work with as soon as they're created, we'll need to add `initialize` methods to those two classes.



As we did with the `Employee` class before, our `initialize` methods will need to accept a parameter for each object attribute we want to set. The `initialize` method for `SalariedEmployee` will look just like it did for the old `Employee` class (since the attributes are the same), but `initialize` for `HourlyEmployee` will accept a different set of parameters (and set different attributes).

This is just like the initialize method for the old Employee class.

```
class SalariedEmployee < Employee
  ...
  def initialize(name = "Anonymous", salary = 0.0)
    self.name = name
    self.salary = salary
  end
  ...
end

class HourlyEmployee < Employee
  ...
  def initialize(name = "Anonymous", hourly_wage = 0.0, hours_per_week = 0.0)
    self.name = name
    self.hourly_wage = hourly_wage
    self.hours_per_week = hours_per_week
  end
  ...
end
```

Again, we make parameters optional by providing defaults.

This method needs to accept 3 parameters, and set 3 attributes.

With our `initialize` methods added, we can once again pass arguments to the `new` method for each class. Our objects will be ready to use as soon as they're created.

```
salaried_employee = SalariedEmployee.new("Jane Doe", 50000)
salaried_employee.print_pay_stub

hourly_employee = HourlyEmployee.new("John Smith", 14.97, 30)
hourly_employee.print_pay_stub
```

```
Name: Jane Doe
Pay This Period: $1917.81
Name: John Smith
Pay This Period: $898.20
```

Inheritance and "initialize"

There's one small weakness in our new `initialize` methods, though: the code to set the employee name is duplicated between our two subclasses.

```
class SalariedEmployee < Employee
  ...
  def initialize(name = "Anonymous", salary = 0.0)
    self.name = name
    self.salary = salary
  end
  ...
end

class HourlyEmployee < Employee
  ...
  def initialize(name = "Anonymous", hourly_wage = 0.0, hours_per_week = 0.0)
    self.name = name
    self.hourly_wage = hourly_wage
    self.hours_per_week = hours_per_week
  end
  ...
end
```

Duplicated in SalariedEmployee!*

In all other aspects of our subclasses, we delegate handling of the `name` attribute to the `Employee` superclass. We define the reader and writer methods there. We even print the name via the `print_name` method, which the subclasses call from their respective `print_pay_stub` methods.

```
class Employee

  attr_reader :name

  def name=(name)
    # Code to validate and set @name
  end

  def print_name
    puts "Name: #{name}"
  end

end
```

Superclass holds the "name" attribute.

Superclass holds shared code to print the name.

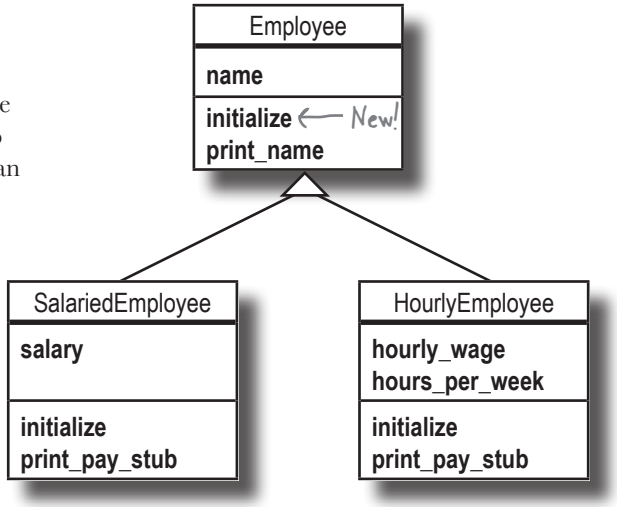
…But we don't do this for `initialize`. Could we?

Yes! We've said it before, and we'll say it again, `initialize` is just an *ordinary instance method*. That means that it gets inherited like any other, that means it can be overridden like any other, and it means that overriding methods can call it via `super` like any other. We'll demonstrate on the next page.

*Okay, we realize it's just one line of duplicated code. But the technique we're about to show you will work for much larger amounts of duplication.

"super" and "initialize"

To eliminate the repeated `name` setup code in our `Employee` subclasses, we can move the name handling to an `initialize` method in the superclass, then have the subclass `initialize` methods call it with `super`. `SalariedEmployee` will keep the logic to set up a salary, `HourlyEmployee` will keep the logic to set up an hourly wage and hours per week, and the two classes can delegate the shared logic for `name` to their shared superclass.



First, let's try moving the name handling from the `initialize` method in `SalariedEmployee` to the `Employee` class.

```
class Employee
  ...
  def initialize(name = "Anonymous")
    self.name = name
  end
  ...
end

class SalariedEmployee < Employee
  ...
  def initialize(name = "Anonymous", salary = 0.0)
    super
    self.salary = salary
  end
  ...
end
```

New initialize method that handles only the name!

Attempt to call "initialize" in Employee to set up the name.

Trying to use this revised `initialize` method reveals a problem, though…

```
salaried_employee = SalariedEmployee.new("Jane Doe", 50000)
salaried_employee.print_pay_stub
```

Error → `in initialize: wrong number of arguments (2 for 0..1)`

"super" and "initialize" (cont.)

Oops! We forgot a key detail about `super` that we learned earlier—if you don't specify a set of arguments, it calls the superclass method with the same set of arguments that the subclass method received. (This is true when using `super` in other instance methods, and it's true when using `super` within `initialize`.) The `initialize` method in `SalariedEmployee` received *two* parameters, and `super` passed them *both* on to the `initialize` method in `Employee`. (Even though it only accepts *one* argument.)

The fix, then, is to specify which parameter we want to pass on: the `name` parameter.

```
class SalariedEmployee < Employee
  ...
  def initialize(name = "Anonymous", salary = 0.0)
    super(name)
    self.salary = salary
  end
  ...
end
```

Call "initialize" in Employee, passing only the name.

Let's try to initialize a new `SalariedEmployee` again…

```
salaried_employee = SalariedEmployee.new("Jane Doe", 50000)
salaried_employee.print_pay_stub
```

```
Name: Jane Doe
Pay This Period: $1917.81
```

It worked! Let's make the same changes to the `HourlyEmployee` class…

```
class HourlyEmployee < Employee
  ...
  def initialize(name = "Anonymous", hourly_wage = 0.0, hours_per_week = 0.0)
    super(name)
    self.hourly_wage = hourly_wage
    self.hours_per_week = hours_per_week
  end
  ...
end

hourly_employee = HourlyEmployee.new("John Smith", 14.97, 30)
hourly_employee.print_pay_stub
```

Call "initialize" in Employee, passing only the name.

```
Name: John Smith
Pay This Period: $898.20
```

Previously, we used `super` within our `print_pay_stub` methods in `SalariedEmployee` and `HourlyEmployee` to delegate printing of the employee name to the `Employee` superclass. Now, we've just done the same thing with the `initialize` method, allowing the superclass to handle setting of the `name` attribute.

Why does it work? Because `initialize` is an instance method just like any other. Any feature of Ruby that you can use with an ordinary instance method, you can use with `initialize`.

there are no Dumb Questions

Q: If I override `initialize` in a subclass, does the superclass's `initialize` method run when the overriding `initialize` method runs?

A: Not unless you explicitly call it with the `super` keyword, no. Remember, in Ruby, `initialize` is just an ordinary method, like any other. If you call the `move` method on a `Dog` instance, does `move` from the `Animal` class get run as well? No, not unless you use `super`. It's no different with the `initialize` method.

Ruby is *not* the same as many other object-oriented languages, which automatically call the superclass's constructor before calling the subclass constructor.

Q: If I use `super` to call the superclass's `initialize` method explicitly, does it have to be the first thing I do in the subclass's `initialize` method?

A: If your subclass depends on instance variables that are set up by the superclass's `initialize` method, then you may want to invoke `super` before doing anything else. But Ruby doesn't require it. As with other methods, you can invoke `super` anywhere you want within `initialize`.

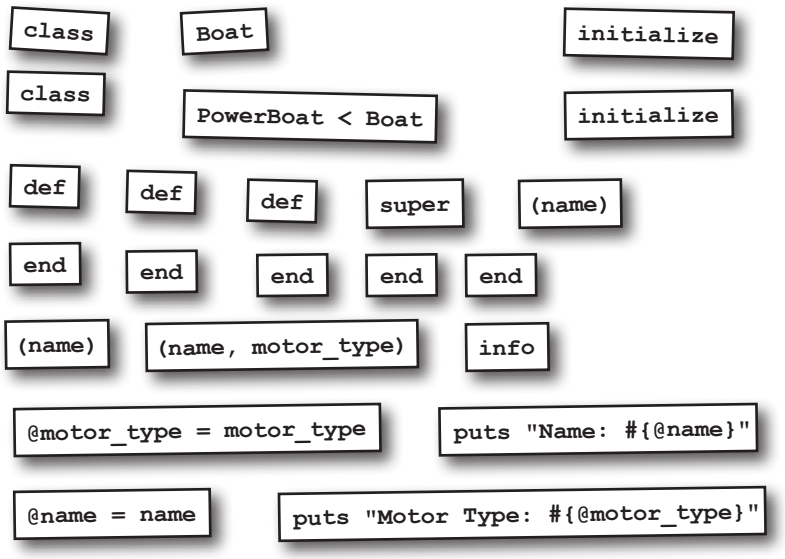
Q: You *say* the superclass's `initialize` method doesn't get run unless you call `super`... If that's true, then how does `@last_name` get set in this sample?

```
class Parent
  attr_accessor :last_name
  def initialize(last_name)
    @last_name = last_name
  end
end

class Child < Parent
end

child = Child.new("Smith")
puts child.last_name
```

A: Because `initialize` is *inherited* from the `Parent` class. With Ruby instance methods, you only need to call `super` to invoke the parent class's method *if* you want it to run, *and* you've overridden it in the subclass. If you haven't overridden it, then the inherited method is run directly. This works the same for `initialize` as it does for any other method.

Code Magnets

A Ruby program is all scrambled up on the fridge. Can you reconstruct the code snippets to make a working superclass and subclass, so the sample code below can execute and produce the given output?



Sample code:

```
boat = PowerBoat.new("Guppy", "outboard")
boat.info
```

Output:

```
File Edit Window Help
Name: Guppy
Motor Type: outboard
```

Code Magnets Solution

A Ruby program is all scrambled up on the fridge. Can you reconstruct the code snippets to make a working superclass and subclass, so the sample code below can execute and produce the given output?

```
class Boat

  def initialize(name)
    @name = name
  end

end
```

```
class PowerBoat < Boat

  def initialize(name, motor_type)
    super(name)
    @motor_type = motor_type
  end

  def info
    puts "Name: #{@name}"
    puts "Motor Type: #{@motor_type}"
  end

end
```

Sample code:

```
boat = PowerBoat.new("Guppy", "outboard")
boat.info
```

Output:

```
File Edit Window Help
Name: Guppy
Motor Type: outboard
```

Same class, same attribute values

With your `HourlyEmployee` class complete, Chargemore is ready to begin a hiring blitz to staff its new stores. Here's the set of employees they need created for their first store downtown:

Ruby lets us use as many space characters as we want, so we've aligned this code for easier reading.

```
ivan    = HourlyEmployee.new("Ivan Stokes",      12.75, 25)
harold  = HourlyEmployee.new("Harold Nguyen",    12.75, 25)
tamara  = HourlyEmployee.new("Tamara Wells",     12.75, 25)
susie   = HourlyEmployee.new("Susie Powell",     12.75, 25)

edwin   = HourlyEmployee.new("Edwin Burgess",    10.50, 20)
ethel   = HourlyEmployee.new("Ethel Harris",     10.50, 20)

angela  = HourlyEmployee.new("Angela Matthews", 19.25, 30)
stewart = HourlyEmployee.new("Stewart Sanchez", 19.25, 30)
```

If you look at the above code, you'll probably notice there are large groups of objects where similar arguments are passed to the `new` method. There's a good reason for this: the first group are cashiers for the new store, the second group are janitors, and the third group are security guards.

Chargemore starts all new cashiers off at the same base pay and number of hours per week. Janitors get a different rate and number of hours than cashiers, but it's the same for all janitors. And the same is true for security guards. (Individuals may get raises later, depending on performance, but they all start out the same.)

The upshot is that there's a lot of repetition of arguments in those calls to `new`, and a lot of chances to make a typo. And this is just the first wave of hiring, for the first Chargemore store, so things can only get worse. Seems like we can make this easier.

An inefficient factory method

When we need to make many instances of a class that have similar data, you can often save some repetition by making a *factory method* to create objects pre-populated with the needed attribute values. (Factory methods are a programming pattern that can be used in any object-oriented language, not just Ruby.)

But using only the tools we have now, any factory method we make will be inefficient at best.

To demonstrate what we mean, let's try making a method to set up new `HourlyEmployee` objects with the default pay and hours per week for cashiers.

```
class HourlyEmployee
  ...
  def turn_into_cashier
    self.hourly_wage = 12.75
    self.hours_per_week = 25
  end
  ...
end

ivan = HourlyEmployee.new("Ivan Stokes")
ivan.turn_into_cashier
ivan.print_pay_stub
```

Set hourly wage.

Set hours per week.

```
Name: Ivan Stokes
Pay This Period: $637.50
```

This works, yes. So what's so inefficient about it? Let's look at our `initialize` method (which of course has to run when we create a new `HourlyEmployee`) again…

```
class HourlyEmployee
  ...
  def initialize(name = "Anonymous", hourly_wage = 0, hours_per_week = 0)
    super(name)
    self.hourly_wage = hourly_wage
    self.hours_per_week = hours_per_week
  end
  ...
end
```

Set hourly wage.

Set hours per week.

We're setting the `hourly_wage` and `hours_per_week` attributes within `initialize`, then immediately turning around and setting them *again* within `turn_into_cashier`!

This is inefficient for Ruby, but there's potential for it to be inefficient for us, too. What if we didn't have default parameters for `hourly_wage` and `hours_per_week` on `initialize`? Then, *we'd* have to specify the arguments we're throwing away!

```
ivan = HourlyEmployee.new("Ivan Stokes", 0, 0)
ivan.turn_into_cashier
```

We won't use either of these values!

That's the problem with writing factory methods as instance methods: we're trying to *make* a new instance of the class, but there has to already *be* an instance to run the methods on! There must be a better way…

Fortunately, there is! Up next, we're going to learn about *class methods*.

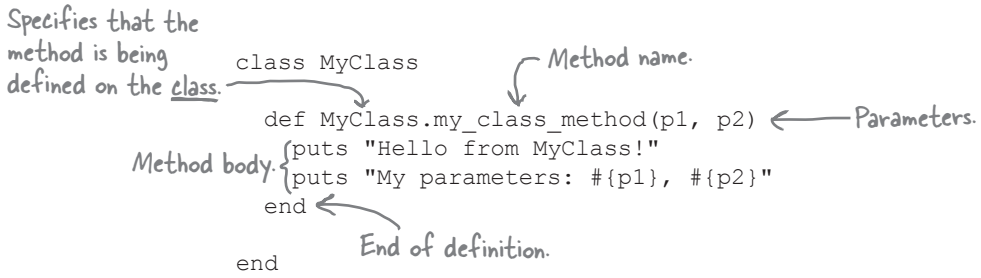
Class methods

You don't *have* an instance of a class, but you *need* one. And you need a method to set it up for you. Where do you put that method?

You could stick it off by itself in some little Ruby source file, but it would be better to keep it together with the class that it makes instances of. You can't make it an instance method on that class, though. If you *had* an instance of the class, you wouldn't need to *make* one, now would you?

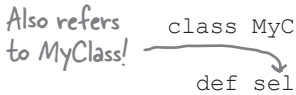
It's for situations like this that Ruby supports **class methods**—methods that you can invoke directly on a class, without the need for any instance of that class. You don't *have* to use a class method as a factory method, but they're *perfect* for the job.

A class method definition is very similar to any other method definition in Ruby. The difference: you specify that you're defining it *on the class itself*.




```
class MyClass
  def MyClass.my_class_method(p1, p2)
    puts "Hello from MyClass!"
    puts "My parameters: #{p1}, #{p2}"
  end
end
```

Within a class definition (but outside any instance method definitions), Ruby sets `self` to refer to the class that's being defined. So, many Rubyists prefer to replace the class name with `self`:




```
class MyClass
  def self.my_class_method(p1, p2)
    puts "Hello from MyClass!"
    puts "My parameters: #{p1}, #{p2}"
  end

end
```

In most ways, class method definitions behave just like you're used to:

- You can put as many Ruby statements as you like in the method body.
- You can return a value with the `return` keyword. If you don't, the value of the last expression in the method body is used as the return value.
- You can optionally define one or more parameters that the method accepts, and you can make the parameters optional by defining defaults.

Class methods (cont.)

We've defined a new class, `MyClass`, with a single class method:

```
class MyClass

  def self.my_class_method(p1, p2)
    puts "Hello from MyClass!"
    puts "My parameters: #{p1}, #{p2}"
  end

end
```

Once a class method is defined, you can call it directly on the class:

```
MyClass.my_class_method(1, 2)
```

```
Hello from MyClass!
My parameters: 1, 2
```

Perhaps that syntax for calling a class method looks familiar to you…

```
MyClass.new
```

That's right, `new` is a class method! If you think about it, that makes sense; `new` can't be an *instance* method, because you're calling it to *get* an instance in the first place! Instead, you have to ask the *class* for a new instance of itself.

Now that we know how to create class methods, let's see if we can write some factory methods that will create new `HourlyEmployee` objects with the pay rate and hours per week already populated for us. We need methods to set up predefined pay and hours for three positions: cashier, janitor, and security guard.

```
class HourlyEmployee < Employee
  ...
  def self.security_guard(name)
    HourlyEmployee.new(name, 19.25, 30)
  end

  def self.cashier(name)
    HourlyEmployee.new(name, 12.75, 25)
  end

  def self.janitor(name)
    HourlyEmployee.new(name, 10.50, 20)
  end
  ...
end
```

Accept the employee name as a parameter.

Use the given name to construct an employee.

Use predefined hourly_wage and hours_per_week for each employee type.

Same for the cashiers.

Same for the janitors.

We won't know the name of the employee in advance, so we accept that as a parameter to each of the class methods. We *do* know the values for `hourly_wage` and `hours_per_week` for each employee position, though. We pass those three arguments to the `new` method for the class, and get a new `HourlyEmployee` object back. That new object is then returned from the class method.

Class methods (cont.)

Now, we can call the factory methods directly on the class, providing only the employee name.

```
angela = HourlyEmployee.security_guard("Angela Matthews")
edwin = HourlyEmployee.janitor("Edwin Burgess")
ivan = HourlyEmployee.cashier("Ivan Stokes")
```

The `HourlyEmployee` instances returned are fully configured with the name we provided, and the appropriate `hourly_wage` and `hours_per_week` for the position. We can begin printing pay stubs for them right away!

```
angela.print_pay_stub
edwin.print_pay_stub
ivan.print_pay_stub
```

```
Name: Angela Matthews
Pay This Period: $1155.00
Name: Edwin Burgess
Pay This Period: $420.00
Name: Ivan Stokes
Pay This Period: $637.50
```

In this chapter, you've learned that there are some pitfalls when creating new objects. But you've also learned techniques to ensure *your* objects are safe to use as soon as you make them. With well-designed `initialize` methods and factory methods, creating and configuring new objects is a snap!

Our complete source code


employees.rb

```
class Employee

  attr_reader :name

  def name=(name)
    if name == ""
      raise "Name can't be blank!"
    end
    @name = name
  end

  def initialize(name = "Anonymous")
    self.name = name
  end

  def print_name
    puts "Name: #{name}"
  end

end

class SalariedEmployee < Employee

  attr_reader :salary

  def salary=(salary)
    if salary < 0
      raise "A salary of #{salary} isn't valid!"
    end
    @salary = salary
  end

  def initialize(name = "Anonymous", salary = 0.0)
    super(name)
    self.salary = salary
  end

  def print_pay_stub
    print_name
    pay_for_period = (salary / 365.0) * 14
    formatted_pay = format("$%.2f", pay_for_period)
    puts "Pay This Period: #{formatted_pay}"
  end

end
```

The "name" attribute is inherited by both SalariedEmployee and HourlyEmployee.

The "initialize" methods of both SalariedEmployee and HourlyEmployee will call this method via "super".

The "print_pay_stub" methods of both SalariedEmployee and HourlyEmployee will call this method.

This attribute is specific to salaried employees.

Called when we call "SalariedEmployee.new".

Call the superclass's "initialize" method, passing only the name.

Set the salary ourselves, since it's specific to this class.

Have the superclass print the name.

Calculate 2 weeks' pay.

Format the pay with 2 decimal places.

Continued on next page!

employees.rb
(continued)

```
class HourlyEmployee < Employee

  def self.security_guard(name)
    HourlyEmployee.new(name, 19.25, 30)
  end
  def self.cashier(name)
    HourlyEmployee.new(name, 12.75, 25)
  end
  def self.janitor(name)
    HourlyEmployee.new(name, 10.50, 20)
  end

  attr_reader :hourly_wage, :hours_per_week

  def hourly_wage=(hourly_wage)
    if hourly_wage < 0
      raise "An hourly wage of #{hourly_wage} isn't valid!"
    end
    @hourly_wage = hourly_wage
  end

  def hours_per_week=(hours_per_week)
    if hours_per_week < 0
      raise "#{hours_per_week} hours per week isn't valid!"
    end
    @hours_per_week = hours_per_week
  end

  def initialize(name = "Anonymous", hourly_wage = 0.0, hours_per_week = 0.0)
    super(name)
    self.hourly_wage = hourly_wage
    self.hours_per_week = hours_per_week
  end

  def print_pay_stub
    print_name
    pay_for_period = hourly_wage * hours_per_week * 2
    formatted_pay = format("$%.2f", pay_for_period)
    puts "Pay This Period: #{formatted_pay}"
  end

end

jane = SalariedEmployee.new("Jane Doe", 50000)
jane.print_pay_stub

angela = HourlyEmployee.security_guard("Angela Matthews")
ivan = HourlyEmployee.cashier("Ivan Stokes")
angela.print_pay_stub
ivan.print_pay_stub
```

Define a new class method.

Create a new instance with the specified name, and a predefined hourly wage and hours per week.

Do the same as above for the other hourly employee types.

These attributes are specific to hourly employees.

Called when we call "HourlyEmployee.new".

Call the superclass's "initialize" method, passing only the name.

Set these ourselves, since they're specific to this class.

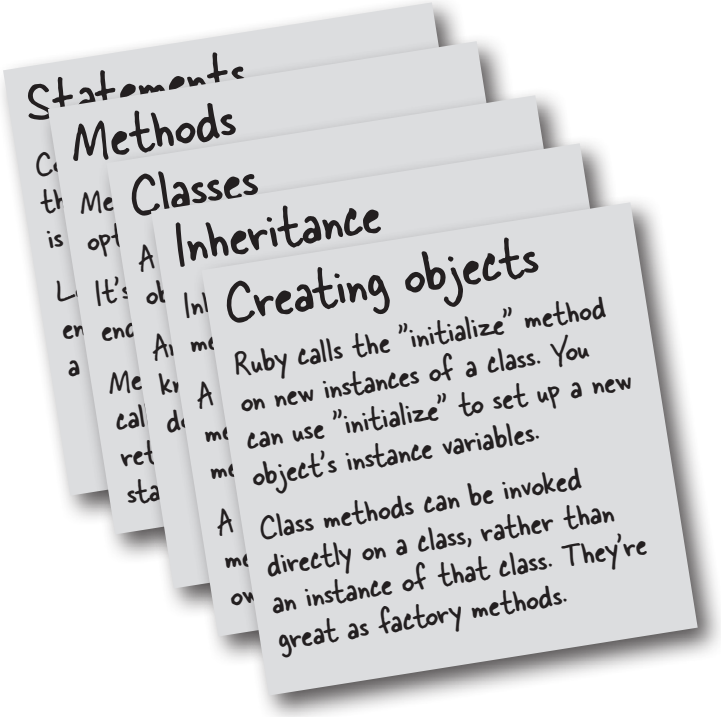
Have the superclass print the name.

Calculate 2 weeks' pay.

Format the pay with 2 decimal places.

Your Ruby Toolbox

That's it for Chapter 4! You've added the initialize method and class methods to your tool box.



BULLET POINTS

- Number literals *with* a decimal point will be treated as `Float` instances. *Without* a decimal point, they'll be treated as `Fixnum` instances.
- If either operand in a mathematical operation is a `Float`, the result will be a `Float`.
- The `format` method uses format sequences to insert formatted values into a string.
- The format sequence type indicates the type of value that will be inserted. There are types for floating-point numbers, integers, strings, and more.
- The format sequence width determines the number characters a formatted value will take up within the string.
- The value `nil` represents *nothing* - the *absence* of a value.
- Operators such as `+`, `-`, `*`, and `/` are implemented as methods in Ruby. When an operator is encountered in your code, it's converted into a method call.
- Within instance methods, the `self` keyword refers to the instance that the method is being called on.
- If you don't specify a receiver when calling an instance method, the receiver defaults to `self`.
- Within a class body, you can use either `def ClassName.method_name` or `def self.method_name` to define a class method.

5 arrays and blocks

It's Already Written

A whole lot of programming deals with lists of things. Lists of addresses. Lists of phone numbers. Lists of products. Matz, the creator of Ruby, knew this. So he worked *really hard* to make sure that working with lists in Ruby is *really easy*.

First, he ensured that **arrays**, which keep track of lists in Ruby, have lots of *powerful methods* to do almost anything you might need with a list.

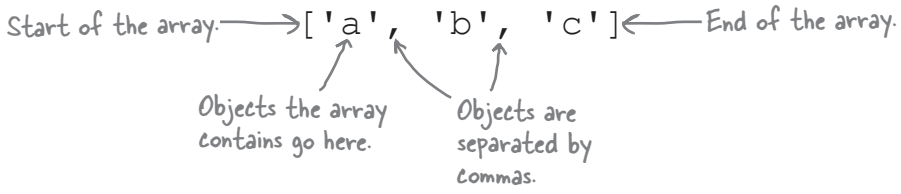
Second, he realized that writing code to *loop over a list* to do something with each item, although tedious, is something developers were doing *a lot*. So he added **blocks** to the language, and removed the need for all that looping code. What is a block, exactly? Read on to find out...

Arrays

Your new client is working on an invoicing program for an online store. They need three different methods, each of which works with the prices on an order. The first method needs to add all the prices together to calculate a total. The second will process a refund to the customer's account. And the third will take 1/3 off each price, and display the discount.

Hmm, so you have a list of prices (a *collection* of them, if you will), and you don't know in advance how many there will be... That means you can't use variables to store them - there's no way to know how many variables to create. You're going to need to store the prices in an *array*.

An **array** is used to hold a collection of objects. The collection can be any size you need.



Let's create an array to hold the prices from our first order now.

```
prices = [2.99, 25.00, 9.99]
```

You don't have to know an array's entire contents at the time you create it, though. You can also manipulate arrays *after* creating them...

Accessing arrays

So now we've got a place to store all our item prices. To retrieve the prices we stored in the array, we first have to specify which one we want.

Items in an array are numbered from left to right, starting with 0. This is called the array **index**.

To retrieve an item, you specify the integer index of the item you want within square brackets:

```
prices[0]   <- First item.
prices[1]   <- Second item.
prices[2]   <- Third item.
```

So we can print out elements from our array like this.

```
puts prices[0]
puts prices[2]
puts prices[1]
```

```
3.99
25.0
8.99
```

You can assign to a given array index with =, much like assigning to a variable.

(The "p" and "inspect" methods are useful for arrays, too!)

```
prices[0] = 0.99
prices[1] = 1.99
prices[2] = 2.99
p prices
```

```
[0.99, 1.99, 2.99]
```

If you assign to an index that's beyond the end of an array, the array will grow as necessary.

```
prices[3] = 3.99
p prices
```

Here's the new element.

```
[0.99, 1.99, 2.99, 3.99]
```

If you assign to an element that's *way* beyond the end of an array, it will still grow to accommodate your assignment. There just won't be anything at the intervening indexes.

```
prices[6] = 6.99
p prices
```

"nil" means "there's nothing here"!

Here's the element we assigned to.

```
[0.99, 1.99, 2.99, 3.99, nil, nil, 6.99]
```

Here, Ruby has placed `nil` (which, you may recall, represents the absence of a value) at the array indexes you haven't assigned to yet.

You'll also get `nil` back if you access an element that's beyond the end of an array.

```
p prices[7]
```

The array only extends through index 6!

```
nil
```

Arrays are objects, too!

Like everything else in Ruby, arrays are objects:

```
prices = [7.99, 25.00, 3.99, 9.99]
puts prices.class
```

```
Array
```

That means they have lots of useful methods attached directly to the array object. Here are some highlights...

Instead of using array indexes like `prices[0]`, there are easy-to-read methods you can use:

```
puts prices.first
```

```
7.99
```

```
puts prices.last
```

```
9.99
```

There are methods to find out an array's size:

```
puts prices.length
```

```
4
```

There are methods to let you search for values within the array:

```
puts prices.include?(25.00)
```

```
true
```

```
puts prices.find_index(9.99)
```

```
3
```

There are methods that will let you insert or remove elements, causing the array to grow or shrink:

```
prices.push(0.99)
p prices
```

```
[7.99, 25.0, 3.99, 9.99, 0.99]
```

```
prices.pop
p prices
```

```
[7.99, 25.0, 3.99, 9.99]
```

```
prices.shift
p prices
```

```
[25.0, 3.99, 9.99]
```

The << operator (which, like most operators, is actually a method behind the scenes) also adds elements:

```
prices << 5.99
prices << 8.99
p prices
```

```
[25.0, 3.99, 9.99, 5.99, 8.99]
```

Arrays have methods that can convert them to strings:

```
puts ["d", "o", "g"].join
puts ["d", "o", "g"].join("-")
```

```
dog
d-o-g
```

And strings have methods that can convert them to arrays:

```
p "d-o-g".chars
```

```
["d", "-", "o", "-", "g"]
```

```
p "d-o-g".split("-")
```

```
["d", "o", "g"]
```

Open a new terminal or command prompt, type "irb" and hit the Enter/Return key. For each of the Ruby expressions below, write your guess for what the result will be on the line below it. Then try typing the expression into `irb`, and hit Enter. See if your guess matches what `irb` returns!

```
mix = ["one", 2, "three", Time.new]
```

.....

```
mix.length
```

.....

```
mix[0]
```

.....

```
mix[1]
```

.....

```
mix[0].capitalize
```

.....

```
mix[1].capitalize
```

.....

```
letters = ["b", "c", "b", "a"]
```

.....

```
letters.shift
```

.....

```
letters
```

.....

```
letters.join("/")
```

.....

```
letters.pop
```

.....

```
letters
```

.....

Exercise Solution

Open a new terminal or command prompt, type "irb" and hit the Enter/Return key. For each of the Ruby expressions below, write your guess for what the result will be on the line below it. Then try typing the expression into `irb`, and hit Enter. See if your guess matches what `irb` returns!

```
mix = ["one", 2, "three", Time.new]
```

["one", 2, "three", 2014-01-01 11:11:11]

You can have instances of different classes in the same array!

```
mix.length
```

4

```
mix[0]
```

"one"

```
mix[1]
```

2

You can call methods directly on the objects you retrieve.

```
mix[0].capitalize
```

"One"

```
mix[1].capitalize
```

undefined method `capitalize' for 2:Fixnum

If you mix classes, watch what methods you call!

```
letters = ["b", "c", "b", "a"]
```

["b", "c", "b", "a"]

```
letters.shift
```

"b" ← "shift" removes the first element in the array, and returns it.

```
letters
```

["c", "b", "a"] ← "shift" permanently modifies the array.

```
letters.join("/")
```

"c/b/a"

```
letters.pop
```

"a" ← "pop" removes the last element in the array, and returns it.

```
letters
```

["c", "b"] ← "pop" also permanently modifies the array.

Looping over the items in an array

Right now, we can only access the particular array indexes that we specify in our code. Just to print all the prices in an array, we have to write this:

```
prices = [3.99, 25.00, 8.99]

puts prices[0]
puts prices[1]
puts prices[2]
```

First item.
Second item.
Third item.

That won't work when the arrays get very large, or when we don't know their size beforehand.

But we can use a `while` loop to process *all* of an array's elements, one at a time.

```
index = 0
while index < prices.length
  puts prices[index]
  index += 1
end
```

Start with index 0.
Loop until we reach the end of the array.
Access the element at the current index.
Move to the next array element.

```
3.99
25.0
8.99
```

Watch it!

Calling the `length` instance method on an array gets you the number of elements it holds, not the index of the last element.

So this code won't get you the last element:

```
p prices[prices.length]
```

```
nil
```

But this code will:

```
p prices[prices.length - 1]
```

```
8.99
```

Likewise, a loop like this will go beyond the end of the array:

```
index = 0
while index <= prices.length
  puts prices[index]
  index += 1
end
```

We don't want an index equal to the length!

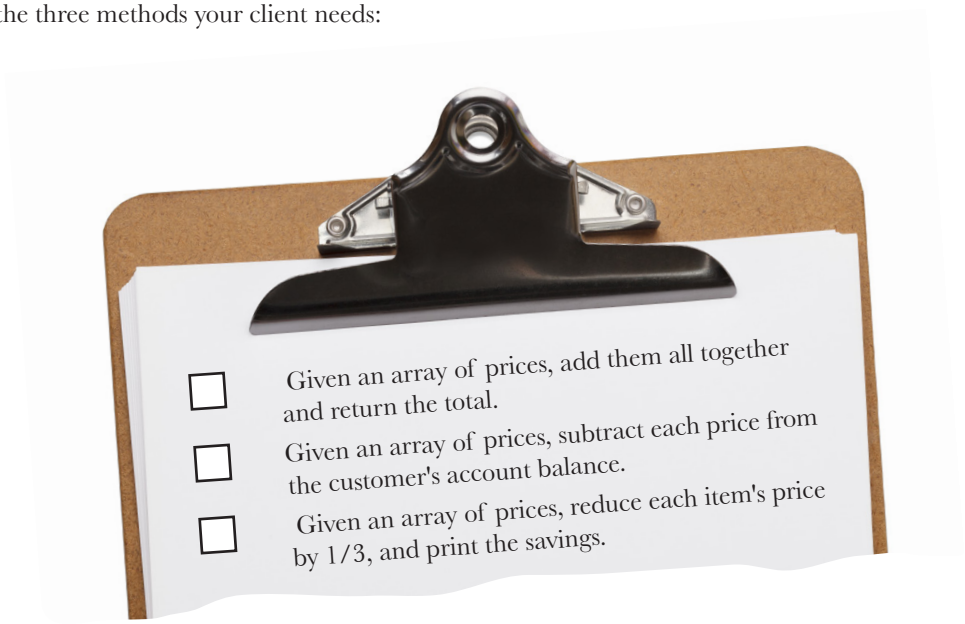
*Because **indexes start with zero**, you need to ensure you're working with index numbers **less than** `prices.length`:*

```
index = 0
while index < prices.length
  puts prices[index]
  index += 1
end
```

We want indexes LESS than the length.

The repeating loop

Now that we understand how to store the prices from an order in an array, and how to use a `while` loop to process each of those prices, it's time to work on the three methods your client needs:



The first requested feature is the ability to take these prices and total them. We'll create a method that keeps a running total of the amounts in an array. It will loop over each element in the array, and add it to a total (which we'll keep in a variable). After all the elements are processed, the method will return the total.

```
def total(prices)
  amount = 0
  index = 0
  while index < prices.length
    amount += prices[index]
    index += 1
  end
  amount
end

prices = [3.99, 25.00, 8.99]

puts format("%.2f", total(prices))
```

The total starts at 0.

Start at the first array index.

While we're still within the array...

Add the current price to the total.

Move to the next price.

Return the total.

Create an array holding prices from our order.

```
37.98
```

Pass our array of prices to the method, and format the result.

Ensure the correct number of decimal places are shown.

The repeating loop (cont.)

We need a second method that can process a refund for orders. It needs to loop through each item in an array, and subtract the amount from the customer's account balance.

```
def refund(prices)
  amount = 0
  index = 0
  while index < prices.length
    amount -= prices[index]
    index += 1
  end
  amount
end

puts format("%.2f", refund(prices))
```

The total starts at 0.

Start at the first array index.

While we're still within the array...

Subtract the current price.

Move to the next price.

Return the total refund.

Pass our array of prices to the method, and format the result.

```
-37.98
```

Lastly, we need a third method that will reduce each item's price by 1/3 and print the savings.

```
def show_discounts(prices)
  index = 0
  while index < prices.length
    amount_off = prices[index] / 3.0
    puts format("Your discount: $%.2f", amount_off)
    index += 1
  end
end

show_discounts(prices)
```

Start at the first array index.

While we're still within the array...

Determine discount for the current price.

Format the discount..

Move to the next price.

Pass our array of prices to the method.

```
Your discount: $1.33
Your discount: $8.33
Your discount: $3.00
```

That wasn't so bad! Looping over the items in the array let us implement all 3 of the methods your client needs!

- [x] Given an array of prices, add them all together and return the total.
- [x] Given an array of prices, subtract each price from the customer's account balance.
- [x] Given an array of prices, reduce each item's price by 1/3, and print the savings.

The repeating loop (cont.)

If we look at the three methods together, though, you'll notice there's a *lot* of duplicated code. And it all seems to be related to looping through the array of prices. We've highlighted the duplicated lines below.

Highlighted lines are duplicated among the 3 methods.

This line in the middle differs, though...

Differs...

Differs...

```
def total(prices)
  amount = 0
  index = 0
  while index < prices.length
    amount += prices[index]
    index += 1
  end
  amount
end

def refund(prices)
  amount = 0
  index = 0
  while index < prices.length
    amount -= prices[index]
    index += 1
  end
  amount
end

def show_discounts(prices)
  index = 0
  while index < prices.length
    amount_off = prices[index] / 3.0
    puts format("Your discount: $%.2f", amount_off)
    index += 1
  end
end
```

This is definitely a violation of the DRY (Don't Repeat Yourself) principle. We need to go back to the drawing board and refactor these methods.

Refactored

- ☐ Given an array of prices, add them all together and return the total.
- ☐ Given an array of prices, subtract each price from the customer's account balance.
- ☐ Given an array of prices, reduce each item's price by 1/3, and print the savings.

Eliminating repetition... the WRONG way...

Our `total`, `refund`, and `show_discounts` methods have a fair amount of repeated code related to looping over array elements. It would be nice if we could extract the repeated code out into another method, and have `total`, `refund`, and `show_discounts` call it.

But a method that combines *all* the logic in `total`, `refund`, and `show_variables` wouldn't look very pretty… Sure, the code for the loop *itself* is repeated, but the code in the *middle* of the loop is all different. Also, the `total` and `refund` methods need a *variable* to track the total amount, but `show_discounts` doesn't.

Let's show you exactly *how* awful such a method would look. (We want you to fully appreciate it when we show you a better solution.) We'll try writing a method with an extra parameter, `operation`. We'll use the value in `operation` to switch which variables we use, and what code gets run in the middle of the loop.

```
def do_something_with_every_item(array, operation)

  if operation == "total" or operation == "refund"
    amount = 0
  end
  index = 0
  while index < array.length

    if operation == "total"
      amount += array[index]
    elsif operation == "refund"
      amount -= array[index]
    elsif operation == "show discounts"
      amount_off = array[index] / 3.0
      puts format("Your discount: $%.2f", amount_off)
    end

    index += 1
  end

  if operation == "total" or operation == "refund"
    return amount
  end

end
```

"operation" should be set to "total", "refund", or "show discounts". Don't make a typo!

We won't need this variable for the "show discounts" operation.

Here's the start of the loop – no more duplication!

Use the correct logic for the current operation.

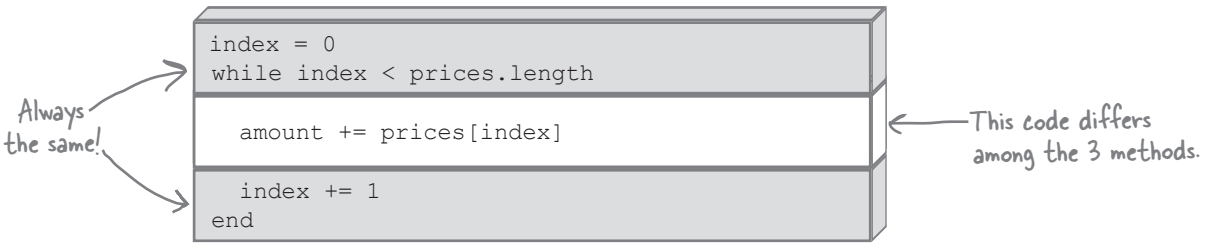
We don't return the value of this variable for "show discounts".

We warned you it would be bad. We've got `if` statements all over the place, each checking the value of the `operation` parameter. We've got an `amount` variable that we use in some cases, but not others. And we return a value in some cases, but not others. The code is ugly, and it's way too easy to make a mistake when calling it.

But if you *don't* write your code this way, how will you set up the variables you need prior to running the loop? And how will you execute the code you need in the *middle* of the loop?

Chunks of code?

The problem is that the repeated code at the top and bottom of each method *surrounds* the code that needs to change.

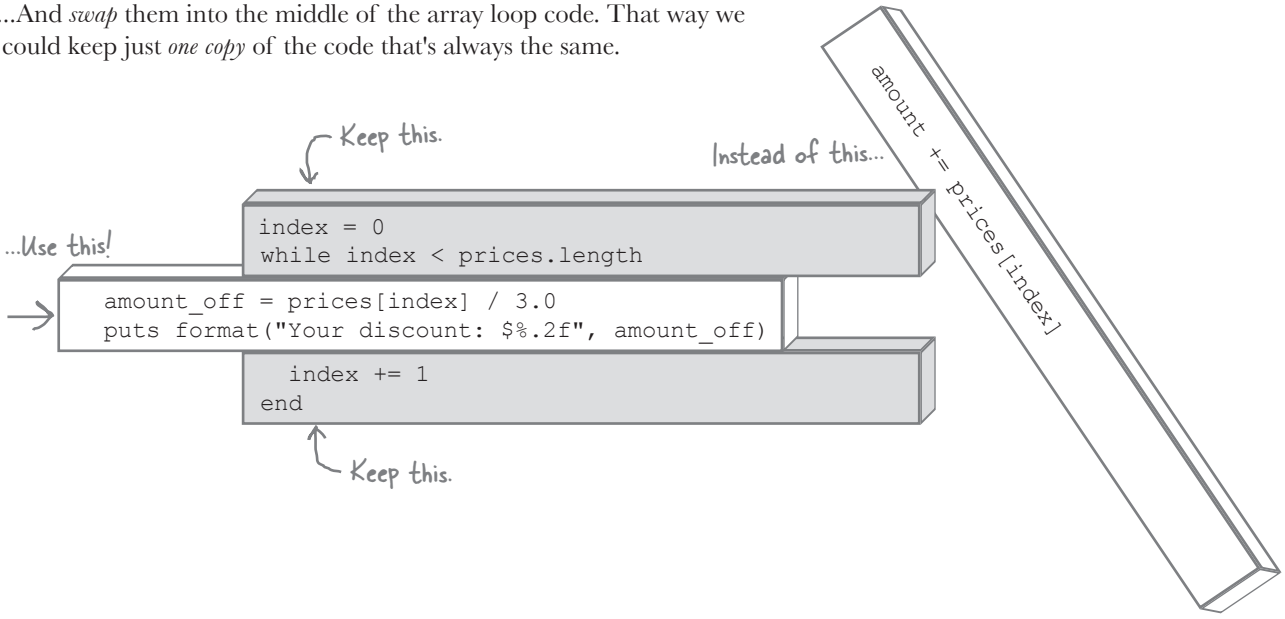


It would sure be nice if we could take those other chunks of code that *vary*...

```
amount -= prices[index]
```

```
amount_off = prices[index] / 3.0
puts format("Your discount: $%.2f", amount_off)
```

...And *swap* them into the middle of the array loop code. That way we could keep just *one copy* of the code that's always the same.



Blocks

It turns out we can do just that, using Ruby's blocks.

A **block** is a chunk of code that you associate with a method call. While the method runs, it can *invoke* (execute) the block one or more times. *Methods and blocks work in tandem to process your data.*

Blocks are mind-bending stuff. But stick with it!

We won't mince words. Blocks are going to be the hardest part of this book. Even if you've programmed in other languages, you've probably never seen anything like blocks. But *stick with it*, because the payoff is *big*.

Imagine if, for all the methods you have to write for the rest of your career, someone else *wrote half of the code for you*. For free. *They'd* write all the tedious stuff at the beginning and end, and just leave a little blank space in the middle for you to insert *your* code, the clever code, the code that runs your business.

If we told you that blocks can give you that, you'd be willing to do whatever it takes to learn them, right?

Well, here's what you'll have to do: be patient, and persistent. We're here to help. We'll look at each concept repeatedly, from different angles. We'll provide exercises for practice. Make sure to *do them*, because they'll help you understand and remember how blocks work.

A few hours of hard work now are going to pay dividends for the rest of your Ruby career, we promise. Let's get to it!

Defining a method that takes blocks

Blocks and methods work in tandem. In fact, you can't *have* a block without also having a method to accept it. So to start, let's define a method that works with blocks.

[On this page, we're going to show you how to use `&` to accept a block, and `call` to call it. This isn't the quickest way to work with blocks, but it DOES make it more obvious what's going on. We'll show you `yield`, which is more commonly used, in a few pages!]

Since we're just starting off, we'll keep it simple. The method will print a message, invoke the block it received, and print another message.

This method takes a block as an parameter!

```
def my_method(&my_block)
  puts "We're in the method, about to invoke your block!"
  my_block.call
  puts "We're back in the method!"
end
```

The "call" method calls the block.

If you place an ampersand (`&`) before the last parameter in a method definition, Ruby will expect a block to be attached to any call to that method. It will take the block, convert it to an object, and store it in that parameter.

```
def my_method(&my_block)
  ...
end
```

When you call this method with a block, it will be stored in "my_block".

Remember, a block is just a chunk of code that you pass into a method. To execute that code, stored blocks have a `call` instance method that you can call on them. The `call` method invokes the block's code.

```
def my_method(&my_block)
  ...
  my_block.call
  ...
end
```

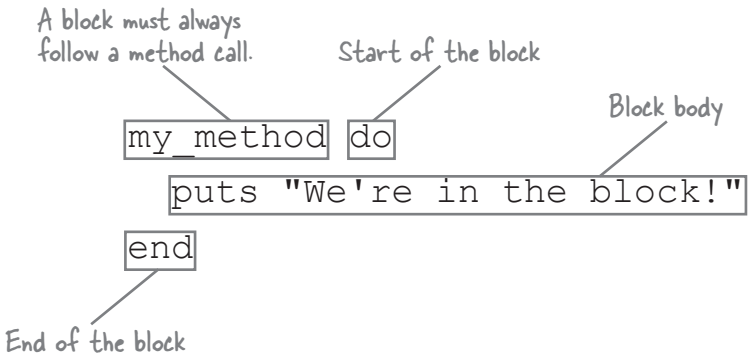
No ampersand; that's only used when defining the parameter.

Run the block's code.

OK, we know, you still haven't *seen* an actual block, and you're going crazy wondering what they look like. Now that the setup's out of the way, we can show you...

Your first block

Are you ready? Here it comes: your first glimpse of a Ruby block.



There it is! Like we said, a block is just a *chunk of code* that you pass to a method. We invoke `my_method`, which we just defined, and then place a block immediately following it. The method will receive the block in its `my_block` parameter.

- The start of the block is marked with the keyword `do`, and the end is marked by the keyword `end`.
- The block *body* consists of one or more lines of Ruby code between `do` and `end`. You can place any code you like here.
- When the block is called from the method, the code in the block body will be executed.
- After the block runs, control returns to the method that invoked it.

there are no Dumb Questions

Q: Can I use a block by itself?

A: No, that will give you a syntax error. Blocks are meant to be used together with methods.

```
do
  puts "Woooo!"
end
```

```
syntax error,
unexpected
keyword_do_block
```

This shouldn't ever get in your way; if you're writing a block that isn't associated with a method call, then whatever you're trying to express can probably be done with standalone Ruby statements.

So, we can call `my_method` and pass it the above block:

```
def my_method(&my_block)
  puts "We're in the method, about to invoke your block!"
  my_block.call
  puts "We're back in the method!"
end

my_method do
  puts "We're in the block!"
end
```

The call to my_method.

The block. It will be stored in the "my_block" parameter.

...And here's the output we'd see:

```
We're in the method, about to invoke your block!
We're in the block!
We're back in the method!
```

Flow of control between a method and block

We declared a method named `my_method`, called it with a block, and got this output:

```
my_method do
  puts "We're in the block!"
end
```

```
We're in the method, about to invoke your block!
We're in the block!
We're back in the method!
```

Let's break down what happened in the method and block, step by step.

1. The first `puts` statement in `my_method`'s body runs.

The method:

```
def my_method(&my_block)
  puts "We're in the method, about to invoke your block!"
  my_block.call
  puts "We're back in the method!"
end
```

The block:

```
do
  puts "We're in the block!"
end
```

```
We're in the method, about to invoke your block!
```

2. The `my_block.call` expression runs, and control is passed to the block. The `puts` expression in the block's body runs.

```
def my_method(&my_block)
  puts "We're in the method, about to invoke your block!"
  my_block.call
  puts "We're back in the method!"
end
```

```
do
  puts "We're in the block!"
end
```

```
We're in the block!
```

3. When the statements within the block body have all run, control returns to the method. The second call to `puts` within `my_method`'s body runs, and then the method returns.

```
def my_method(&my_block)
  puts "We're in the method, about to invoke your block!"
  my_block.call
  puts "We're back in the method!"
end
```

```
do
  puts "We're in the block!"
end
```

```
We're back in the method!
```

Calling the same method with different blocks

You can pass *many different blocks* to a *single method*.

We can pass different blocks to the method we just defined, and do different things:

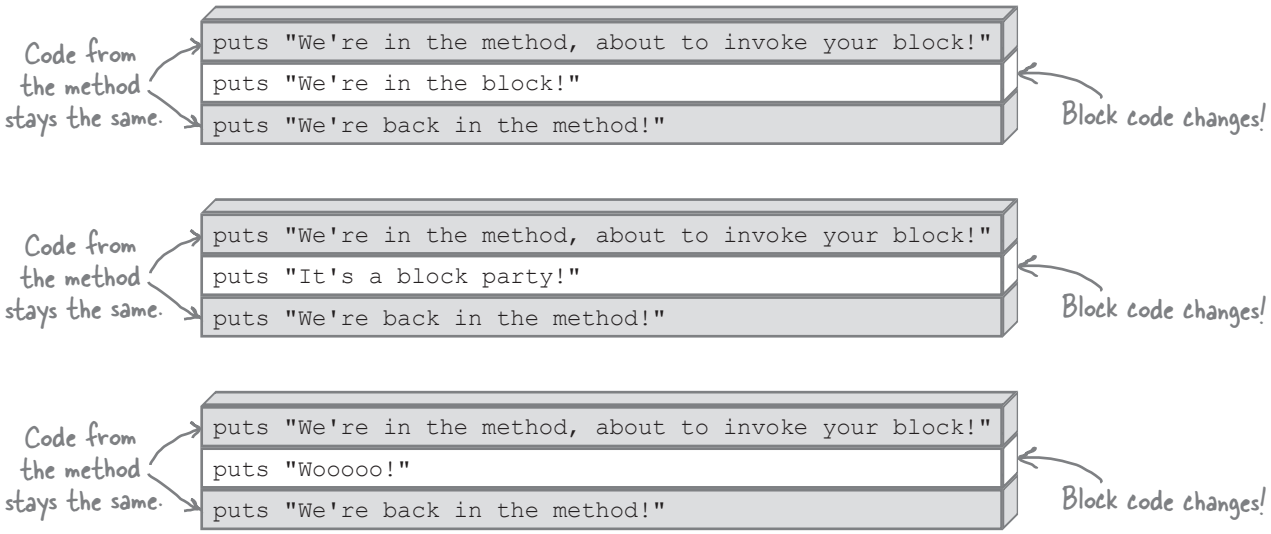
```
my_method do
  puts "It's a block party!"
end
```

```
We're in the method, about to invoke your block!
It's a block party!
We're back in the method!
```

```
my_method do
  puts "Wooooo!"
end
```

```
We're in the method, about to invoke your block!
Wooooo!
We're back in the method!
```

The code in the method is always the *same*, but you can *change* the code you provide in the block.



Calling a block multiple times

A method can invoke a block as many times as it wants.

This method is just like our previous one, except that it has *two* `my_block.call` expressions:

Declaring another method that takes a block.

Calling the method and passing it a block.

```
def twice(&my_block)
  puts "In the method, about to call the block!"
  my_block.call          # Call the block.
  puts "Back in the method, about to call the block again!"
  my_block.call          # Call the block AGAIN.
  puts "Back in the method, about to return!"
end

twice do
  puts "Woooo!"
end
```

The method name is appropriate: as you can see from the output, the method does indeed call our block twice!

```
In the method, about to call the block!
Woooo!
Back in the method, about to call the block again!
Woooo!
Back in the method, about to return!
```

1 Statements in the method body run until the first `my_block.call` expression is encountered. The block is then run. When it completes, control returns to the method.

```
def twice(&my_block)
  puts "In the method, about to call the block!"
  my_block.call
  puts "Back in the method, about to call the block again!"
  my_block.call
  puts "Back in the method, about to return!"
end

do
  puts "Woooo!"
end
```

2 The method body resumes running. When the second `my_block.call` expression is encountered, the block is run again. When it completes, control returns to the method so that any remaining statements there can run..

```
def twice(&my_block)
  puts "In the method, about to call the block!"
  my_block.call
  puts "Back in the method, about to call the block again!"
  my_block.call
  puts "Back in the method, about to return!"
end

do
  puts "Woooo!"
end
```

Block parameters

We learned back in Chapter 2 that when defining a Ruby method, you can specify that it will accept one or more parameters:

```
def print_parameters(p1, p2)
  puts p1, p2
end
```

You're probably also aware that you can pass arguments when calling the method that will determine the value of those parameters.

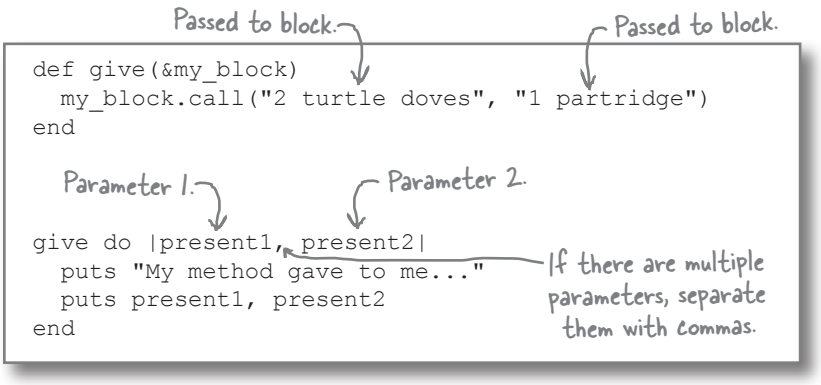
```
print_parameters("one", "two")
```

```
one
two
```

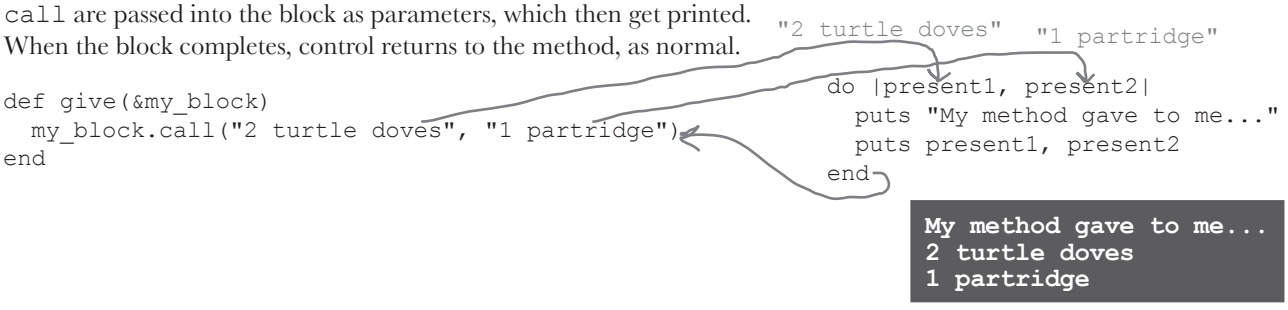
In a similar vein, a method can pass one or more arguments to a block. Block parameters are similar to method parameters; they're values that are passed in when the block is run, and that can be accessed within the block body.

Arguments to `call` get forwarded on to the block:

A block can accept one or more parameters from the method by defining them between vertical bar (|) characters at the start of the block:



So, when we call our method and provide a block, the arguments to `call` are passed into the block as parameters, which then get printed. When the block completes, control returns to the method, as normal.




```
My method gave to me...
2 turtle doves
1 partridge
```

there are no Dumb Questions

Q: Can I define a block once, and use it across many methods?

A: You can do something like this using Ruby *procs* (which are beyond the scope of this book). But it's not something you'll want to do in practice. A block is intimately tied to a particular method call, so much that a particular block will usually only work with a single method.

Q: Can a method take more than one block at the same time?

A: No. A single block is by far the most common use case, to the point that it's not worth the syntactic mess it would create for Ruby to support multiple blocks. If you ever want to do this, you could also use Ruby procs (but again, that's beyond the scope of this book).

Using the "yield" keyword

So far, we've been treating blocks like an argument to our methods. We've been declaring an extra method parameter that takes a block as an object, then using the `call` method on that object.

```
def twice(&my_block)
  my_block.call
  my_block.call
end
```

We mentioned that this wasn't the easiest way to accept blocks, though. Now, let's learn the less-obvious, but more-concise way: the `yield` keyword.

The `yield` keyword will find and invoke the block a method was called with—there's no need to declare a parameter to accept the block.

This method is functionally equivalent to the one above:

```
def twice
  yield
  yield
end
```

Just like with `call`, we can also give one or more arguments to `yield`, which will be passed to the block as parameters. Again, these methods are functionally equivalent:

```
def give(&my_block)
  my_block.call("2 turtle doves", "1 partridge")
end

def give
  yield "2 turtle doves", "1 partridge"
end
```

Declaring a `&block` parameter is useful in a few rare instances (which are beyond the scope of this book). But now that you understand what the `yield` keyword does, you should just use that in most cases. It's cleaner, and easier to read.

Block formats

So far, we've been using the `do ... end` format for blocks. Ruby has a second block format, though: "curly-brace" style. You'll see both formats being used "in the wild", so you should learn to recognize both.

```
def run_block
  yield
end

run_block do
  puts "do/end"
end
```

The do...end format we've been using so far.

"Curly-brace" format.

```
run_block { puts "brackets" }
```

Start of block. End of block.

Block body, just like with "do...end".

```
do/end
brackets
```

Aside from replacing `do` and `end` with curly brackets, the syntax and functionality are identical.

And just as `do ... end` blocks can accept parameters, so can curly-brace blocks:

```
def take_this
  yield "present"
end

take_this do |thing|
  puts "do/end block got #{thing}"
end

take_this { |thing| puts "brackets block got #{thing}" }
```

```
do/end block got present
brackets block got present
```

By the way, you've probably noticed that all our `do ... end` blocks span multiple lines, but our curly-brace blocks all appear on a single line… This follows another convention that much of the Ruby community has adopted. It's valid *syntax* to do it the other way:

Breaks convention!

```
take_this { |thing|
  puts "brackets: got #{thing}"
}
take_this do |thing| puts "do/end: got #{thing}" end
```

Breaks convention (and is really ugly)!

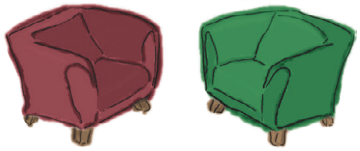
```
brackets: got present
do/end: got present
```

But not only is that out of line with the convention, it's really ugly.

Ruby blocks that fit on a single line should be surrounded with curly brackets. Blocks that span multiple lines should be surrounded with `do ... end`.

This is not the only convention for block formatting, but it is a common one.

Fireside Chats



Tonight's talk: **A method and a block talk about how they became associated with each other.**

Method:

Hello, Block! I called you here tonight so we could educate people on how blocks and methods work together. I've had people ask me exactly what you contribute to the relationship, and I think we can clear those questions up for everyone.

So most parts of a method's job are pretty clearly defined. My task, for example, is to loop through each item in an array.

Sure! It's a task *lots* of developers need done; there's a lot of demand for my services. But then I encounter a problem: *what do I do* with each of those array elements? Every developer needs something different! And that's where blocks come in...

I know another method that does nothing but open and close a file. He's *very* good at that part of the task. But he has *no clue* what to do with the *contents* of the file...

I handle the general work that's needed on a *wide variety* of tasks...

Block:

Sure, Method! I'm here to help whenever you call.

Right. Not a very glamorous job, but an important one.

Precisely. Every developer can write their *own* block that describes exactly what they need done with each element in the array.

...And so he calls on a block, right? And the block prints the file contents, or updates them, or whatever else the developer needs done. It's a great working relationship!

And I handle the logic that's specific to an *individual* task.

Here are three Ruby method definitions, each of which takes a block:

```
def call_block(&block)
  puts 1
  block.call
  puts 3
end
```

```
def call_twice
  puts 1
  yield
  yield
  puts 3
end
```

```
def pass_parameters_to_block
  puts 1
  yield 9, 3
  puts 3
end
```

And here are several calls to the above methods.
Match each method call to the output it produces.

```
call_block do
  puts 2
end
```

1
2
2
3

```
call_block { puts "two" }
```

1
2
3

```
call_twice { puts 2 }
```

1
3
3

```
call_twice do
  puts "two"
end
```

1
12
3

```
pass_parameters_to_block do |param1, param2|
  puts param1 + param2
end
```

1
two
3

```
pass_parameters_to_block do |param1, param2|
  puts param1 / param2
end
```

1
two
two
3

Here are three Ruby method definitions, each of which takes a block:

```
def call_block(&block)
  puts 1
  block.call
  puts 3
end
```

```
def call_twice
  puts 1
  yield
  yield
  puts 3
end
```

```
def pass_parameters_to_block
  puts 1
  yield 9, 3
  puts 3
end
```

And here are several calls to the above methods.
Match each method call to the output it produces.

```
call_block do
  puts 2
end
```

```
call_block { puts "two" }
```

```
call_twice { puts 2 }
```

```
call_twice do
  puts "two"
end
```

```
pass_parameters_to_block do |param1, param2|
  puts param1 + param2
end
```

```
pass_parameters_to_block do |param1, param2|
  puts param1 / param2
end
```

```
1
2
2
3
```

```
1
2
3
```

```
1
3
3
```

```
1
12
3
```

```
1
two
3
```

```
1
two
two
3
```

The "each" method

We had a lot to learn in order to get here: how to write a block, how a method calls a block, how a method can pass parameters to a block. And now, it's finally time to take a good, long look at the method that will let us get rid of that repeated loop code in our `total`, `refund`, and `show_discounts` methods. It's an instance method that appears on every `Array` object, and it's called `each`.

You've seen that a method can yield to a block more than once, with different values each time:

```
def my_method
  yield 1
  yield 2
  yield 3
end

my_method { |param| puts param }
```

```
1
2
3
```

The `each` method uses this feature of Ruby to loop through each of the items in an array, yielding them to a block, one at a time.

```
["a", "b", "c"].each { |param| puts param }
```

```
a
b
c
```

If we were to write our own method that works like `each`, it would look very similar to the code we've been writing all along:

```
class Array

  def each
    index = 0
    while index < self.length
      yield self[index]
      index += 1
    end
  end

end
```

This is just like the loops in our "total", "refund", and "show_discounts" methods!

Remember, "self" refers to the current object. In this case, the current array.

The key difference: we yield the current element to a block!

Then move to the next element, just like before.

We loop through each element in the array, just like in our `total`, `refund`, and `show_discounts` methods. The key difference is that instead of putting code to process the current array element in the *middle of the loop*, we use the `yield` keyword to *pass the element to a block*.

The "each" method, step-by-step

We're using the `each` method and a block to process each of the items in an array:

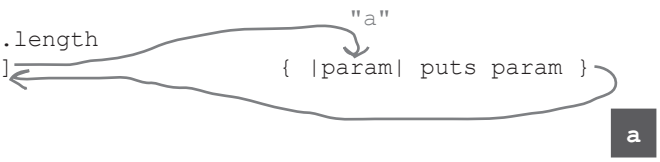
```
["a", "b", "c"].each { |param| puts param }
```

```
a
b
c
```

Let's go step-by-step through each of the calls to the block, and see what it's doing.

1. For the first pass through the `while` loop, `index` is set to `0`, so the first element of the array gets yielded to the block as a parameter. In the block body, the parameter gets printed. Then control returns to the method, `index` gets incremented, and the `while` loop continues.

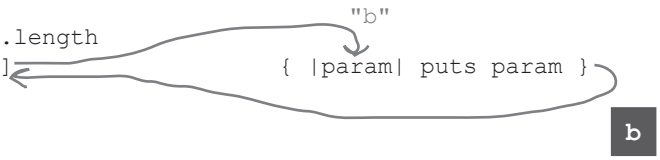
```
def each
  index = 0
  while index < self.length
    yield self[index]
    index += 1
  end
end
```




```
a
```

2. Now, on the second pass through the `while` loop, `index` is set to `1`, so the *second* element in the array will be yielded to the block as a parameter. As before, the block body prints the parameter, control then returns to the method, and the loop continues.

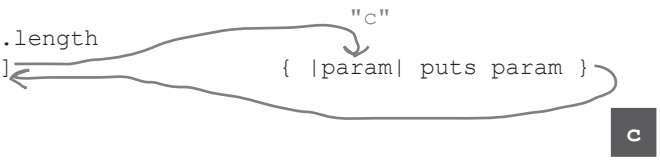
```
def each
  index = 0
  while index < self.length
    yield self[index]
    index += 1
  end
end
```




```
b
```

3. After the third array element gets yielded to the block for printing and control returns to the method, the `while` loop ends, because we've reached the end of the array. No more loop iterations means no more calls to the block; we're done!

```
def each
  index = 0
  while index < self.length
    yield self[index]
    index += 1
  end
end
```




```
c
```

That's it! We've found a method that can handle the repeated looping code, and yet allows us to run our own code in the middle of the loop (using a block). Let's put it to use!

DRYing up our code with "each" and blocks

Our invoicing system requires us to implement these three methods. All three of them have nearly identical code for looping through the contents of an array.

It's been difficult to get rid of that duplication, though, because all three methods have *different* code in the *middle* of that loop.

Highlighted lines are duplicated among the 3 methods.

This line in the middle differs, though...

```
def total(prices)
  amount = 0
  index = 0
  while index < prices.length
    amount += prices[index]
    index += 1
  end
  amount
end

def refund(prices)
  amount = 0
  index = 0
  while index < prices.length
    amount -= prices[index]
    index += 1
  end
  amount
end

def show_discounts(prices)
  index = 0
  while index < prices.length
    amount_off = prices[index] / 3.0
    puts format("Your discount: $%.2f", amount_off)
    index += 1
  end
end
```

Differs...

Differs...

But now, we've finally mastered the `each` method, which loops over the elements in an array, and passes them to a block for processing.

```
["a", "b", "c"].each { |param| puts param }
```

```
a
b
c
```

Let's see if we can use `each` to refactor our three methods and eliminate the duplication.

Refactored

- ☐ Given an array of prices, add them all together and return the total.
- ☐ Given an array of prices, subtract each price from the customer's account balance.
- ☐ Given an array of prices, reduce each item's price by 1/3, and print the savings.

DRYing up our code with "each" and blocks (cont.)

First up for refactoring is the `total` method. Just like the others, it contains code for looping over prices stored in an array. In the middle of that looping code, `total` adds the current price to a total amount.

The `each` method looks like it will be perfect for getting rid of the repeated looping code! We can just take the code in the middle that adds to the total, and place in it a block that's passed to `each`.

```
index = 0
while index < prices.length
  amount += prices[index]
  index += 1
end
```

From here...

To here!

```
prices.each { |price| amount += price }
```

We don't have to pull the item out of the array any more; "each" does that for us!

Let's re-define our `total` method to utilize `each`, then try it out.

```
def total(prices)
  amount = 0
  prices.each do |price|
    amount += price
  end
  amount
end

prices = [3.99, 25.00, 8.99]

puts format("%.2f", total(prices))
```

Start the total at 0.

Process each price.

Add the current price to the total.

Return the final total.

```
37.98
```

Perfect! There's our total amount. The `each` method worked!

DRYing up our code with "each" and blocks (cont.)

For each element in the array, `each` passes it as a parameter to the block. The code in the block adds the current array element to the `amount` variable, and then control returns back to `each`.

```
prices = [3.99, 25.00, 8.99]
puts format("%.2f", total(prices))
```

```
37.98
```

1

```
def each
  index = 0
  while index < self.length
    yield self[index]
    index += 1
  end
end
```

```
3.99
do |price|
  amount += price
end
```

2

```
def each
  index = 0
  while index < self.length
    yield self[index]
    index += 1
  end
end
```

```
25.00
do |price|
  amount += price
end
```

3

```
def each
  index = 0
  while index < self.length
    yield self[index]
    index += 1
  end
end
```

```
8.99
do |price|
  amount += price
end
```

We've successfully refactored the `total` method!

But before we move on to the other two methods, let's take a closer look at how that `amount` variable interacts with the block.

Refactored

- [x] Given an array of prices, add them all together and return the total.
- [ ] Given an array of prices, subtract each price from the customer's account balance.
- [ ] Given an array of prices, reduce each item's price by 1/3, and print the savings.

Blocks and variable scope

We should point something out about our new `total` method. Did you notice that we use the `amount` variable both *inside* and *outside* the block?

```
def total(prices)
  amount = 0
  prices.each do |price|
    amount += price
  end
  amount
end
```

As you may remember from chapter 2, local variables defined within a method are *out of scope* as soon as the method ends. You can't access variables that are local to the method from *outside* the method.

```
def my_method
  greeting = "hello"
end

my_method

puts greeting
```

Define the variable within the method.

Call the method.

Try to print the variable.

```
undefined local variable
or method `greeting'
```

The same is true of blocks, *if* you define the variable for the first time *inside* the block.

```
def run_block
  yield
end

run_block do
  greeting = "hello"
end

puts greeting
```

Define the variable within the block.

Try to print the variable.

```
undefined local variable
or method `greeting'
```

But, if you define a variable *before* a block, you can access it *inside* the block body. You can *also* continue to access it *after* the block ends!

```
greeting = nil

run_block do
  greeting = "hello"
end

puts greeting
```

Define the variable BEFORE the block.

Assign a new value within the block.

Print the variable.

```
hello
```

Blocks and variable scope (cont.)

Since Ruby blocks can access variables declared outside the block body, our `total` method is able to use `each` with a block to update the `amount` variable.

We can call `total` like this:

```
total([3.99, 25.00, 8.99])
```

```
def total(prices)
  amount = 0
  prices.each do |price|
    amount += price
  end
  amount
end
```

The `amount` variable is set to `0`, and then `each` is called on the array. Each of the values in the array are passed to the block. Each time the block is called, `amount` is updated:

1

```
def each
  index = 0
  while index < self.length
    yield self[index]
    index += 1
  end
end
```

```
3.99
do |price|
  amount += price
end
```

Updated from 0 to 3.99

2

```
def each
  index = 0
  while index < self.length
    yield self[index]
    index += 1
  end
end
```

```
25.00
do |price|
  amount += price
end
```

Updated from 3.99 to 28.99

3

```
def each
  index = 0
  while index < self.length
    yield self[index]
    index += 1
  end
end
```

```
8.99
do |price|
  amount += price
end
```

Updated from 28.99 to 37.98

When the `each` method completes, `amount` is still set to that final value, `37.98`. It's that value that gets returned from the method.

there are no Dumb Questions

Q: Why can blocks access variables that were declared outside their bodies, when methods can't? Isn't that unsafe?

A: A method can be accessed from other places in your program, far from where it was declared (maybe even in a different source file). A block, by contrast, is normally accessible only during the method call it's associated with. A block, and the variables it has access to, are all kept in the *same place* in your code. That means you can easily see all the variables a block is interacting with, meaning that accessing them is less prone to nasty surprises.

Using "each" with the "refund" method

We've revised the `total` method to get rid of the repeated loop code. We need to do the same with the `refund` and `show_discounts` methods, and then we'll be done!

The process of updating the `refund` method is very similar to the process we used for `total`. We simply take the specialized code from the middle of the generic loop code, and move it to a block that's passed to `each`.

```
def refund(prices)
  amount = 0
  index = 0
  while index < prices.length
    amount -= prices[index]
    index += 1
  end
  amount
end
```

From here...

To here!

```
def refund(prices)
  amount = 0
  prices.each do |price|
    amount -= price
  end
  amount
end
```

Again, we don't have to pull the item out of the array; "each" gets it for us!

Much cleaner, and calls to the method still work just the same as before!.

```
prices = [3.99, 25.00, 8.99]
puts format("%.2f", refund(prices))
```

```
-37.98
```

Within the call to `each` and the block, the flow of control looks very similar to what we saw in the `total` method:

1

```
def each
  index = 0
  while index < self.length
    yield self[index]
    index += 1
  end
end
```

```
3.99
do |price|
  amount -= price
end
```

Updated from 0 to -3.99

2

```
def each
  index = 0
  while index < self.length
    yield self[index]
    index += 1
  end
end
```

```
25.00
do |price|
  amount -= price
end
```

Updated from -3.99 to -28.99

3

```
def each
  index = 0
  while index < self.length
    yield self[index]
    index += 1
  end
end
```

```
8.99
do |price|
  amount -= price
end
```

Updated from -28.99 to -37.98

Using "each" with our last method

One more method, and we're done! Again, with `show_discounts`, it's a matter of taking the code out of the middle of the loop, and moving it into a block that's passed to `each`.

```
def show_discounts(prices)
  index = 0
  while index < prices.length
    amount_off = prices[index] / 3.0
    puts format("Your discount: $%.2f", amount_off)
    index += 1
  end
end
```

From here...

To here!

```
def show_discounts(prices)
  prices.each do |price|
    amount_off = price / 3.0
    puts format("Your discount: $%.2f", amount_off)
  end
end
```

Again, as far as users of your method are concerned, no one will notice you've changed a thing!

```
prices = [3.99, 25.00, 8.99]
show_discounts(prices)
```

```
Your discount: $1.33
Your discount: $8.33
Your discount: $3.00
```

Here's what the calls to the block look like:

1

```
def each
  index = 0
  while index < self.length
    yield self[index]
    index += 1
  end
end
```

3.99

```
prices.each do |price|
  amount_off = price / 3.0
  puts format("Your discount: $%.2f", amount_off)
end
```

```
Your discount: $1.33
```

2

```
def each
  index = 0
  while index < self.length
    yield self[index]
    index += 1
  end
end
```

25.00

```
prices.each do |price|
  amount_off = price / 3.0
  puts format("Your discount: $%.2f", amount_off)
end
```

```
Your discount: $8.33
```

3

```
def each
  index = 0
  while index < self.length
    yield self[index]
    index += 1
  end
end
```

8.99

```
prices.each do |price|
  amount_off = price / 3.0
  puts format("Your discount: $%.2f", amount_off)
end
```

```
Your discount: $3.00
```

Our complete invoicing methods

```
def total(prices)
  amount = 0
  prices.each do |price|
    amount += price
  end
  amount
end

def refund(prices)
  amount = 0
  prices.each do |price|
    amount -= price
  end
  amount
end

def show_discounts(prices)
  prices.each do |price|
    amount_off = price / 3.0
    puts format("Your discount: $%.2f", amount_off)
  end
end

prices = [3.99, 25.00, 8.99]

puts format("%.2f", total(prices))
puts format("%.2f", refund(prices))
show_discounts(prices)
```

Start the total at 0.

Process each price.

Add the current price to the total.

Return the final total.

Start the total at 0.

Process each price.

Refund the current price.

Return the final total.

Process each price.

Calculate discount.

Format and print the current discount.

Save this code in a file named `prices.rb`. Then try running it from the command line!

```
$ ruby prices.rb
37.98
-37.98
Your discount: $1.33
Your discount: $8.33
Your discount: $3.00
```

We've gotten rid of the repetitive loop code!

We've done it! We've refactored the repetitive loop code out of our methods! We were able to move the portion of the code that *differed* into blocks, and rely on a method, `each`, to replace the code that remained the *same*!

Refactored

- ☑ Given an array of prices, add them all together and return the total.
- ☑ Given an array of prices, subtract each price from the customer's account balance.
- ☑ Given an array of prices, reduce each item's price by 1/3, and print the savings.

Pool Puzzle

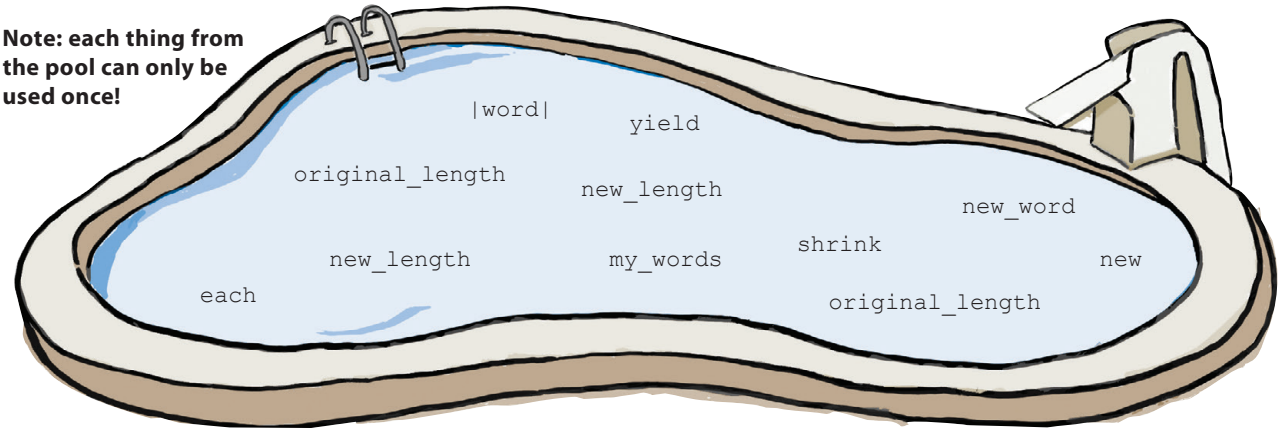
Your **job** is to take code snippets from the pool and place them into the blank lines in the code. **Don't** use the same snippet more than once, and you won't need to use all the snippets. Your **goal** is to make code that will run and produce the output shown.

```
def pig_latin(words)

  original_length = 0
  __________ = 0

  words.____ do ______
    puts "Original word: #{word}"
    _______________ += word.length
    letters = word.chars
    first_letter = letters.shift
    new_word = "#{letters.join}#{first_letter}ay"
    puts "Pig Latin word: #{________}"
    __________ += new_word.length
  end

  puts "Total original length: #{_______________}"
  puts "Total Pig Latin length: #{new_length}"

end

my_words = ["blocks", "totally", "rock"]
pig_latin(________)
```

Output:

```
File  Edit  Window  Help
Original word: blocks
Pig Latin word: locksbay
Original word: totally
Pig Latin word: otallytay
Original word: rock
Pig Latin word: ockray
Original total length: 17
Total Pig Latin length: 23
```

Note: each thing from the pool can only be used once!



Pool Puzzle Solution

```
def pig_latin(words)

  original_length = 0
  new_length = 0

  words.each do |word|
    puts "Original word: #{word}"
    original_length += word.length
    letters = word.chars
    first_letter = letters.shift
    new_word = "#{letters.join}#{first_letter}ay"
    puts "Pig Latin word: #{new_word}"
    new_length += new_word.length
  end

  puts "Total original length: #{original_length}"
  puts "Total Pig Latin length: #{new_length}"

end

my_words = ["blocks", "totally", "rock"]
pig_latin(my_words)
```

Output:

```
File Edit Window Help
Original word: blocks
Pig Latin word: locksbay
Original word: totally
Pig Latin word: otallytay
Original word: rock
Pig Latin word: ockray
Original total length: 17
Total Pig Latin length: 23
```

Utilities and Appliances, Blocks and Methods

Imagine two very different electric appliances: a mixer, and a drill. They have pretty different jobs: one is used for baking, the other for carpentry. And yet, they have a very similar need: electricity.

Now, imagine a world where, any time you wanted to use an electric mixer or drill, you had to wire your appliance into the power grid yourself. Sounds tedious (and fairly dangerous), right?

That's why, when your house was built, an electrician came and installed *power outlets* in every room. They provide the same utility (electricity) through the same interface (an electric plug) to very different appliances.

The electrician doesn't know the details of how your mixer or drill works, and he doesn't care. He just uses his skills and training to get the current safely from the electric grid to the outlet.

The designers of your appliance, likewise, have no idea how to wire a home for electricity. They just know how to take power from an outlet and use it to make their devices operate.

You can think of the author of a method that takes a block as being kind of like an electrician. They don't know how the block works, and they don't care. They just use their knowledge of a problem (say, looping through an array's elements) to get the neccessary data to the block.

```
def wire
  yield "current"
end
```

You can think of calling a method with a block as being kind of like plugging an appliance into an outlet. Like the outlet supplying power, the block parameters offer a safe, consistent interface for the method to supply data to your block. Your block doesn't have to worry about how the data got there, it just has to process the parameters it's been handed.

Like a power outlet.

```
wire { |power| puts "Using #{power} to turn drill bit" }
wire { |power| puts "Using #{power} to spin mixer" }
```

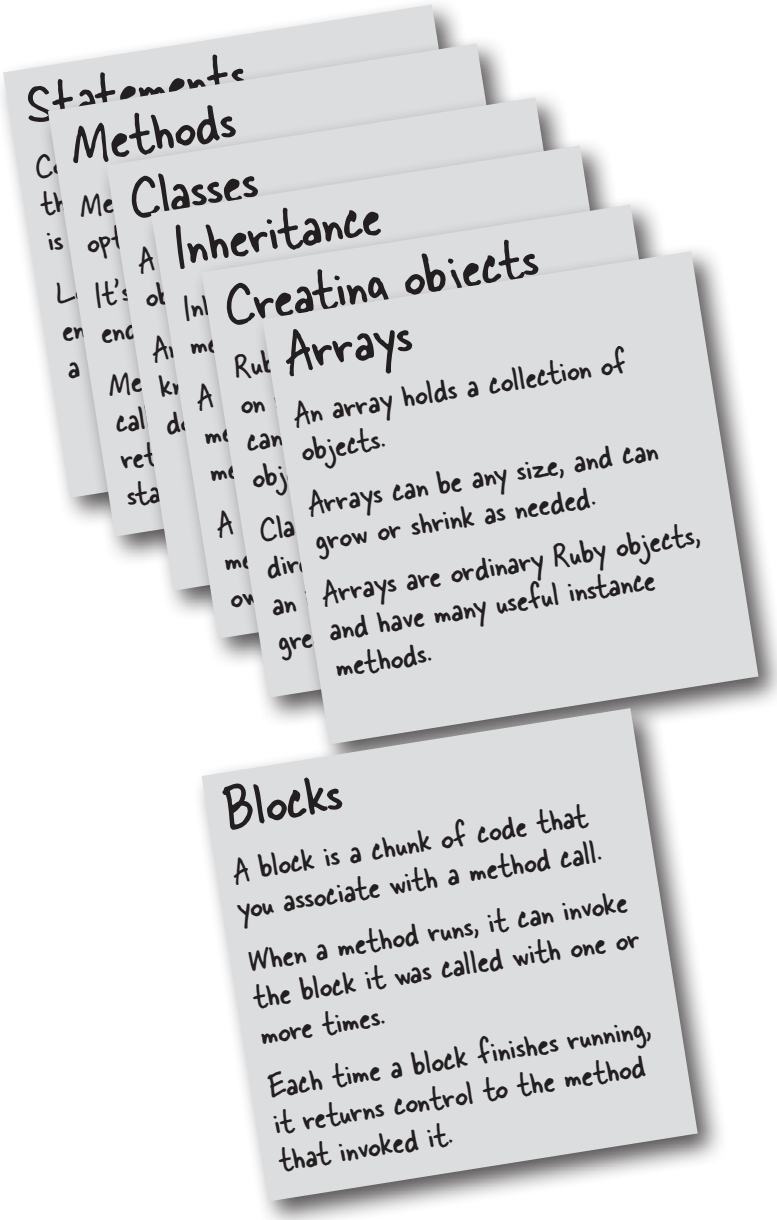
```
Using current to turn drill bit
Using current to spin mixer
```

Not every appliance uses electricity, of course; some require other utilities. There are stoves and furnaces that require gas. There are automatic sprinklers and spray nozzles that use water.

Just as there are many kinds of utilities to supply many kinds of appliances, there are many methods in Ruby that supply data to blocks. The `each` method was just the beginning. We'll be looking at some of the others over the next chapter.

Your Ruby Toolbox

That's it for Chapter 5! You've added arrays and blocks to your tool box.

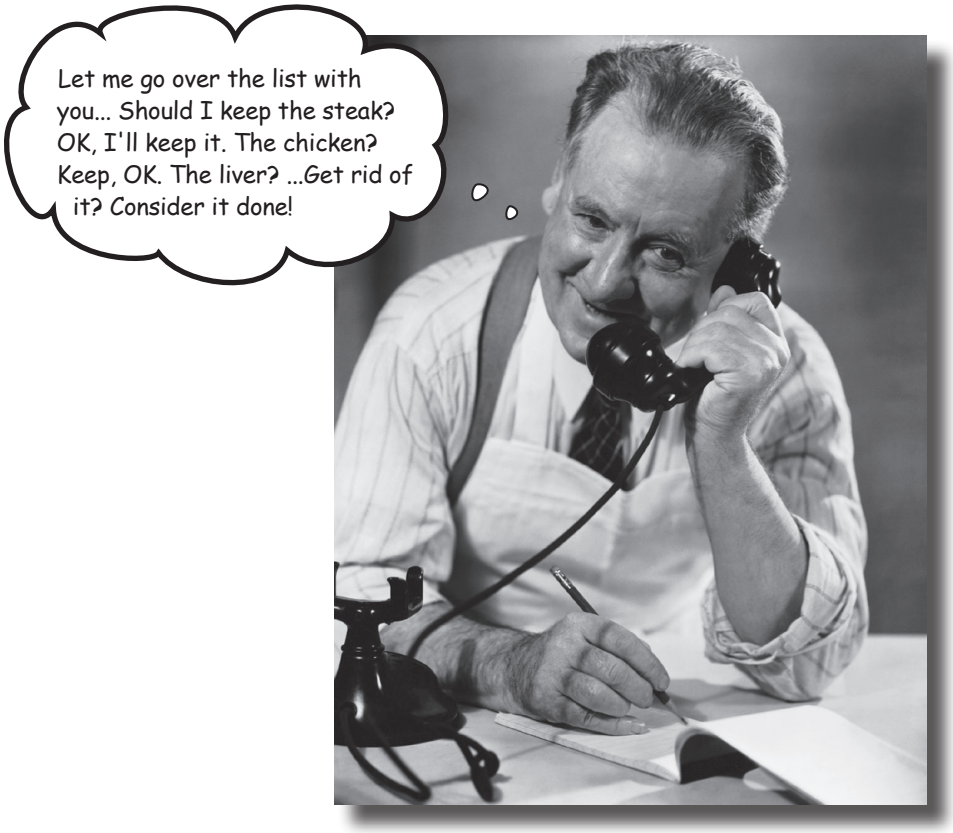


BULLET POINTS

- The index is a number that can be used to retrieve a particular item from an array. An array's index starts with `0`.
- You can also use the index to assign a new value to a particular array location.
- The `length` method can be used to get the number of items in an array.
- Ruby blocks are only allowed following a method call.
- There are two ways to write a block: with `do ... end` or with curly brackets (`{}`)
- You can specify that the last method parameter should be a block by preceding the parameter name with an ampersand (`&`).
- It's more common to use the `yield` keyword, though. You don't have to specify a method parameter to take the block - `yield` will find and invoke it for you.
- A block can receive one or more parameters from the method. Block parameters are similar to method parameters.
- A block can get or update the value of local variables that appear in the same scope as the block.
- Arrays have an `each` method which invokes a block once for each item in an array.

6 block return values

How Should I Handle This?



You've only seen a fraction of the power of blocks. Up until now, the *methods* have just been handing data off to a *block*., and expecting the block to do all the work with it. But a *block* can also return data back to the *method*. This feature lets the method get *directions* from the block, allowing it to do more of the work.

In this chapter, we'll show you some methods that will let you take a *big*, *complicated* collection, and use **block return values** to cut it down to size.

A big collection of words to search through

Word got out on the great work you did on the invoicing program, and your next client has already come in - a movie studio. They release a lot of films each year, and the task of making commercials for all of them is enormous. They want you to write a program that will go through the text of movie reviews, find adjectives that describe a given movie, and generate a collage of those adjectives:

The critics agree, Hindenburg is:

"Romantic"

"Thrilling"

"Explosive"

They've given you a sample text file to work off of, and they want you to see if you can make a collage for their new release, Truncated.

Looking at the file, though, you can see your work is cut out for you:

Lines are wrapped so they fit here...

```
Line 1  Normally producers and directors would stop this kind of
        garbage from getting published. Truncated is amazing in that
        it got past those hurdles.
Line 2      --Joseph Goldstein, "Truncated: Awful", New York Minute
Line 3  Guppies is destined to be the family film favorite of the
        summer.
Line 4      --Bill Mosher, "Go see Guppies", Topeka Obscurant
Line 5  Truncated is funny - it can't be categorized as comedy,
        romance, or horror, because none of those genres would want
        to be associated with it.
Line 6      --Liz Smith, "Truncated Disappoints", Chicago Some-Times
Line 7  I'm pretty sure this was shot on a mobile phone. Truncated
        is astounding in its disregard for filmmaking aesthetics.
Line 8      --Bill Mosher, "Don't See Truncated", Topeka Obscurant
```

These reviewer bylines need to be ignored

There are reviews for other movies mixed in here.

The adjectives are capitalized in the collage, but not in the text.

reviews.txt

It's true, this job is a bit complex. But don't worry, arrays and blocks can help!

A big collection of words to search through (cont.)

Let's break our tasks down into a checklist:

Five tasks to accomplish. Sounds simple enough. Let's get to it!

Opening the file

Our first task is to open the text file with the review contents. This is easier than it sounds - Ruby has a built-in class named `File` that represents files on disk. To open a file named "reviews.txt" in the current directory (folder) so you can read data from it, call the `open` method on the `File` class:

```
review_file = File.open("reviews.txt")
```

The `open` method returns a new `File` object. (It actually calls `File.new` for you, and returns the result of that.)

```
puts review_file.class
```

```
File
```

There are many different methods that you can call on this `File` instance, but the most useful one for our current purpose is the `readlines` method, which returns all the lines in the file as an array.

```
lines = review_file.readlines
puts "Line 4: #{lines[3]}"
puts "Line 1: #{lines[0]}"
```

(Wrapped to fit this page.)

```
Line 4:     --Bill Mosher, "Go see Guppies",
Topeka Obscurant
Line 1: Normally producers and directors would
stop this kind of garbage from getting published.
Truncated is amazing in that it got past those
hurdles.
```

Safely closing the file

We've opened the file, and read its contents. Your next step should be to *close the file*. Closing the file tells the operating system, "I'm done with this file; others can use it now."

```
review_file.close
```

Why are we so emphatic about doing this? Because *bad things happen* when you forget to close files.

You can get errors if your operating system detects that you have too many files open at once. If you try to read all the contents of the same file multiple times without closing it, it will appear to be empty on subsequent attempts (because you've already read to the end of the file, and there's nothing after that). If you're writing to a file, no other program can see the changes you made until you *close the file*. It is *very important* not to forget.

Are we making you nervous? Don't be. As usual, Ruby has a developer-friendly solution to this problem.

Safely closing the file, with a block

Ruby offers a way to open a file, do whatever you need with it, and *automatically* close it again when you're done with it. The secret is to call `File.open`... with *a block*!

We just change our code from this:

File object is returned and needs to be stored in a variable.

```
review_file = File.open("reviews.txt")
lines = review_file.readlines
review_file.close
```

Need to call "close" when done.

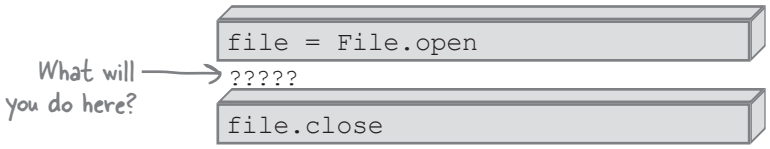
...To this!

File object is passed as a parameter to the block.

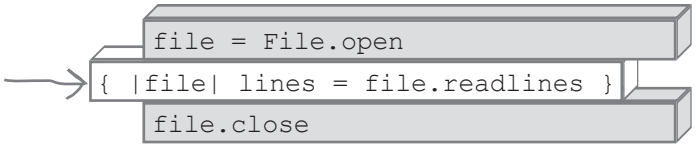
```
File.open("reviews.txt") do |review_file|
  lines = review_file.readlines
end
```

When the block finishes, the file is automatically closed for you!

Why does `File.open` use a block for this purpose? Well, the first and last steps in the process are pretty well-defined:



...But the creators of `File.open` have *no idea* what you intend to do with that file while it's open. Will you read it one line at a time? All at once? That's why they let *you* decide what to do, by passing in a block.



Don't forget about variable scope!

When we're *not* using a block, we can access the array of lines from the `File` object just fine.

```
review_file = File.open("reviews.txt")
lines = review_file.readlines
review_file.close

puts lines.length
```

```
8
```

Switching to the block form of `File.open` has introduced a problem, however. We store the array returned by `readlines` in a variable *within* the block, but we can't access it *after* the block.

```
File.open("reviews.txt") do |review_file|
  lines = review_file.readlines
end

puts lines.length
```

```
undefined local variable
or method `lines'
```

The problem is that we're *creating* the `lines` variable *within* the block. As we learned back in Chapter 5, any variable created within a block has a scope that's limited to within the block. Those variables can't be "seen" from outside the block.

But, as we also learned in Chapter 5, local variables declared *before* a block *can* be seen *within* the block body (and are still visible after the block, of course). So the simplest solution is to create the `lines` variable *before* declaring the block.

```
lines = []

File.open("reviews.txt") do |review_file|
  lines = review_file.readlines
end

puts lines.length
```

Still in scope!

```
8
```

Still in scope!

OK, we've safely closed the file, and we've got our review contents. What do we do with them? We'll be tackling that problem next.

there are no Dumb Questions

Q: How can `File.open` work both with a block *and* without one?

A: Within a Ruby method, you can call the `block_given?` method to check whether the method caller used a block, and change the method behavior accordingly.

If we were coding our own (simplified) version of `File.open`, it might look like this:

```
def File.open(name, mode)
  file = File.new(name, mode)
  if block_given?
    yield(file)
  else
    return file
  end
end
```

If a block is given, the file is passed to it for use within the block. If it's not, the file is returned.

Three Ruby scripts are below. Fill in the blank in each script so that it will run successfully and produce the specified output.

1

```
def yield_number
  yield 4
end

_____________________

yield_number { |number| array << number }

p array
```

```
[1, 2, 3, 4]
```

2

```
_______

[1, 2, 3].each { |number| sum += number }

puts sum
```

```
6
```

3

```
_____________

File.open("sample.txt") do |file|
  contents = file.readlines
end

puts contents
```

```
This is the first line in the file.
This is the second.
This is the last line.
```

Three Ruby scripts are below. Fill in the blank in each script so that it will run successfully and produce the specified output.

1

```
def yield_number
  yield 4
end

array = [1, 2, 3]

yield_number { |number| array << number }

p array
```

```
[1, 2, 3, 4]
```

2

```
sum = 0

[1, 2, 3].each { |number| sum += number }

puts sum
```

```
6
```

3

```
contents = []

File.open("sample.txt") do |file|
  contents = file.readlines
end

puts contents
```

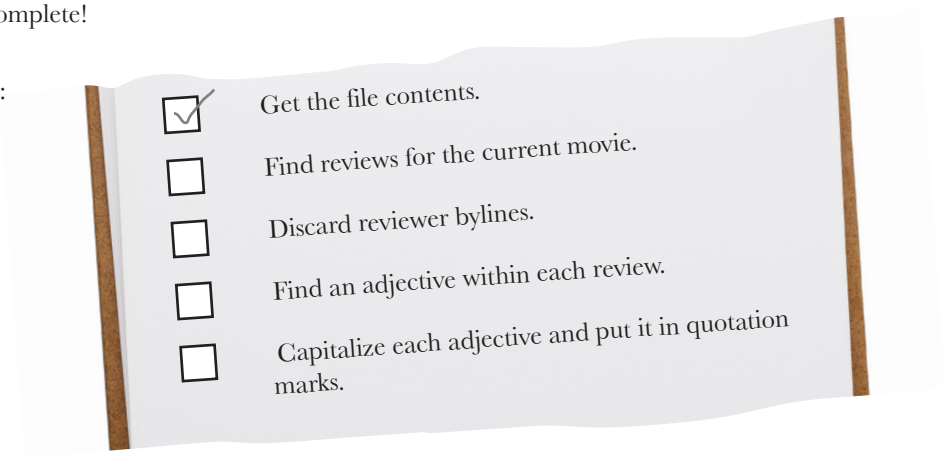
Any value at all will work here, since we assign a completely new value in the block.

```
This is the first line in the file.
This is the second.
This is the last line.
```

Finding array elements we want, with a block

We've opened the file, and used the `readlines` method to get an array with every line from the file in its own element. The first feature from our checklist is complete!

Let's see what remains:



It seems we can't expect the text file to contain only reviews for the movie we want. Reviews for other movies are mixed in there, too:

```
Line 1  Normally producers and directors would stop this kind of
        garbage from getting published. Truncated is amazing in that
        it got past those hurdles.
Line 2      --Joseph Goldstein, "Truncated: Awful", New York Minute
Line 3  Guppies is destined to be the family film favorite of the
        summer.
Line 4      --Bill Mosher, "Go see Guppies", Topeka Obscurant
Line 5  Truncated is funny - it can't be categorized as comedy,
        romance, or horror, because none of those genres would want
        to be associated with it.
Line 6      --Liz Smith, "Truncated Disappoints", Chicago Some-Times
...
```

A review for a completely different movie!

reviews.txt

Fortunately, it also looks like every review mentions the name of the movie at least once. We can use that fact to find only the reviews for our target movie.

```
Normally producers and directors would stop this kind of
garbage from getting published. Truncated is amazing in that it
got past those hurdles.
```

We can look for this within the string.

The verbose way to find array elements, using "each"

You can call the `include?` method on any instance of the `String` class to determine if it includes a substring (which you pass as an argument). Remember, by convention, methods that end in `?` return a boolean value. The `include?` method will return `true` if the string contains the specified substring, and `false` if it doesn't.

```
my_string = "I like apples, bananas, and oranges"
puts my_string.include?("bananas")
puts my_string.include?("elephants")
```

```
true
false
```

It doesn't matter if the substring you're looking for is at the beginning of the string, at the end, or somewhere in the middle; `include?` will find it.

So, here's one way you could select only the relevant reviews, using the `include?` method and the other techniques we've learned so far...

Our old code to read the file contents.

```
lines = []

File.open("reviews.txt") do |review_file|
  lines = review_file.readlines
end

relevant_lines = []

lines.each do |line|
  if line.include?("Truncated")
    relevant_lines << line
  end
end

puts relevant_lines
```

Remember to create the variable outside the block!

Process each line from the file.

The current line is passed to the block as a parameter.

Add the current line to the array of reviews.

Review for other movie removed!

```
Normally producers and directors would stop this kind of
garbage from getting published. Truncated is amazing in that
it got past those hurdles.
    --Joseph Goldstein, "Truncated: Awful", New York Minute
Truncated is funny - it can't be categorized as comedy,
romance, or horror, because none of those genres would want
to be associated with it.
    --Liz Smith, "Truncated Disappoints", Chicago Some-Times
I'm pretty sure this was shot on a mobile phone. Truncated
is astounding in its disregard for filmmaking aesthetics.
    --Bill Mosher, "Don't See Truncated", Topeka Obscurant
```

Introducing a faster method...

But actually, Ruby offers a much quicker way to do this. The `find_all` method uses a block to run a test against each element in an array. It returns a new array that contains only the elements for which the test returned a true value.

We can use the `find_all` method to achieve the same result, by calling `include?` in its block:

```
lines = []

File.open("reviews.txt") do |review_file|
  lines = review_file.readlines
end

relevant_lines = lines.find_all { |line| line.include?("Truncated") }
```

This shortened code works just as well: only lines that include the substring `"Truncated"` are copied to the new array!

```
puts relevant_lines
```

```
Normally producers and directors would stop this kind of
garbage from getting published. Truncated is amazing in that
it got past those hurdles.
    --Joseph Goldstein, "Truncated: Awful", New York Minute
Truncated is funny - it can't be categorized as comedy,
romance, or horror, because none of those genres would want
to be associated with it.
    --Liz Smith, "Truncated Disappoints", Chicago Some-Times
I'm pretty sure this was shot on a mobile phone. Truncated
is astounding in its disregard for filmmaking aesthetics.
    --Bill Mosher, "Don't See Truncated", Topeka Obscurant
```

Replacing six lines of code with a single line... Not bad, huh?

Uh, oh. Did we just blow your mind again?

We'll explain everything that one line of code is doing behind the scenes.

Over the next few pages, we'll walk you through everything you need in order to fully understand how `find_all` works. There are many other Ruby methods that work in a similar way, so trust us, the effort will be worth it!

Blocks have a return value

We just saw the `find_all` method. You pass it a block with selection logic, and `find_all` finds only the elements in an array that match the block's criteria.

```
lines.find_all { |line| line.include?("Truncated") }
```

By "elements that match the block's criteria", we mean elements for which the block *returns* a true value. The `find_all` method uses the *return value of the block* to determine which elements to keep, and which to discard.

As we've progressed, you've probably noticed a few similarities between blocks and methods...

Methods:

- Accept parameters
- Have a body that holds Ruby expressions
- Return a value

Blocks:

- Accept parameters
- Have a body that holds Ruby expressions
- Return a value

Wait, what? Do they?

That's right, just like methods, Ruby blocks return the value of the last expression they contain! It's returned to the method as the result of the `yield` keyword.

We can create a simple method that shows this in action, and then call it with different blocks to see their return values:

```
def print_block_result
  block_result = yield
  puts block_result
end

print_block_result { 1 + 1 }

print_block_result do
  "I'm not the last expression, so I'm not the return value."
  "I'm the result!"
end

print_block_result { "I hated Truncated".include?("Truncated") }
```

Assigns the result of the block to a variable.

```
2
I'm the result!
true
```

Blocks have a return value (cont.)

The method isn't limited to *printing* the block return value, of course. It can also do math with it:

```
def triple_block_result
  puts 3 * yield
end

triple_block_result { 2 }
triple_block_result { 5 }
```

```
6
15
```

...Or use it in a string:

```
def greet
  puts "Hello, #{yield}!"
end

greet { "Liz" }
```

```
Hello, Liz!
```

...Or use it in a conditional:

```
def alert_if_true
  if yield
    puts "Block returned true!"
  else
    puts "Block returned false."
  end
end

alert_if_true { 2 + 2 == 5 }
alert_if_true { 2 > 1 }
```

```
Block returned false.
Block returned true!
```

Up next, we'll take a detailed look at how `find_all` uses the block's return value to give you just the array elements you want.

We say that blocks have a "return value", but that doesn't mean you should use the `return` keyword.

Using the `return` keyword within a block isn't a syntax error, but we don't recommend it. Within a block body, the `return` keyword returns from the method where the block is being defined, not the block itself. It's very unlikely that this is what you want to do.

```
def print_block_value
  puts yield
end

def other_method
  print_block_value { return 1 + 1 }
end

other_method
```

The above code won't print anything, because `other_method` exits as the block is being defined.

If you change the block to simply use its last expression as a return value, then everything works as expected:

```
def other_method
  print_block_value { 1 + 1 }
end

other_method
```

```
2
```

there are no Dumb Questions

Q: Do *all* blocks return a value?

A: Yes! They return the result of the last expression in the block body.

Q: If that's true, then why didn't we learn about this sooner?

A: We haven't needed to. A block may `return` a value, but the associated method doesn't have to *use* it. The `each` method, for example, ignores the values returned from its block.

Q: Can I pass parameters to a block *and* use its return value?

A: Yes! You can pass parameters, use the return value, do both, or do neither; it's up to you.

```
def one_two
  result = yield(1, 2)
  puts result
end

one_two do |param1, param2|
  param1 + param2
end
```

Code Magnets

A Ruby program is all scrambled up on the fridge. Can you reconstruct the code snippets so that they produce the given output?

```
puts "Preheat oven to 375 degrees"
puts "Place #{ingredients} in dish"
puts "Bake for 20 minutes"
"rice, broccoli, and chicken"
"noodles, celery, and tuna"
def
end
=
do
end
yield
do
end
ingredients
make_casserole
make_casserole
make_casserole
```

Output:

```
File Edit Window Help
Preheat oven to 375 degrees
Place noodles, celery, and tuna in dish
Bake for 20 minutes
Preheat oven to 375 degrees
Place rice, broccoli, and chicken in dish
Bake for 20 minutes
```

Code Magnets Solution

A Ruby program is all scrambled up on the fridge. Can you reconstruct the code snippets so that they produce the given output?

```
def make_casserole
  puts "Preheat oven to 375 degrees"
  ingredients = yield
  puts "Place #{ingredients} in dish"
  puts "Bake for 20 minutes"
end
```

```
make_casserole do
  "noodles, celery, and tuna"
end
```

```
make_casserole do
  "rice, broccoli, and chicken"
end
```

Output:

```
File Edit Window Help
Preheat oven to 375 degrees
Place noodles, celery, and tuna in dish
Bake for 20 minutes
Preheat oven to 375 degrees
Place rice, broccoli, and chicken in dish
Bake for 20 minutes
```

How the method uses a block return value

We're close to deciphering how this snippet of code works:

```
lines.find_all { |line| line.include?("Truncated") }
```

The last step is understanding the `find_all` method. It passes each element in an array to a block, and builds a new array including only the elements for which the block returns a true value.

```
p [1, 2, 3, 4, 5].find_all { |number| number.even? }
p [1, 2, 3, 4, 5].find_all { |number| number.odd? }
```

```
[2, 4]
[1, 3, 5]
```

You can think of the values the block returns as a set of *instructions* for the method. The `find_all` method's job is to keep some array elements and discard others. But it relies on the block's return value to tell it which elements to keep.

Think of block return values as instructions from the block to the method.

All that matters in this selection process is the block's return value. The block body doesn't even have to use the parameter with the current array element (although in most practical programs, it will). If the block returns `true` for everything, *all* the array elements will be included...

```
p ['a', 'b', 'c'].find_all { |item| true }
```

```
["a", "b", "c"]
```

...If it returns `false` for everything, *none* of them will be.

```
p ['a', 'b', 'c'].find_all { |item| false }
```

```
[]
```

If we were to write our own version of `find_all`, it might look like this:

```
class Array
  def find_all
    matching_items = []
    self.each do |item|
      if yield(item)
        matching_items << item
      end
    end
    matching_items
  end
end
```

Create a new array to hold the elements for which the block returns "true".

Process each element.

Pass the element to the block. If the result is "true"...

Add it to the array of matching elements.

If this code looks familiar, it should. It's a more generalized version of our earlier code to find lines that were relevant to our target movie!

The old code:

```
relevant_lines = []
lines.each do |line|
  if line.include?("Truncated")
    relevant_lines << line
  end
end
puts relevant_lines
```

Putting it all together

Now that we know how the `find_all` method works, we're really close to understanding this code.

```
lines = []

File.open("reviews.txt") do |review_file|
  lines = review_file.readlines
end

relevant_lines = lines.find_all { |line| line.include?("Truncated") }
```

Here's what we've learned (not necessarily in order):

- The last expression in a block becomes its return value.

```
lines.find_all { |line| line.include?("Truncated") }
```

Result will be used as block return value.

- The `include?` method returns `true` if the string contains the specified substring, and `false` if it doesn't.

```
lines.find_all { |line| line.include?("Truncated") }
```

Returns true if line contains "Truncated".

- The `find_all` method passes each element in an array to a block, and builds a new array including only the elements for which the block returns a true value.

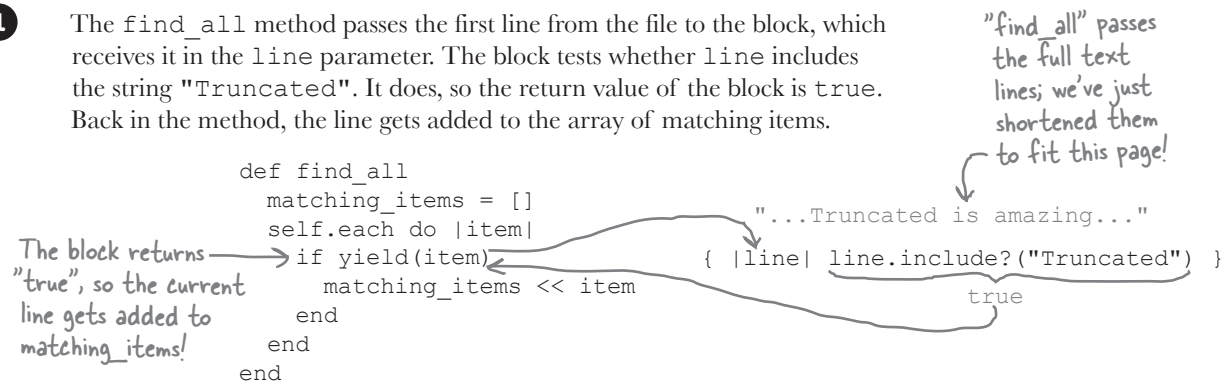
```
lines.find_all { |line| line.include?("Truncated") }
```

Result will be an array with all the elements of "lines" that contain string "Truncated".

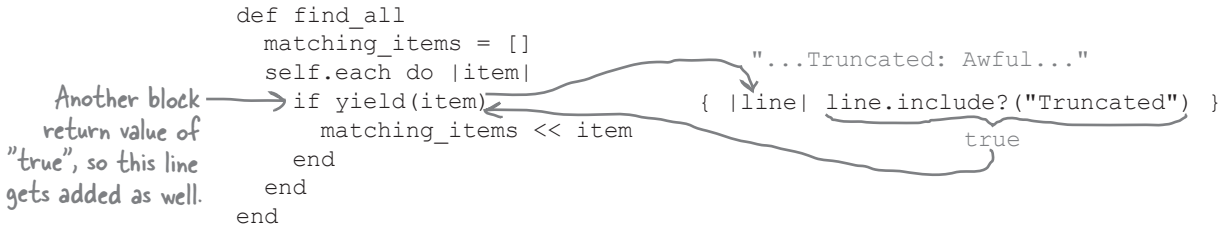
Let's look inside the `find_all` method and the block as they process the first few lines of the file, to see what they're doing...

A closer look at the block return values

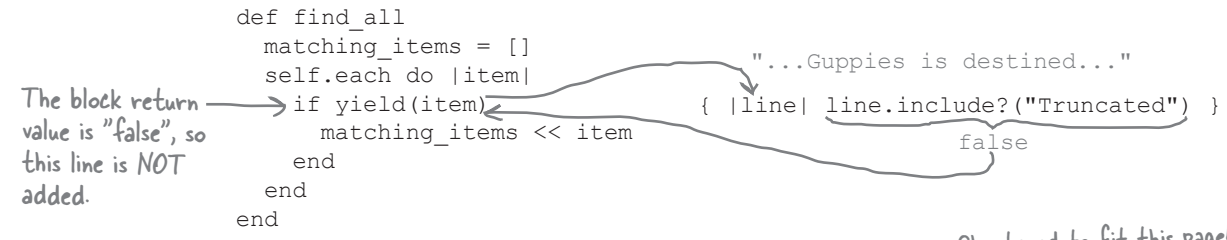
1. The `find_all` method passes the first line from the file to the block, which receives it in the `line` parameter. The block tests whether `line` includes the string `"Truncated"`. It does, so the return value of the block is `true`. Back in the method, the line gets added to the array of matching items.



2. The `find_all` method passes the second line from the file to the block. Again, the `line` block parameter includes the string `"Truncated"`, so the return value of the block is again `true`. Back in the method, this line also gets added to the array of matching items.



3. The *third* line from the file *doesn't* include the string `"Truncated"`, so the return value of the block is `false`. This line is *not* added to the array.



...And so on, through the rest of the lines in the file. The `find_all` method adds the current element to a new array if the block returns a true value, and skips it if the block returns a false value. The result is an array that contains only the lines that mention the movie we want!

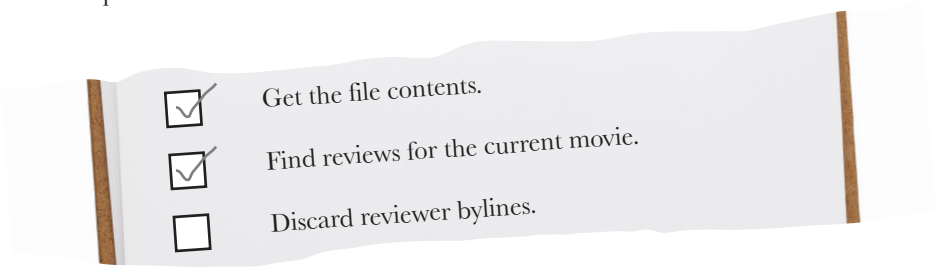
```
p relevant_lines
```

Shortened to fit this page!

```
["...Truncated is amazing...",
 "...Truncated: Awful...",
 "...Truncated is funny...",
 "...Truncated Disappoints...",
 "...Truncated is astounding...",
 "...Don't See Truncated..."]
```

Eliminating elements we don't want, with a block

Using the `find_all` method, we've successfully found all the reviews for our target movie, and placed them in the `relevant_lines` array. We can check another requirement off our list!



Our next requirement is to discard the reviewer bylines, because we're only interested in retrieving adjectives from the main text of each review.

We want to get rid of these:

```
Normally producers and directors would stop this kind of
garbage from getting published. Truncated is amazing in that
it got past those hurdles.
    --Joseph Goldstein, "Truncated: Awful", New York Minute
Truncated is funny - it can't be categorized as comedy,
romance, or horror, because none of those genres would want
to be associated with it.
    --Liz Smith, "Truncated Disappoints", Chicago Some-Times
...
```

Fortunately, they're clearly marked. Each one starts with the characters `"--"`, so it should be easy to use the `include?` method to determine if a string contains a byline.

Before, we used the `find_all` method to *keep* lines that included a particular string. The `reject` method is basically the opposite of `find_all` - it passes elements from an array to a block, and *rejects* an element if the block returns a true value. If `find_all` relies on the block to tell it which items to *keep*, `reject` relies on the block to tell it which items to *discard*.

If we were to implement our own version of `reject`, it would look very similar to `find_all`:

```
class Array
  def reject
    kept_items = []
    self.each do |item|
      unless yield(item)
        kept_items << item
      end
    end
    kept_items
  end
end
```

Create a new array to hold the elements for which the block returns "false".

Process each element.

Pass the element to the block. If the result is "false"...

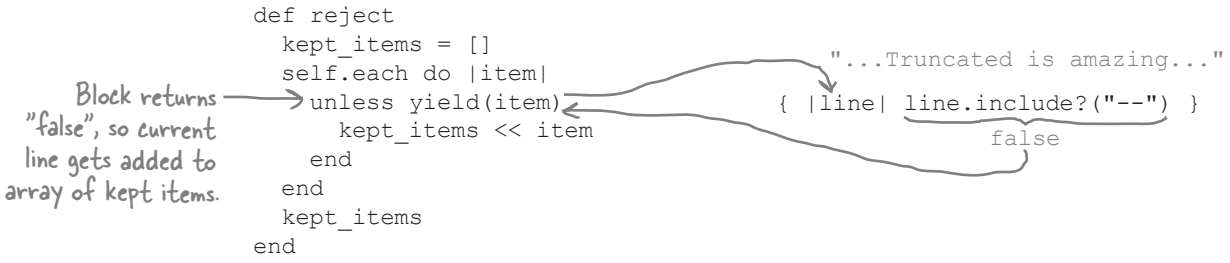
Add it to the array of kept elements.

The return values for "reject"

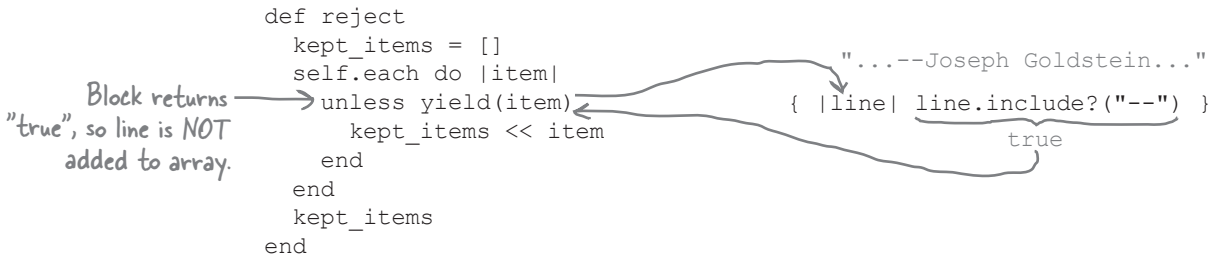
So `reject` works just like `find_all`, except that instead of *keeping* elements that the block returns a true value for, it *rejects* them. Using `reject`, it should be easy to get rid of the bylines!

```
reviews = relevant_lines.reject { |line| line.include?("--") }
```

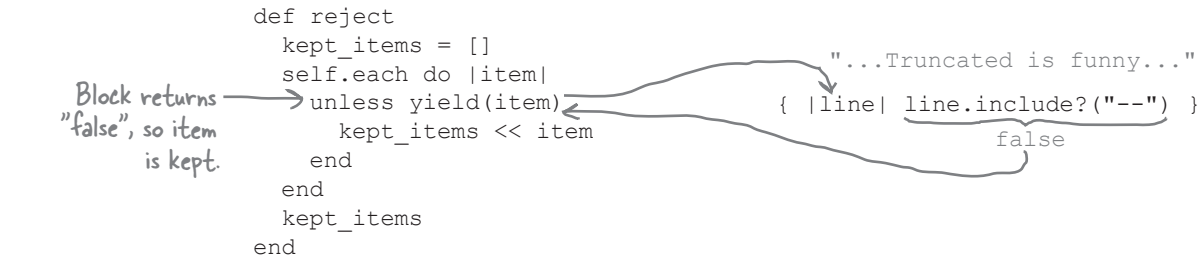
1. The `reject` method passes the first line from the file to the block. The `line` block parameter does *not* include the string `"--"`, so the return value of the block is `false`. Back in the method, this line gets added to the array of items we're keeping.



2. The `reject` method passes the second line to the block. The `line` parameter *does* include the string `"--"`, so the return value of the block is `true`, and the method discards (rejects) this line.



3. The third line *doesn't* include `"--"`, so the return value of the block is `false`, and the method keeps this line.



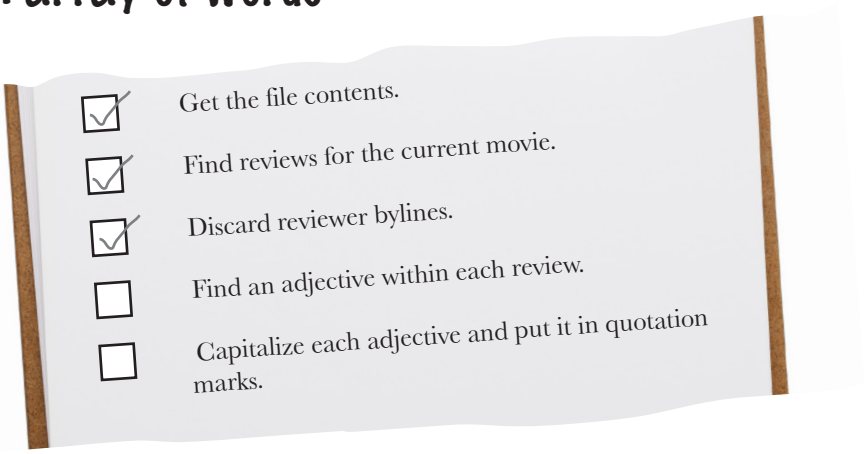
...And so on, for the rest of the lines in the file. The `reject` method *skips* adding a line to the new array if it includes `"--"`. The result is a new array that omits the bylines and includes only the reviews!

```
p reviews
```

```
["...Truncated is amazing...",
 "...Truncated is funny...",
 "...Truncated is astounding..."]
```

Breaking a string into an array of words

We've discarded the reviewer bylines, leaving us with an array containing only the text of each review. That's another requirement down! Two to go...



For our next requirement, we're going to need a couple new methods. They don't take blocks at all, but they *are* super-useful.

We need to find an adjective in each review:

```
p reviews
```

```
["...Truncated is amazing...",
 "...Truncated is funny...",
 "...Truncated is astounding..."]
```

We need to select just the adjectives...

If you look above, you'll notice a pattern... The adjective we want always seems to follow the word "is".

So, we need to get one word that follows another word... What we have right now are *strings*. How can we convert those to *words*?

Strings have a `split` instance method that you can call to split them into an array of substrings.

```
p "1-800-555-0199".split("-")
p "his/her".split("/")
p "apple, avocado, anvil".split(", ")
```

```
["1", "800", "555", "0199"]
["his", "her"]
["apple", "avocado", "anvil"]
```

The argument to `split` is the *separator*: one or more characters that separate the string into sections.

What separates words in the English language? A space! If we pass `" "` (a space character) to `split`, we'll get an array back. Let's try it with our first review.

```
string = reviews.first
words = string.split(" ")
p words
```

```
["Normally", "producers", "and", "directors",
"would", "stop", "this", "kind", "of", "garbage",
"from", "getting", "published.", "Truncated", "is",
"amazing", "in", "that", "it", "got", "past",
"those", "hurdles."]
```

There you have it - an array of words!

Finding the index of an array element

The `split` method converted our review string into an array of words. Now, we need to find the word "is" within that array. Again, Ruby has a method ready to go for us. If you pass an argument to the `find_index` method, it will find us the first index where that element occurs in the array.

```
p ["1", "800", "555", "0199"].find_index("800")
p ["his", "her"].find_index("his")
p ["apple", "avocado", "anvil"].find_index("anvil")
```

```
1
0
2
```

Using `find_index`, let's write a method that will split a string into an array of words, find the index of the word "is", and return the word that comes *after* that.

```
def find_adjective(string)
  words = string.split(" ")
  index = words.find_index("is")
  words[index + 1]
end
```

Split the sentences into words.

Find the array index of "is".

Find the word AFTER "is", and return it.

We can easily test our method out on one of our reviews...

```
adjective = find_adjective(reviews.first)
```

```
amazing
```

There's our adjective! That only takes care of one review, though. Next, we need to process *all* the reviews, and create an array of the adjectives we find. With the `each` method, that's easy enough to do.

```
adjectives = []

reviews.each do |review|
  adjectives << find_adjective(review)
end

puts adjectives
```

Create a new array to add adjectives into.

For each review in the array...

Call the method we made, and add the adjective to the list.

```
amazing
funny
astounding
```

Now we have an array of adjectives, one for each review!

Would you believe there's an even *easier* way to create an array of adjectives based on the array of reviews, though?

Making one array that's based on another, the hard way

We had no problem looping through our array of reviews to build up an array of adjectives using `each` and our new `find_adjective` method.

But creating a new array based on the contents of another array is a really common operation, that requires similar code each time. Some examples:

```
numbers = [2, 3, 4]

squares = []                          # Make an array to hold results.
numbers.each do |number|              # Loop through source array.
  squares << number ** 2              # Perform an operation, and copy result to results array.
end

p squares
```

```
[4, 9, 16]
```

```
numbers = [2, 3, 4]

cubes = []                            # Make an array to hold results.
numbers.each do |number|              # Loop through source array.
  cubes << number ** 3                # Perform an operation, and copy result to results array.
end

p cubes
```

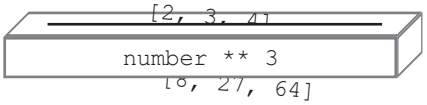
```
[8, 27, 64]
```

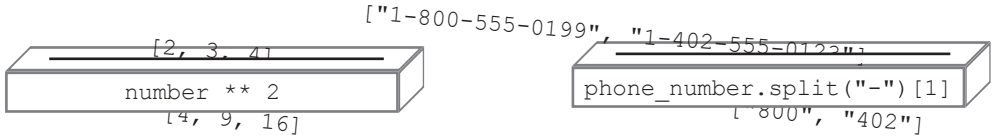
```
phone_numbers = ["1-800-555-0199", "1-402-555-0123"]

area_codes = []                       # Make an array to hold results.
phone_numbers.each do |phone_number|  # Loop through source array.
  area_codes << phone_number.split("-")[1]   # Perform an operation, and copy result to results array.
end

p area_codes
```

```
["800", "402"]
```

In each of these examples, we have to set up a new array to hold the results, loop through the original array and apply some logic to each of its members, and add the result to the new array. (Just like in our adjective finder code.) It's a bit repetitive...

Wouldn't it be great if there were some sort of magic processor for arrays? You drop in your array, it runs some (interchangeable) logic on its elements, and out pops a new array with the elements you need!





Making one array that's based on another, using "map"

Ruby has just the magic array processor we're looking for: the `map` method. The `map` method takes each element of an array, passes it to a block, and builds a new array out of the values the block returns.

No need to create the result arrays beforehand – "map" creates them for us!

Make a new array with the squares of each number.

Make a new array with the cubes of each number.

Make a new array with just area codes.

```
squares = [2, 3, 4].map { |number| number ** 2 }
cubes = [2, 3, 4].map { |number| number ** 3 }
area_codes = ['1-800-555-0199', '1-402-555-0123'].map do |phone|
  phone.split("-")[1]
end
p squares, cubes, area_codes
```

```
[4, 9, 16]
[8, 27, 64]
["800", "402"]
```

The `map` method is similar to `find_all` and `reject`, in that it processes each element in an array. But `find_all` and `reject` use the block's return value to decide whether to copy *the original element* from the old array to the new one. The `map` method adds the block's *return value itself* to the new array.

If we were to code our own version of `map`, it might look like this:

Make a new array to hold the block return values.

Loop through each element.

Pass the element to the block, and add the return value to the new array.

Return the array of block return values.

```
class Array
  def map
    results = []
    self.each do |item|
      results << yield(item)
    end
    results
  end
end
```

The `map` method can shorten our code to gather adjectives down to a single line!

An array with all the return values from find_adjective.

Call our method. Its return value will be the return value of the block.

```
adjectives = reviews.map { |review| find_adjective(review) }
```

The return value of `map` is an array with all the values the block returned:

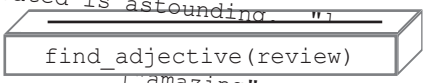
```
p adjectives
```

```
["amazing", "funny", "astounding"]
```

Making one array that's based on another, using "map" (cont.)

Let's look at how the map method and our block process the array of reviews, step by step...

```
["...Truncated is amazing...",
 "...Truncated is funny...",
 "...Truncated is astounding..."]
```




```
["amazing",
 "funny",
 "astounding"]
```

```
adjectives = reviews.map { |review| find_adjective(review) }
```

1 The map method passes our first review to the block. The block, in turn, passes the review to `find_adjective`, which returns `"amazing"`. The return value of `find_adjective` also becomes the return value of the block. Back in the map method, `"amazing"` is added to the results array.

```
def map
  results = []
  self.each do |item|
    results << yield(item)
  end
  results
end
```

```
"...Truncated is amazing..."
```

```
{ |review| find_adjective(review) }
```

```
"amazing"
```

2 The second review is passed to the block, and `find_adjective` returns `"funny"`. Back in the method, the new adjective is added to the results array.

```
def map
  results = []
  self.each do |item|
    results << yield(item)
  end
  results
end
```

```
"...Truncated is funny..."
```

```
{ |review| find_adjective(review) }
```

```
"funny"
```

3 For the third review, `find_adjective` returns `"astounding"`, which gets added to the array with the others.

```
def map
  results = []
  self.each do |item|
    results << yield(item)
  end
  results
end
```

```
"...Truncated is astounding..."
```

```
{ |review| find_adjective(review) }
```

```
"astounding"
```

We have just one more requirement, and this one will be easy!

- [x] Find an adjective within each review.
- [ ] Capitalize each adjective and put it in quotation marks.

Some additional logic in the "map" block body

We're already using `map` to find the adjectives for each review:

```
adjectives = reviews.map { |review| find_adjective(review) }
```

We can just add code to capitalize the adjective and enclose it in quotation marks to the block, right after the call to our `find_adjective` method.

The block takes up more than one line now, so we follow convention and switch to a "do ... end" block.

We need to work with this value further, so we assign it to a variable instead of returning it.

```
adjectives = reviews.map do |review|
  adjective = find_adjective(review)
  "'#{adjective.capitalize}'"
end
```

Here's our new return value.

Here are the new return values that this updated code produces:

1

```
def map
  results = []
  self.each do |item|
    results << yield(item)
  end
  results
end
```

```
"...Truncated is amazing..."

do |review|
  adjective = find_adjective(review)
  "'#{adjective.capitalize}'"
end
      "'Amazing'"
```

2

```
def map
  results = []
  self.each do |item|
    results << yield(item)
  end
  results
end
```

```
"...Truncated is funny..."

do |review|
  adjective = find_adjective(review)
  "'#{adjective.capitalize}'"
end
      "'Funny'"
```

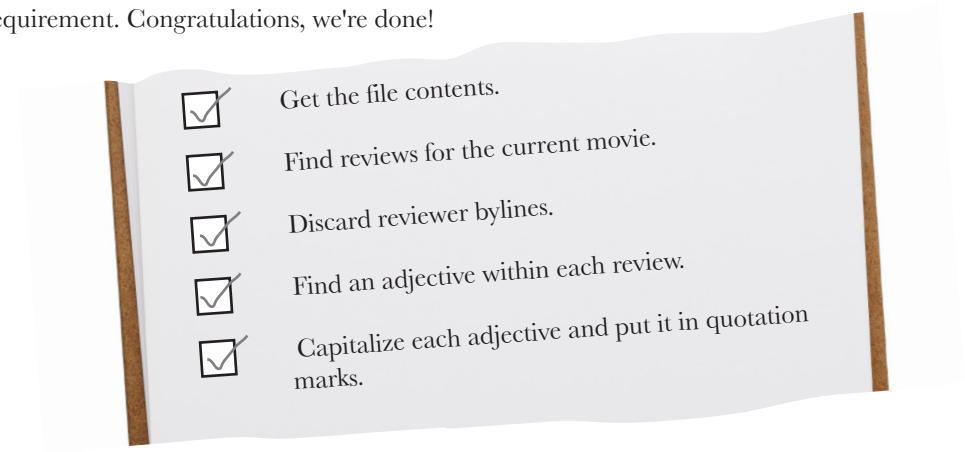
3

```
def map
  results = []
  self.each do |item|
    results << yield(item)
  end
  results
end
```

```
"...Truncated is astounding..."

do |review|
  adjective = find_adjective(review)
  "'#{adjective.capitalize}'"
end
      "'Astounding'"
```

The finished product

That's our last requirement. Congratulations, we're done!



You've successfully learned to use block return values to find elements you want within an array, reject elements you don't want, and even to use an algorithm to create an entirely new array!

Processing a complex text file like this would take dozens of lines of code in other languages, with lots of repetition. The `find_all`, `reject`, and `map` methods handled all of that for you! They're not the easiest methods to learn to use, but now that you have, you've got powerful new tools at your disposal!

Here's our complete code listing:

```
def find_adjective(string)
  words = string.split(" ")
  index = words.find_index("is")
  words[index + 1]
end

lines = []
File.open("reviews.txt") do |review_file|
  lines = review_file.readlines
end

relevant_lines = lines.find_all { |line| line.include?("Truncated") }
reviews = relevant_lines.reject { |line| line.include?("--") }

adjectives = reviews.map do |review|
  adjective = find_adjective(review)
  "'#{adjective.capitalize}'"
end

puts "The critics agree, Truncated is:"
puts adjectives
```

We'll call this method below, to find adjectives within each review.

Break the string into an array of words.

Find the index of the word "is".

Return the word following "is".

We need to create this variable outside the block.

Open the file, and automatically close it when we're done.

Read every line in the file into an array.

Find lines that include the movie name.

Exclude reviewer bylines.

Process each review.

Find the adjective.

Return the adjective, capitalized and surrounded by quotes.

```
The critics agree, Truncated is:
'Amazing'
'Funny'
'Astounding'
```

Open a new terminal or command prompt, type "irb" and hit the Enter/Return key. For each of the Ruby expressions below, write your guess for what the result will be on the line next to it. Then try typing the expression into `irb`, and hit Enter. See if your guess matches what `irb` returns!

```
[1, 2, 3, 4].find_all { |number| number.odd? }
```
.....

```
[1, 2, 3, 4].find_all { |number| true }
```
.....

```
[1, 2, 3, 4].find_all { |number| false }
```
.....

```
[1, 2, 3, 4].find { |number| number.even? }
```
.....

```
[1, 2, 3, 4].reject { |number| number.odd? }
```
.....

```
[1, 2, 3, 4].all? { |number| number.odd? }
```
.....

```
[1, 2, 3, 4].any? { |number| number.odd? }
```
.....

```
[1, 2, 3, 4].none? { |number| number > 4 }
```
.....

```
[1, 2, 3, 4].count { |number| number.odd? }
```
.....

```
[1, 2, 3, 4].partition { |number| number.odd? }
```
.....

```
['$', '$$', '$$$'].map { |string| string.length }
```
.....

```
['$', '$$', '$$$'].max_by { |string| string.length }
```
.....

```
['$', '$$', '$$$'].min_by { |string| string.length }
```
.....

Open a new terminal or command prompt, type "irb" and hit the Enter/Return key. For each of the Ruby expressions below, write your guess for what the result will be on the line next to it. Then try typing the expression into `irb`, and hit Enter. See if your guess matches what `irb` returns!

```
[1, 2, 3, 4].find_all { |number| number.odd? }
```

An array of all values for which the block returns "true".
`[1, 3]`

```
[1, 2, 3, 4].find_all { |number| true }
```

If it always returns "true", all values get included.
`[1, 2, 3, 4]`

```
[1, 2, 3, 4].find_all { |number| false }
```

If it NEVER returns true, NO values are included.
`[]`

```
[1, 2, 3, 4].find { |number| number.even? }
```

"find" returns the FIRST value for which the block returns "true".
`2`

```
[1, 2, 3, 4].reject { |number| number.odd? }
```

An array of all values for which the block returns "false".
`[2, 4]`

```
[1, 2, 3, 4].all? { |number| number.odd? }
```

"all?" returns true if the block returned true for ALL elements.
`false`

```
[1, 2, 3, 4].any? { |number| number.odd? }
```

"any?" returns true if the block returned true for ANY elements.
`true`

```
[1, 2, 3, 4].none? { |number| number > 4 }
```

"none?" returns true if the block returned FALSE for all elements.
`true`

```
[1, 2, 3, 4].count { |number| number.odd? }
```

The number of elements for which the block returned "true".
`2`

```
[1, 2, 3, 4].partition { |number| number.odd? }
```

`[[1, 3], [2, 4]]`

Two arrays, the first with all the elements where the block returned TRUE, the second with all the elements where it returned FALSE.

```
['$', '$$', '$$$'].map { |string| string.length }
```

An array with all the values the block returns.
`[1, 2, 3]`

```
['$', '$$', '$$$'].max_by { |string| string.length }
```

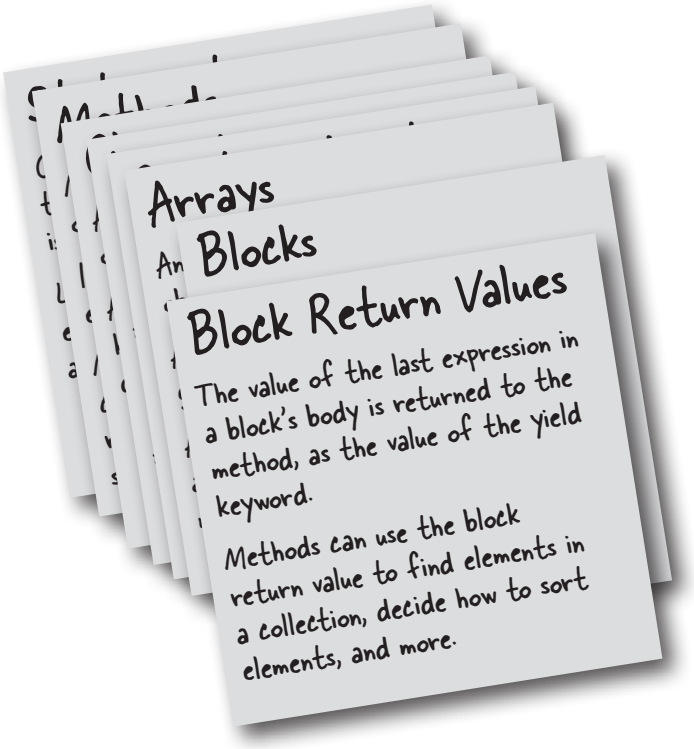
The element for which the block returned the LARGEST value.
`"$$$"`

```
['$', '$$', '$$$'].min_by { |string| string.length }
```

The element for which the block returned the SMALLEST value.
`"$"`

Your Ruby Toolbox

That's it for Chapter 6! You've added block return values to your tool box.

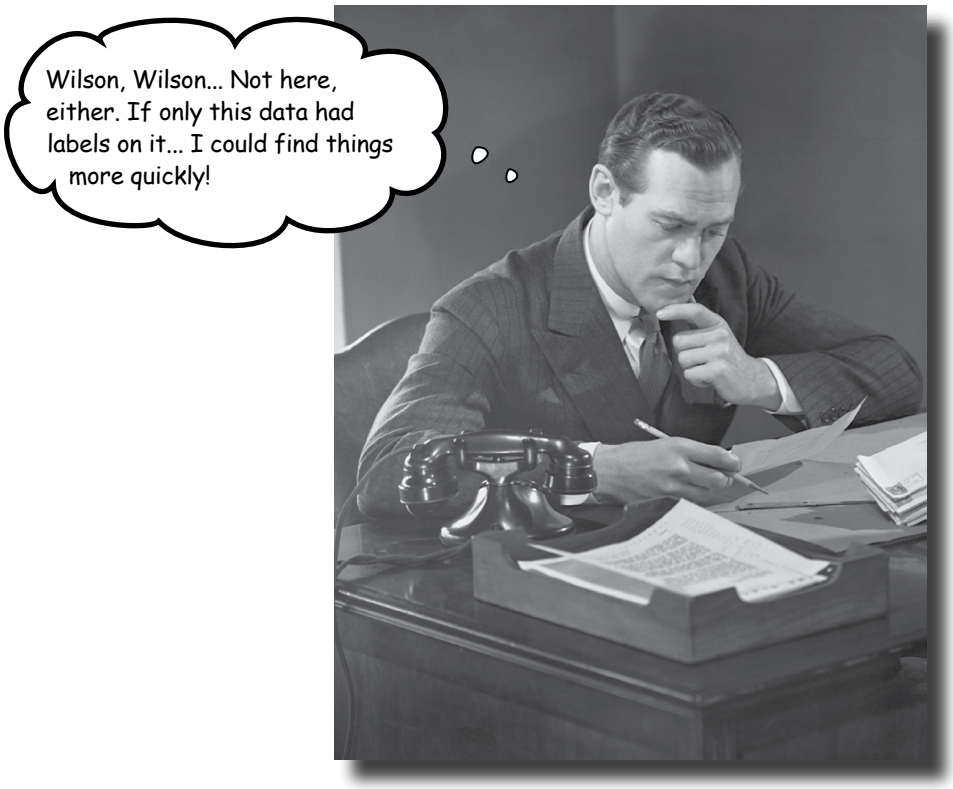


BULLET POINTS

- If you pass a block to `File.open`, it will yield the file to the block so you can do whatever you need with it. When the block ends, the file will automatically be closed.
- Strings have an instance method called `include?`, which takes a substring as an argument. It will return `true` if the string includes the substring, `false` if not.
- When you need to find all elements of an array that meet some criteria, you can use the `find_all` method. It passes each element of the array to a block, and will return a new array with all the elements for which the block returned a true value.
- The `reject` method works just like `find_all`, except that it rejects array elements for which a block returns a true value.
- The `split` method on strings takes a separator as an argument. It finds each instance of the separator within the string, and returns an array with all of the substrings that were between each separator.
- The `find_index` method searches for the first occurrence of an element within an array, and returns its index.
- The `map` method takes each element of an array, passes it to a block, and builds a new array out of the values the block returns.

7 hashes

Labelling Data



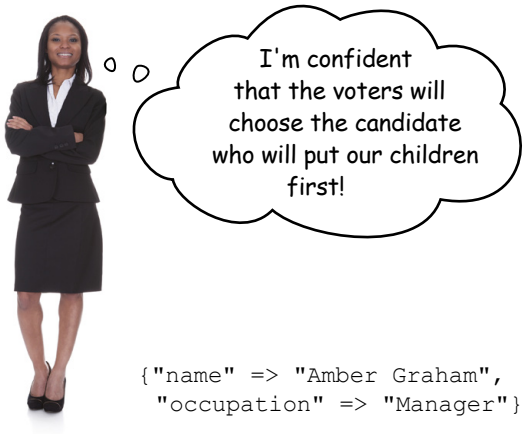
Throwing things in piles is fine, until you need to find something again. You've already seen how to create a collection of objects using an *array*. You've seen how to process *each item* in an array, and how to *find items* you want. In both cases, you start at the beginning of the array, and *look through Every. Single. Object*.

You've also seen methods that take big collections of parameters. You've seen the problems this causes: method calls require a big, *confusing collection of arguments* that you have to remember the exact order for.

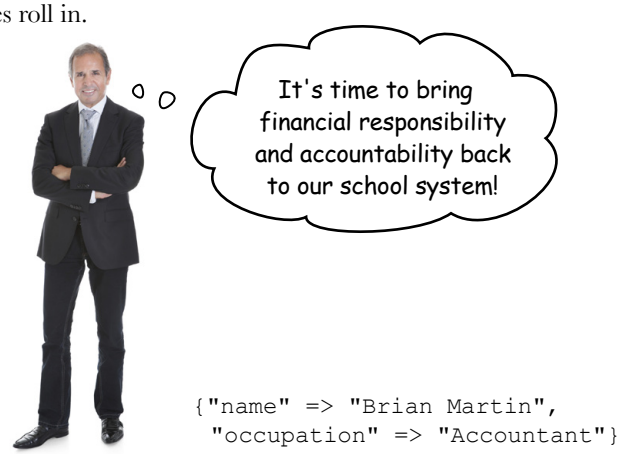
What if there was a kind of collection where *all the data had labels* on it? You could *quickly find the elements* you needed! In this chapter, we'll learn about Ruby **hashes**, which do just that.

Counting votes

A seat on the Sleepy Creek County School Board is up for grabs this year, and polls have been showing the election to be really close. Now that it's election night, the candidates are excitedly watching the votes roll in.



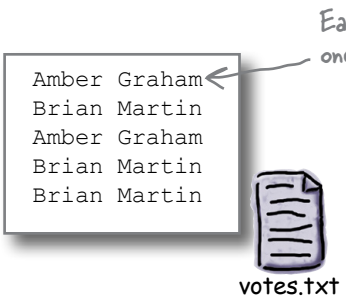

```
{"name" => "Amber Graham",
 "occupation" => "Manager"}
```




```
{"name" => "Brian Martin",
 "occupation" => "Accountant"}
```

The electronic voting machines in use this year record the votes to text files, one vote per line. (Budgets are tight, so the city council chose the cheap voting machine vendor.)

Here's a file with all the votes for District A:



We need to process each line of the file, and tally the total number of times each name occurs. The name with the most votes will be our winner!

The development team's first order of business is to read the contents of the "`votes.txt`" file. That part is easy; it's just like the code we used to read the movie reviews file back in Chapter 6.

```
lines = []
File.open("votes.txt") do |file|
  lines = file.readlines
end
```

Create a variable that will still be accessible after the block.

Open the file, and pass it to the block.

Store all the file lines in an array.

Now, we need to get the name from each line of the file, and increment a tally of the number of times that name has occurred.

An array of arrays... is not ideal

But how do we keep track of all those names *and* associate a vote total with each of them? We'll show you two ways. The first approach uses arrays, which we already know about from Chapter 5. Then we'll show you a second way using a new data structure, *hashes*.

If all we had to work with were arrays, we might build an *array of arrays* to hold everything. That's right, Ruby arrays can hold any object, including *other arrays*. So we could create an array with the candidate's name, and the number of votes we've counted for it:

```
["Brian Martin", 1]
```

We could put this array *inside* another array that holds all the *other* candidate names and *their* totals:

```
[                                    <- Outer array.
  ["Amber Graham", 1],               <- An inner array.
  ["Brian Martin", 1]                <- Insert the new array here...
]
```

For each name we encountered in the text file...

```
"Mikey Moose"
```

...We'd need to loop through the *outer* array and check whether the first element of the *inner* array matches it.

```
[
  ["Amber Graham", 1],               <- "Mikey Moose"? Nope...
  ["Brian Martin", 1],               <- "Mikey Moose"? Nope...
  ...
]
```

If none matched, we'd add a new inner array with the new name.

```
[
  ["Amber Graham", 1],
  ["Brian Martin", 1],
  ["Mikey Moose", 1]                 <- Insert the new array here...
]
```

But if we encountered a name in the text file that *did* already exist in the array of arrays...

```
"Brian Martin"
```

Then we'd update the existing total for that name.

```
[
  ["Amber Graham", 1],               <- "Brian Martin"? Nope.
  ["Brian Martin", 2],               <- "Brian Martin"? Yes!  Update this vote count.
  ["Mikey Moose", 1]
]
```

...You *could* do all that. But it would require extra code, and all that looping would take a long time when processing large lists. As usual, Ruby has a better way.

Hashes

The problem with storing the vote tally for each candidate in an array is the inefficiency of looking them up again later. For each name we want to find, we have to search through *all* the others.

```
[
  ["Amber Graham", 4],
  ["Brian Martin", 5],
  ["Mikey Moose", 2]
]
```

"Mikey Moose"? Nope...
"Mikey Moose"? Nope...
"Mikey Moose"?

Putting data in an array is like stacking it in a big pile; you can get particular items back out, but you'll have to search through everything to find them.

Ruby has another way of storing collections of data... *hashes*. A **hash** is a collection where each value is accessed via a *key*. Keys are an easy way to get data back out of your hash. It's like having neatly labelled file folders instead of a messy pile.

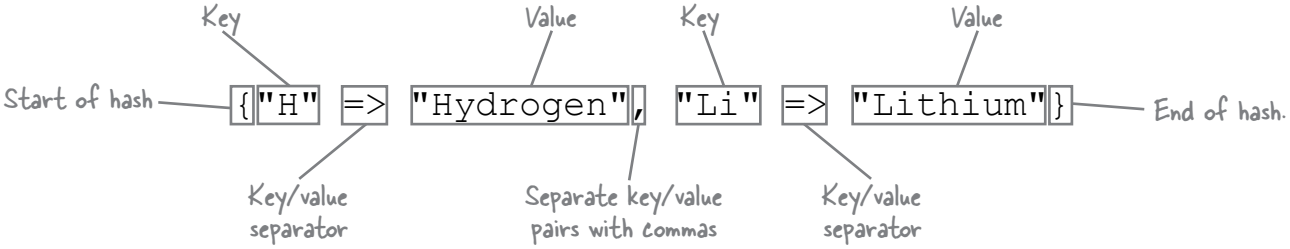
Start at the top; search the whole pile.

Array

Keys let you quickly find data again!

Hash

Just like with arrays, you can create a new hash and add some data to it at the same time using a hash literal. The syntax looks like this:



Those => symbols show which key points to which value. They look a bit like a rocket, so they are sometimes called "hash rockets".

We can assign a new hash to a variable:

```
elements = {"H" => "Hydrogen", "Li" => "Lithium"}
```

Then, we can access values from that hash using the keys we set up for them. Whereas hash literals use *curly braces*, you use *square brackets* to access individual values. It looks just like the syntax to access values from an array, except you place the hash key within the brackets instead of a numeric index.

Use a hash key here, and you'll get the corresponding value.

```
puts elements["Li"]
puts elements["H"]
```

```
Lithium
Hydrogen
```

Hashes (cont.)

We can also add new keys and values to an existing hash. Again, the syntax looks a lot like the syntax to assign to an array element:

Hash key we're assigning a value for.

New value.

```
elements["Ne"] = "Neon"
puts elements["Ne"]
```

```
Neon
```

Whereas an array can only use *integers* as indexes, a hash can use *any object* as a key. That includes numbers, strings, and symbols.

```
mush = {1 => "one", "two" => 2, :three => 3.0}

p mush[:three]
p mush[1]
p mush["two"]
```

```
3.0
"one"
2
```

Although arrays and hashes have major differences, there are enough similarities that it's worth taking a moment to compare them...

Arrays:

- Grow and shrink as needed
- Can hold any object, even hashes or other arrays
- Can hold instances of more than one class at the same time
- Literals surrounded by *square brackets*
- Elements accessed by specifying index within *square brackets*
- Only integers can be used as indexes
- Index of an element is determined by position within array

```
[2.99, 25.00, 9.99]
 ↑     ↑      ↑
 0     1      2
```

Hashes:

- Grow and shrink as needed
- Can hold any object, even arrays or other hashes
- Can hold instances of more than one class at the same time
- Literals surrounded by *curly braces*
- Values accessed by specifying key within *square brackets*
- Any object can be used as a key
- Keys not calculated; key must be specified whenever a value is added

```
{"M" => "Monday", "T" => "Tuesday"}
 ↑       ↑        ↑       ↑
 Key     Value    Key     Value
```

Fill in the blanks in the code below, so that it will produce the output shown.

```
my_hash = {"one" => _____, :three => "four", _ => "six"}
puts my_hash[5]
puts my_hash["one"]
puts my_hash[_____]
my_hash[_____] = 8
puts my_hash["seven"]
```

Output:

```
six
two
four
8
```

Fill in the blanks in the code below, so that it will produce the output shown.

```
my_hash = {"one" => "two", :three => "four", 5 => "six"}
puts my_hash[5]
puts my_hash["one"]
puts my_hash[:three]
my_hash["seven"] = 8
puts my_hash["seven"]
```

Output:

```
six
two
four
8
```

Hashes are objects

We've been hearing over and over that everything in Ruby is an object. We saw that arrays are objects, and it probably won't surprise you to learn that hashes are objects, too.

```
protons = {"H" => 1, "Li" => 3, "Ne" => 10}
puts protons.class
```

```
Hash
```

And, like most Ruby objects, hashes have lots of useful instance methods. Here's a sampling...

They have the methods that you expect every Ruby object to have, like `inspect`:

```
puts protons.inspect
```

```
{"H"=>1, "Li"=>3, "Ne"=>10}
```

The `length` method lets you determine how many key/value pairs the hash holds:

```
puts protons.length
```

```
3
```

There are methods to quickly test whether the hash includes particular keys or values:

```
puts protons.has_key?("Ne")
```

```
true
```

```
puts protons.has_value?(3)
```

```
true
```

There are methods that will give you an array with all the keys, or all the values:

```
p protons.keys
```

```
["H", "Li", "Ne"]
```

```
p protons.values
```

```
[1, 3, 10]
```

And, as with arrays, there are methods that will let you use a block to iterate over the hash's contents. The `each` method, for example, takes a block with *two* parameters, one for the key and one for the value. (More about `each` in a few pages.)

```
protons.each do |element, count|
  puts "#{element}: #{count}"
end
```

```
H: 1
Li: 3
Ne: 10
```

Open a new terminal or command prompt, type "irb" and hit the Enter/Return key. For each of the Ruby expressions below, write your guess for what the result will be on the line next to it. Then try typing the expression into `irb`, and hit Enter. See if your guess matches what `irb` returns!

```
protons = { "He" => 2 }
```
.....

```
protons["He"]
```
.....

```
protons["C"] = 6
```
.....

```
protons["C"]
```
.....

```
protons.has_key?("C")
```
.....

```
protons.has_value?(119)
```
.....

```
protons.keys
```
.....

```
protons.values
```
.....

```
protons.merge({ "C" => 0, "Uh" => 147.2 })
```
.....

there are no Dumb Questions

Q: Why do they call it a "hash"?

A: Frankly, it's not the best possible name. Other languages refer to this kind of structure as "maps", "dictionaries", or "associative arrays" (because keys are associated with values). In Ruby, it's called a "hash" because an algorithm called a *hash table* is used to quickly look up keys within the hash. The details of that algorithm are beyond the scope of this book, but you can visit your favorite search engine to learn more.

Open a new terminal or command prompt, type "irb" and hit the Enter/Return key. For each of the Ruby expressions below, write your guess for what the result will be on the line next to it. Then try typing the expression into `irb`, and hit Enter. See if your guess matches what `irb` returns!

```
protons = { "He" => 2 }
```
{"He"=>2} — Result of an assignment statement, as always, is the value that was assigned.

```
protons["He"]
```
2 — Provide the key, get the corresponding value.

```
protons["C"] = 6
```
6 — The value that was assigned.

```
protons["C"]
```
6 — Retrieving the value we just assigned from the hash.

```
protons.has_key?("C")
```
true — "true" because the hash includes the given key.

```
protons.has_value?(119)
```
false — "false" because no key in the hash has the given value.

```
protons.keys
```
["He", "C"] — An array containing every key in the hash.

```
protons.values
```
[2, 6] — An array containing every value in the hash.

```
protons.merge({ "C" => 0, "Uh" => 147.2 })
```
{"He"=>2, "C"=>0, "Uh"=>147.2} — If a key in the new hash already exists in the old hash, the old value is overridden. If a key didn't already exist, it just gets added.

Hashes return "nil" by default

Let's take a look at the array of lines we read from the sample file of votes. We need to tally the number of times each name occurs within this array.


votes.txt

```
Amber Graham
Brian Martin
Amber Graham
Brian Martin
Brian Martin
```

```
p lines
```

```
["Amber Graham\n", "Brian Martin\n", "Amber Graham\n",
 "Brian Martin\n", "Brian Martin\n"]
```

These newline characters were read from the file.

In the place of the array of arrays we discussed earlier, let's use a hash to store the vote counts. When we encounter a name within the `lines` array, if that name doesn't exist, we'll add it to the hash.

If we read this line... → `"Amber Graham"`

```
{
  "Amber Graham" => 1,
}
```

We'll add this key and value to the hash.

Each new name we encounter will get its own key and value added to the hash.

If we read this line... → `"Brian Martin"`

```
{
  "Amber Graham" => 1,
  "Brian Martin" => 1,
}
```

We'll add this key and value to the hash.

If we encounter a name that we've already added, we'll update its count, instead.

If we read the same name again... → `"Amber Graham"`

```
{
  "Amber Graham" => 2,
  "Brian Martin" => 1,
}
```

We'll update the corresponding value.

...And so on, until we've counted all the votes.

That's the plan, anyway. But our first version of the code to do this fails with an error...

```
votes = {}

lines.each do |line|
  name = line.chomp
  votes[name] += 1
end

p votes
```

Set up an empty hash.

Remove the newline character.

Increment the total for the current name.

Error:

```
undefined
method `+' for
nil:NilClass
```

So what happened? As we saw in the arrays chapter, if you try to access an *array element* that hasn't been assigned to yet, you'll get `nil` back. If you try to access a *hash key* that has never been assigned to, the default value is *also* `nil`.

```
array = []
p array[999]
hash = {}
p hash["I don't exist"]
```

Doesn't exist.

Doesn't exist.

```
nil
nil
```

When we try to access the votes for a candidate name that has never been assigned to, we get `nil` back. And trying to add to `nil` produces an error.

Hashes return "nil" by default (cont.)

The first time we encounter a candidate's name, instead of getting a vote tally back from the hash, we get `nil`. This results in an error when we try to add to it.

```
lines.each do |line|
  name = line.chomp
  votes[name] += 1
end
```

```
undefined method `+'
for nil:NilClass
```

To fix this, we can test whether the value for the current hash key is `nil`. If it's not, then we can safely increment whatever number is there. But if it *is* `nil`, then we'll need to set up an initial value (a tally of `1`) for that key.

```
lines = []
File.open("votes.txt") do |file|
  lines = file.readlines
end

votes = {}

lines.each do |line|
  name = line.chomp
  if votes[name] != nil <-- If we've seen this name before...
    votes[name] += 1 <-- Increment its total.
  else <-- If this is our first sight of this name...
    votes[name] = 1 <-- Add it to the hash with value of 1.
  end
end
```

And in the output, we see the populated hash. Our code is working!

```
p votes
```

```
{"Amber Graham"=>2, "Brian Martin"=>3}
```

nil (and only nil) is "falsy"

There's a small improvement to be made, though... That conditional is a little ugly.

```
if votes[name] != nil
```

We can clean that up by taking advantage of the fact that *any* Ruby expression can be used in a conditional statement. Most of them will be treated as if they were a "true" value. (Rubyists often say these values are *"truthy"*.)

```
if "any string" <-- Truthy.
  puts "I'll be printed!"
end
```

```
if 42 <-- Truthy.
  puts "I'll be printed!"
end
```

```
if ["any array"] <-- Truthy.
  puts "I'll be printed!"
end
```

In fact, aside from the `false` boolean value, there is only *one* value that Ruby treats as if it was false: `nil`. (Rubyists often say that `nil` is *"falsy"*.)

```
if false <-- Actually false.
  puts "I won't be printed!"
end
```

```
if nil <-- Falsy.
  puts "I won't, either!"
end
```

nil (and only nil) is "falsy" (cont.)

Ruby treats `nil` like it's false to make it easier to test whether values have been assigned or not. For example, if you access a hash value within an `if` statement, the code within will be run if the value exists. If the value doesn't exist, the code won't be run.

Value is nil, which is falsy.

```
votes = {}
if votes["Kremit the Toad"]
  puts "I won't be printed!"
end
votes ["Kremit the Toad"] = 1
if votes["Kremit the Toad"]
  puts "I'll be printed!"
end
```

Value is 1, which is truthy.

We can make our conditional read a little better by changing it from `"if votes[name] != nil"` to just `"if votes[name]"`.

Our code still works the same as before; it's just a bit cleaner looking. This may be a small victory now, but the average program has to test for the existence of objects a *lot*. Over time, this technique will save you many keystrokes!

```
lines.each do |line|
  name = line.chomp
  if votes[name]
    votes[name] += 1
  else
    votes[name] = 1
  end
end

p votes
```

We don't need that ugly "if votes[name] != nil" any more!

```
{"Amber Graham"=>2, "Brian Martin"=>3}
```

Watch it!

We mean it when we say that only `nil` is falsy.

Most values that are treated as falsy in some other languages, such as empty strings, empty arrays, and the number `0`, are truthy in Ruby.

Exercise

Guess the output for the code below, and write it in the blanks provided. (We've filled in the first line for you.)

```
school = {
  "Simone" => "here",
  "Jeanie" => "here"
}

names = ["Simone", "Ferriss", "Jeanie", "Cameron"]

names.each do |name|
  if school[name]
    puts "#{name} is present"
  else
    puts "#{name} is absent"
  end
end
```

Simone is present

Exercise Solution

Guess the output for the code below, and write it in the blanks provided.

```
school = {
  "Simone" => "here",
  "Jeanie" => "here"
}

names = ["Simone", "Ferriss", "Jeanie", "Cameron"]

names.each do |name|
  if school[name]
    puts "#{name} is present"
  else
    puts "#{name} is absent"
  end
end
```

Simone is present

Ferriss is absent

Jeanie is present

Cameron is absent

A hash that returns something other than "nil" by default

A disproportionate amount of our code for tallying the votes lies in the `if/else` statement that checks whether a key exists within the hash...

```
votes = {}

lines.each do |line|
  name = line.chomp
  if votes[name]          <- If votes[name] is not nil...
    votes[name] += 1      <- Increment the existing total.
  else                    <- If votes[name] IS nil...
    votes[name] = 1       <- Add the name to the hash with value of 1.
  end
end
```

And we *need* that `if` statement. Normally, when you try to access a hash key that hasn't had a value assigned yet, you get `nil` back. We'd get an error the first time we tried to add to the tally for a key that didn't yet exist (because you can't add to `nil`).

```
lines.each do |line|
  name = line.chomp
  votes[name] += 1
end
```

On the first name, gets "nil" and tries to add 1 to it...

Error →

```
undefined method `+'
for nil:NilClass
```

But... what if, when we tried to access a hash key that hasn't been assigned to yet, we got a different value instead of `nil`? One that we *can* increment? Let's find out how to make that happen...

A hash that returns something other than "nil" by default (cont.)

Instead of using a hash literal ({}), you can also call `Hash.new` to create new hashes. Without any arguments, `Hash.new` works just like `{}`, giving you a hash that returns `nil` for unassigned keys.

```
votes = Hash.new
votes["Amber Graham"] = 1
p votes["Amber Graham"]
p votes["Brian Martin"]
```

Create a new hash.

When we access a value that's been assigned to, we get that value back.

When we access a value that HASN'T been assigned to, we get "nil".

```
1
nil
```

But when you call `Hash.new` and pass an object as an argument, that argument becomes that hash's default object. Anytime you access a key in that hash that hasn't been assigned to yet, instead of `nil`, you'll get the default object you specified..

```
votes = Hash.new(0)
votes["Amber Graham"] = 1
p votes["Amber Graham"]
p votes["Brian Martin"]
```

Create a new hash with a default object of "0".

When we access a value that's been assigned to, we get that value back.

When we access a value that HASN'T been assigned to, we get the default object.

```
1
0
```

Let's use a hash default object to shorten up our vote counting code...

If we create our hash with `Hash.new(0)`, it will return the default object (0) when we try to access the vote tally for any key that hasn't been assigned to yet. That 0 value gets incremented to 1, then 2, and so on as the same name is encountered again and again.

Using anything other than a number as a hash default object may cause bugs!

We'll cover ways to safely use other objects in Chapter 8. Until then, don't use anything other than a number as a default!

```
lines = []
File.open("votes.txt") do |file|
  lines = file.readlines
end

votes = Hash.new(0)

lines.each do |line|
  name = line.chomp
  votes[name] += 1
end

p votes
```

Create a new hash with a default object of "0".

Increment whatever value is returned: "0" if the key has never been updated, or the current tally otherwise.

We can get rid of the `if` statement entirely!

And as you can see from the output, the code still works.

```
{"Amber Graham"=>2, "Brian Martin"=>3}
```

Normalizing hash keys

Here's what we get if we run this new file through our existing code:

```
{"Amber Graham"=>2, "Brian Martin"=>3, "amber graham"=>3, "brian martin"=>1}
```

These two shouldn't be separate items!

Well, this won't do... It looks like the last few votes were added with the candidates' names in lower case, and they were treated as *entirely separate* candidates!

This highlights a problem when working with hashes: if you want to access or modify a value, whatever you provide as a key needs to match the existing key *exactly*. Otherwise, it will be treated as an entirely new key.

```
votes = Hash.new(0)
votes["Amber Graham"] = 1
p votes["Amber Graham"]
p votes["amber graham"]
```

Accesses the existing value.

This key/value has never been assigned to!

```
1
0
```

So, how will we ensure that the new lower-case entries in our text file get matched with the capitalized entries? We need to *normalize* the input: we need one standard way of representing candidates' names, and we need to use *that* for our hash keys.

Normalizing hash keys (cont.)

Fortunately, in this case, normalizing the candidate names is really easy. We'll add one line of code to ensure the case on each name matches prior to storing it in the hash.

```
lines = []
File.open("votes.txt") do |file|
  lines = file.readlines
end

votes = {}

lines.each do |line|
  name = line.chomp
  name.upcase!
  if votes[name]
    votes[name] += 1
  else
    votes[name] = 1
  end
end

p votes
```

Change the name to ALL CAPS before adding it to the hash (or searching for it in the hash).

And in the output we see the updated contents of our hash: votes from the lower-case entries have been added to the totals for the capitalized entries. Our counts are fixed!

```
{"AMBER GRAHAM"=>5, "BRIAN MARTIN"=>4}
```

We have our winner!

Watch it!

You also need to normalize the keys when <u>accessing</u> values.

If you normalize the keys when you're <u>adding</u> values to the hash, you have to normalize the keys when you're <u>accessing</u> the values as well. Otherwise, it might appear that your value is missing, when it's really just under a different key!

This key doesn't exist!

```
p votes["Amber Graham"]
p votes["AMBER GRAHAM"]
```

```
nil
5
```

....But this one does!

Hashes and "each"

We've processed the lines in the sample file, and built a hash with the total number of votes:

```
p votes
```

```
{"AMBER GRAHAM"=>5, "BRIAN MARTIN"=>4}
```

It would be far better, though, if we could print one line for each candidate name, together with their vote count.

As we saw back in Chapter 5, arrays have an `each` method that takes a block with a single parameter. The `each` method passes each element of the array to the block for processing, one at a time. Hashes also have an `each` method, that works in about the same way. The only difference is that on hashes, `each` expects a block with *two* parameters, one for the key, and one for the corresponding value.

```
hash = { "one" => 1, "two" => 2 }
hash.each do |key, value|
  puts "#{key}: #{value}"
end
```

```
one: 1
two: 2
```

there are no Dumb Questions

Q: What happens if I call `each` on a hash, but pass it a block with <u>one</u> parameter?

A: The `each` method for hashes allows that; it will pass the block a 2-element array with the key and value from each key/value pair in the hash. It's much more common to use blocks with two parameters, though.

We can use `each` to print the name of each candidate in the `votes` hash, along with the corresponding vote count:

```
lines = []
File.open("votes.txt") do |file|
  lines = file.readlines
end

votes = Hash.new(0)

lines.each do |line|
  name = line.chomp
  name.upcase!
  votes[name] += 1
end

votes.each do |name, count|
  puts "#{name}: #{count}"
end
```

Key goes here.

Value goes here.

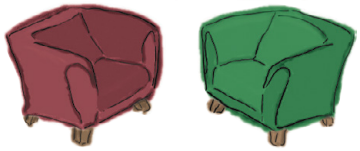
Process each key/value pair.

```
AMBER GRAHAM: 5
BRIAN MARTIN: 4
```

There are our totals, neatly formatted!

Now you've seen one of the classic uses of hashes - a program where we need to look up values for a given key repeatedly. Up next, we'll look at another common way to use hashes: as method arguments.

Fireside Chats



Tonight's talk: **An array and a hash work out their differences.**

Hash:

Nice to see you again, Array.

There's no need to be like that.

Well, I do have a certain glamor about me... But even I know there are still times when developers *should* use an array instead of a hash.

It's true; it's a lot of work keeping all of my elements where I can retrieve them quickly! It pays off if someone wants to retrieve a particular item from the middle of the collection, though. If they give me the correct key, I always know right where to find a value.

Yes, but the developer has to know the exact index where the data is stored, right? All those numbers are a pain to keep track of! But it's either that, or wait for the array to search through all its elements, one by one...

Agreed. Developers should know about both arrays *and* hashes, and pick the right one for their current task.

Array:

I didn't really want to be here, but whatever, Hash.

Isn't there? I was doing a perfectly fine job storing everyone's collections, and then you come along, and developers everywhere are like, "Ooh! Why use an array when I can use a hash? Hashes are so cool!"

Darn right! Arrays are way more efficient than hashes! If you're happy retrieving elements in the same order you added them (say, with `each`), then you want an array, because you won't have to wait while a hash organizes your data for you.

Hey, we arrays can get data back too, you know.

But the point is, we *can* do it. And if you're just building a simple queue, we're still the better choice.

Fair enough.

A mess of method arguments

Suppose we're making an app to track basic information regarding candidates so voters can learn about them. We've created a `Candidate` class to keep all of a candidate's info in one convenient place. For convenience, we've set up an `initialize` method so that we can set all of an instance's attributes directly from a call to `Candidate.new`.

```
class Candidate
  attr_accessor :name, :age, :occupation, :hobby, :birthplace
  def initialize(name, age, occupation, hobby, birthplace)
    self.name = name
    self.age = age
    self.occupation = occupation
    self.hobby = hobby
    self.birthplace = birthplace
  end
end
```

Set up attribute accessors.

Set up Candidate.new to take arguments.

Use the parameters to set the object attributes.

Let's add some code following the class definition to create a `Candidate` instance, and print out its data.

```
def print_summary(candidate)
  puts "Candidate: #{candidate.name}"
  puts "Age: #{candidate.age}"
  puts "Occupation: #{candidate.occupation}"
  puts "Hobby: #{candidate.hobby}"
  puts "Birthplace: #{candidate.birthplace}"
end

candidate = Candidate.new("Carl Barnes", 49, "Attorney", nil, "Miami")
print_summary(candidate)
```

We have to provide an argument even if we're not using it.

```
Candidate: Carl Barnes
Age: 49
Occupation: Attorney
Hobby:
Birthplace: Miami
```

Our very first attempt at calling `Candidate.new` shows that its usage could be a lot smoother. We have to provide all the arguments whether we're going to use them or not.

We could just make the `hobby` parameter optional, *if* it didn't have the `birthplace` parameter following it...

```
class Candidate
  attr_accessor :name, :age, :occupation, :hobby, :birthplace
  def initialize(name, age, occupation, hobby = nil, birthplace)
    ...
  end
end
```

Provide a default value to make the parameter optional...

Since `birthplace` is present, though, we get an error if we try to omit `hobby`...

```
Candidate.new("Carl Barnes", 49, "Attorney", , "Miami")
```

Error → `syntax error, unexpected ',', expecting ')'`

A mess of method arguments (cont.)

We encounter another problem if we forget the order that method arguments should appear in...

```
candidate = Candidate.new("Amy Nguyen", 37, "Lacrosse", "Engineer", "Seattle")
print_summary(candidate)
```

Wait, what order do these go in?

It's becoming clear that there are some issues with using a long list of parameters for a method. The order is confusing, and it's hard to leave unwanted arguments off.

Whoops! We got these two backwards!

```
Candidate: Amy Nguyen
Age: 37
Occupation: Lacrosse
Hobby: Engineer
Birthplace: Seattle
```

Using hashes as method parameters

Historically, Rubyists have dealt with these issues by using hashes as method parameters. Here's a simple `area` method that, instead of separate `length` and `width` parameters, accepts a single hash. [We realize this is a bit ugly. Over the next few pages, we'll show you some shortcuts to make hash parameters much more readable!]

Take one hash instead of multiple parameters.

Ruby convention is to use symbols as keys.

```
def area(options)
  options[:length] * options[:width]
end

puts area({:length => 2, :width => 4})
```

Access values from the hash instead of individual parameters.

Instead of passing multiple arguments, pass a single hash with appropriate keys and values.

```
8
```

The convention in Ruby is to use symbols instead of strings for hash parameter keys, because looking up symbol keys is more efficient than looking up strings.

Using hash parameters offers several benefits over regular method parameters...

With regular parameters:

- Arguments must appear in exactly the right order
- Arguments can be hard to tell apart
- Required parameters have to appear before optional parameters

With hash parameters:

- Keys can appear in any order
- Keys act as "labels" for each value
- Can skip providing a value for any key you want

Hash parameters in our Candidate class

Here's a revision of our `Candidate` class's `initialize` method using a hash parameter.

```
class Candidate
  attr_accessor :name, :age, :occupation, :hobby, :birthplace
  def initialize(name, options)
    self.name = name
    self.age = options[:age]
    self.occupation = options[:occupation]
    self.hobby = options[:hobby]
    self.birthplace = options[:birthplace]
  end
end
```

We'll keep the name as a separate string.

Assign the name as normal.

The hash parameter.

Get values from the hash instead of directly from parameters.

We can now call `Candidate.new` by passing the name as a string, followed by a hash with the values for all the other `Candidate` attributes:

```
candidate = Candidate.new("Amy Nguyen",
  {:age => 37, :occupation => "Engineer", :hobby => "Lacrosse", :birthplace => "Seattle"})
```

Now it's clear which attribute is which!

```
p candidate
```

```
#<Candidate:0x007fbd7a02e858 @name="Amy Nguyen", @age=37,
 @occupation="Engineer", @hobby="Lacrosse", @birthplace="Seattle">
```

No more switched attributes!

We can leave one or more of the hash keys off, if we want. The attribute will just get assigned the hash default object, `nil`.

```
candidate = Candidate.new("Carl Barnes",
  {:age => 49, :occupation => "Attorney", :birthplace => "Miami"})
```

We can leave the hobby off.

```
p candidate
```

```
#<Candidate:0x007f8aaa042a68 @name="Carl Barnes", @age=49,
 @occupation="Attorney", @hobby=nil, @birthplace="Miami">
```

Omitted attributes default to nil.

We can put the hash keys in any order we want:

```
candidate = Candidate.new("Amy Nguyen",
  {:birthplace => "Seattle", :hobby => "Lacrosse", :occupation => "Engineer", :age => 37})
```

```
p candidate
```

```
#<Candidate:0x007f81a890e8c8 @name="Amy Nguyen", @age=37,
  @occupation="Engineer", @hobby="Lacrosse", @birthplace="Seattle">
```

Leave off the braces!

We'll admit that the method calls we've been showing so far are a little uglier than method calls with regular arguments, what with all those curly braces:.

```
candidate = Candidate.new("Carl Barnes",
  {:age => 49, :occupation => "Attorney"})
```

...Which is why Ruby lets you leave the curly braces off, as long as the hash argument is the final argument:

```
candidate = Candidate.new("Carl Barnes",
  :age => 49, :occupation => "Attorney")
p candidate
```

No braces!

```
#<Candidate:0x007fb412802c30
 @name="Carl Barnes", @age=49,
 @occupation="Attorney",
 @hobby=nil, @birthplace=nil>
```

For this reason, you'll find that most methods that define a hash parameter define it as the last parameter.

there are no Dumb Questions

Q: Is there anything special about a hash parameter? It looks like just another method parameter!

A: It *is* just another method parameter; there's nothing stopping you from passing an integer, a string, etc. when you should be passing a hash. But you're likely to get errors when your method code tries to access keys and values on an integer or string!

Leave out the arrows!

Ruby offers one more shortcut we can make use of... If a hash uses symbols as keys, hash literals let you leave the colon (:) off the symbol and replace the hash rocket (=>) with a colon.

```
candidate = Candidate.new("Amy Nguyen", age: 37,
  occupation: "Engineer", hobby: "Lacrosse")
p candidate
```

The same symbols, but more readable!

```
#<Candidate:0x007f9dc412aa98
 @name="Amy Nguyen", @age=37,
 @occupation="Engineer",
 @hobby="Lacrosse",
 @birthplace=nil>
```

Those hash arguments started out pretty ugly, we admit. But now that we know all the tricks to make them more readable, they're looking rather nice, don't you think? Almost like regular method arguments, but with handy labels next to them!

```
Candidate.new("Carl Barnes", age: 49, occupation: "Attorney")
Candidate.new("Amy Nguyen", age: 37, occupation: "Engineer")
```

Conventional Wisdom

When you're defining a method that takes a hash parameter, ensure the hash parameter comes last, so that callers to your method can leave the curly braces off their hash. When calling a method with a hash argument, you should leave the curly braces off if possible - it's easier to read. And lastly, you should use symbols as keys whenever you're working with a hash parameter; it's more efficient.

Making the entire hash optional

There's one last improvement we can make to our `Candidate` class's `initialize` method. Currently we can include all of our hash keys:

```
Candidate.new("Amy Nguyen", age: 37, occupation: "Engineer",
  hobby: "Lacrosse", birthplace: "Seattle")
```

Or we can leave *most* of them off:

```
Candidate.new("Amy Nguyen", age: 37)
```

But if we try to leave them *all* off, we get an error:

```
p Candidate.new("Amy Nguyen")
```

Error →

```
in `initialize': wrong number
of arguments (1 for 2)
```

This happens because if we leave all the keys off, then as far as Ruby is concerned, we didn't pass a hash argument at all.

We can avoid this inconsistency by setting an empty hash as a default for the `options` argument:

```
class Candidate
  attr_accessor :name, :age, :occupation, :hobby, :birthplace
  def initialize(name, options = {})
    self.name = name
    self.age = options[:age]
    self.occupation = options[:occupation]
    self.hobby = options[:hobby]
    self.birthplace = options[:birthplace]
  end
end
```

← If no hash is passed, use an empty one.

Now, if no hash argument is passed, the empty hash will be used by default. All the `Candidate` attributes will be set to the `nil` default value from the empty hash.

```
p Candidate.new("Carl Barnes")
```

```
#<Candidate:0x007fbe0981ec18 @name="Carl Barnes", @age=nil,
 @occupation=nil, @hobby=nil, @birthplace=nil>
```

If we specify at least one key/value pair, though, the hash argument will be treated as before:

```
p Candidate.new("Carl Barnes", occupation: "Attorney")
```

```
#<Candidate:0x007fbe0981e970 @name="Carl Barnes", @age=nil,
 @occupation="Attorney", @hobby=nil, @birthplace=nil>
```

Code Magnets

A Ruby program is all scrambled up on the fridge. Can you reconstruct the code snippets to make a working Ruby program that will produce the given output?

```
volume
result =
options[:depth]
width: 10,
volume
end
options[:height]
)
*
height: 5,
def
(options)
options[:width]
(
*
depth: 2.5
puts "Volume is #{result}"
```

Output:

```
File Edit Window Help
Volume is 125.0
```

Code Magnets Solution

```
def volume (options)
    options[:width] * options[:height] * options[:depth]
end

result = volume ( width: 10, height: 5, depth: 2.5 )
puts "Volume is #{result}"
```

Output:

```
File Edit Window Help
Volume is 125.0
```

Typos in hash arguments are dangerous

There's a downside to hash arguments that we haven't discussed yet, and it's just waiting to cause trouble for us... For example, you might expect this code to set the `occupation` attribute of the new `Candidate` instance, and you might be surprised when it doesn't:

```
p Candidate.new("Amy Nguyen", occupaiton: "Engineer")
```

```
#<Candidate:0x007f862a022cb0 @name="Amy Nguyen", @age=nil,
 @occupation=nil, @hobby=nil, @birthplace=nil>
```

Why is this still nil?

Why didn't it work? Because we misspelled the symbol name in the hash key!

```
p Candidate.new("Amy Nguyen", occupaiton: "Engineer")
```

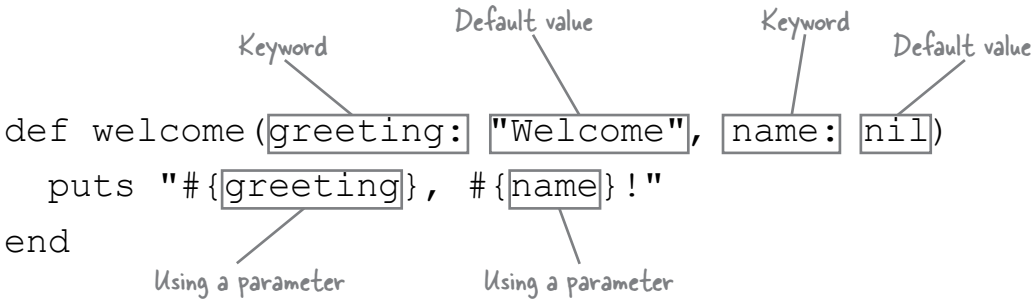
Whoops!

The code doesn't even raise an error. Our `initialize` method just uses the value of the correctly-spelled `options[:occupation]` key, which is of course `nil`, because it's never been assigned to.

Don't worry. In version 2.0, Ruby added keyword arguments, which can prevent this sort of issue.

Keyword arguments

Rather than require a single hash parameter in method definitions, we can specify the individual hash keys we want callers to provide, using this syntax:



When we define the method this way, we don't have to worry about providing keys to a hash to access values in the method body. Ruby stores each value in a separate parameter, which can be accessed directly by name, just like a regular method parameter.

With the method defined, we can call it by providing keys and values, just like we have been:

```
welcome(greeting: "Hello", name: "Amy")
```

```
Hello, Amy!
```

In fact, callers are actually just passing a hash, like before:

```
my_arguments = {greeting: "Hello", name: "Amy"}
welcome(my_arguments)
```

```
Hello, Amy!
```

The hash gets some special treatment within the method, though. Any keywords omitted from the call get set to the specified default values:

```
welcome(name: "Amy")
```

```
Welcome, Amy!
```

And if any unknown keywords are provided (or you make a typo in a key), an error will be raised:

```
welcome(greting: "Hello", nme: "Amy")
```

Error →

```
ArgumentError: unknown
keywords: greting, nme
```

Using keyword arguments with our Candidate class

Currently, our `Candidate` class is using a hash parameter in its `initialize` method. The code is a bit ugly, and it won't warn a caller if they make a typo in a hash key.

```
class Candidate
  attr_accessor :name, :age, :occupation, :hobby, :birthplace
  def initialize(name, options = {})
    self.name = name
    self.age = options[:age]
    self.occupation = options[:occupation]
    self.hobby = options[:hobby]
    self.birthplace = options[:birthplace]
  end
end
```

Hash parameter.

Accessing values from the hash.

Let's revise our `Candidate` class's `initialize` method to take keyword arguments.

```
class Candidate
  attr_accessor :name, :age, :occupation, :hobby, :birthplace
  def initialize(name, age: nil, occupation: nil, hobby: nil, birthplace: "Sleepy Creek")
    self.name = name
    self.age = age
    self.occupation = occupation
    self.hobby = hobby
    self.birthplace = birthplace
  end
end
```

We replace the hash parameter with keywords and default values.

We use parameter names instead of hash keys.

We use `"Sleepy Creek"` as a default value for the `birthplace` keyword, and `nil` as a default for the others. We also replace all those references to the `options` hash in the method body with parameter names. The method is a lot easier to read now!

It can still be called the same way as before...

```
p Candidate.new("Amy Nguyen", age: 37, occupation: "Engineer")
```

```
#<Candidate:0x007fbf5b14e520 @name="Amy Nguyen",
 @age=37, @occupation="Engineer", @hobby=nil, @birthplace="Sleepy Creek">
```

Specified values!

Defaults!

...And it will warn callers if they make a typo in a keyword!

```
p Candidate.new("Amy Nguyen", occupaiton: "Engineer")
```

Error →

```
ArgumentError: unknown keyword: occupaiton
```

Required keyword arguments

Right now, we can still call `Candidate.new` even if we fail to provide the most basic information about a candidate..:

```
p Candidate.new("Carl Barnes")
```

All attributes are set to the defaults!

```
#<Candidate:0x007fe743885d38 @name="Carl Barnes",
 @age=nil, @occupation=nil, @hobby=nil, @birthplace="Sleepy Creek">
```

This isn't ideal. We want to require callers to provide at least an age and an occupation for a candidate.

Back when the `initialize` method was using ordinary method parameters, this wasn't a problem; *all* the arguments were required.

```
class Candidate
  attr_accessor :name, :age, :occupation, :hobby, :birthplace
  def initialize(name, age, occupation, hobby, birthplace)
    ...
  end
end
```

The only way to make a method parameter optional is to provide a default value for it.

```
class Candidate
  attr_accessor :name, :age, :occupation, :hobby, :birthplace
  def initialize(name, age = nil, occupation = nil, hobby = nil, birthplace = nil)
    ...
  end
end
```

But wait, we provide default values for all our keywords now...

```
class Candidate
  attr_accessor :name, :age, :occupation, :hobby, :birthplace
  def initialize(name, age: nil, occupation: nil, hobby: nil, birthplace: "Sleepy Creek")
    ...
  end
end
```

If you take away the default value for an ordinary method parameter, that parameter is required; you can't call the method without providing a value. What happens if we take away the default values for our keyword arguments?

Required keyword arguments (cont.)

Let's try removing the default values for the `age` and `occupation` keywords, and see if they'll be required when calling `initialize`.

Watch it!

Required keyword arguments were only added in Ruby 2.1.

If you're running Ruby 2.0, you'll get a syntax error if you try to use required keyword arguments. You'll need to either upgrade to 2.1, or provide default values.

We can't just remove the colon after the keyword, though. If we did, Ruby wouldn't be able to tell `age` and `occupation` apart from ordinary method parameters.

```
class Candidate
  attr_accessor :name, :age, :occupation, :hobby, :birthplace
  def initialize(name, age, occupation, hobby: nil, birthplace: "Sleepy Creek")
    ...
  end
end
```

Ordinary parameters, not keywords!

What if we removed the default value, but left the colon after the keyword?

```
class Candidate
  attr_accessor :name, :age, :occupation, :hobby, :birthplace
  def initialize(name, age:, occupation:, hobby: nil, birthplace: "Sleepy Creek")
    self.name = name
    self.age = age
    self.occupation = occupation
    self.hobby = hobby
    self.birthplace = birthplace
  end
end
```

Keywords, but with no defaults!

We can still call `Candidate.new`, as long as we provide the required keywords:

```
p Candidate.new("Carl Barnes", age: 49, occupation: "Attorney")
```

```
#<Candidate:0x007fcec281e5a0 @name="Carl Barnes",
@age=49, @occupation="Attorney", @hobby=nil, @birthplace="Sleepy Creek">
```

...And if we leave the required keywords off, Ruby will warn us!

```
p Candidate.new("Carl Barnes")
```

Error →

```
ArgumentError: missing
keywords: age, occupation
```

You used to have to provide a long list of unlabelled arguments to `Candidate.new`, and you had to get the order *exactly* right. Now that you've learned to use hashes as arguments, whether explicitly or behind the scenes with keyword arguments, your code will be a lot cleaner!

Here are definitions for two Ruby methods. Match each of the six method calls below to the output it would produce. (We've filled in the first one for you.)

```
def create(options = {})
  puts "Creating #{options[:database]} for owner #{options[:user]}..."
end

def connect(database:, host: "localhost", port: 3306, user: "root")
  puts "Connecting to #{database} on #{host} port #{port} as #{user}..."
end
```

A `create(database: "catalog", user: "carl")`

B `create(user: "carl")`

C `create`

D `connect(database: "catalog")`

E `connect(database: "catalog", password: "1234")`

F `connect(user: "carl")`

..... `Creating  for owner carl...`

..... `unknown keyword: password`

..... `Connecting to catalog on localhost port 3306 as root...`

A ..... `Creating catalog for owner carl...`

..... `Creating  for owner ...`

..... `missing keyword: database`

Here are definitions for two Ruby methods. Match each of the six method calls below to the output it would produce.

```
def create(options = {})
  puts "Creating #{options[:database]} for owner #{options[:user]}..."
end

def connect(database:, host: "localhost", port: 3306, user: "root")
  puts "Connecting to #{database} on #{host} port #{port} as #{user}..."
end
```

A `create(database: "catalog", user: "carl")`

B `create(user: "carl")`

C `create`

D `connect(database: "catalog")`

E `connect(database: "catalog", password: "1234")`

F `connect(user: "carl")`

B `Creating  for owner carl...`

E `unknown keyword: password`

D `Connecting to catalog on localhost port 3306 as root...`

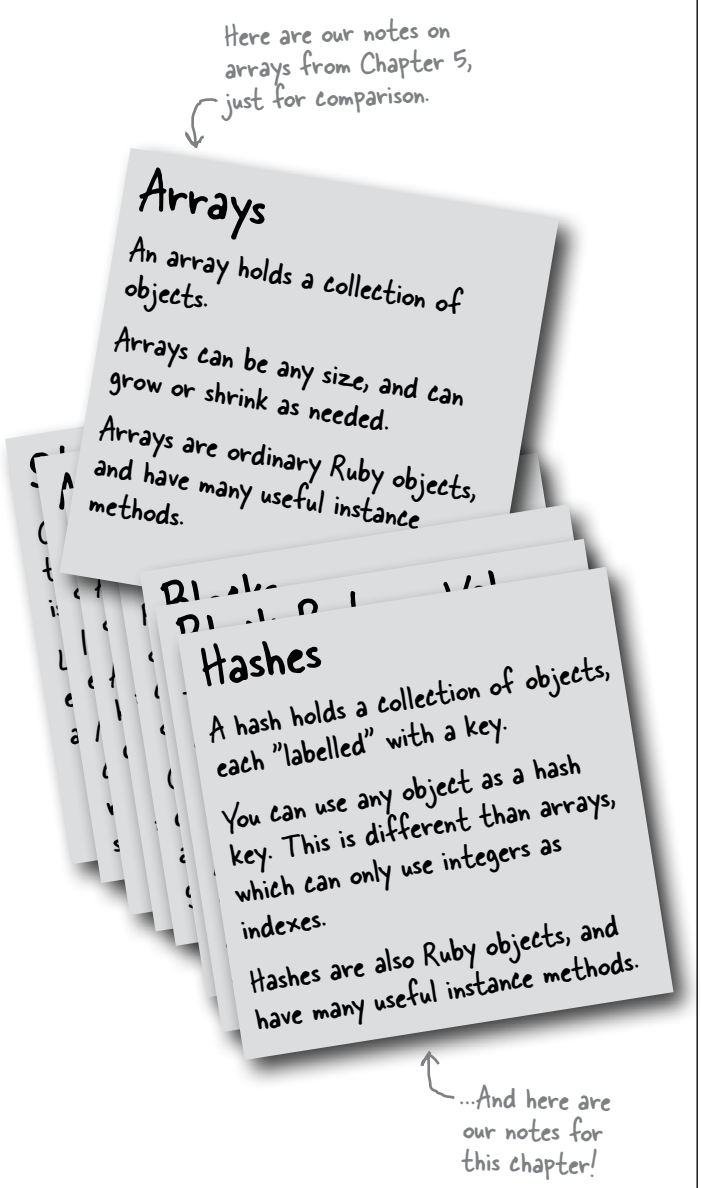
A `Creating catalog for owner carl...`

C `Creating  for owner ...`

F `missing keyword: database`

Your Ruby Toolbox

That's it for Chapter 7! You've added hashes to your tool box.

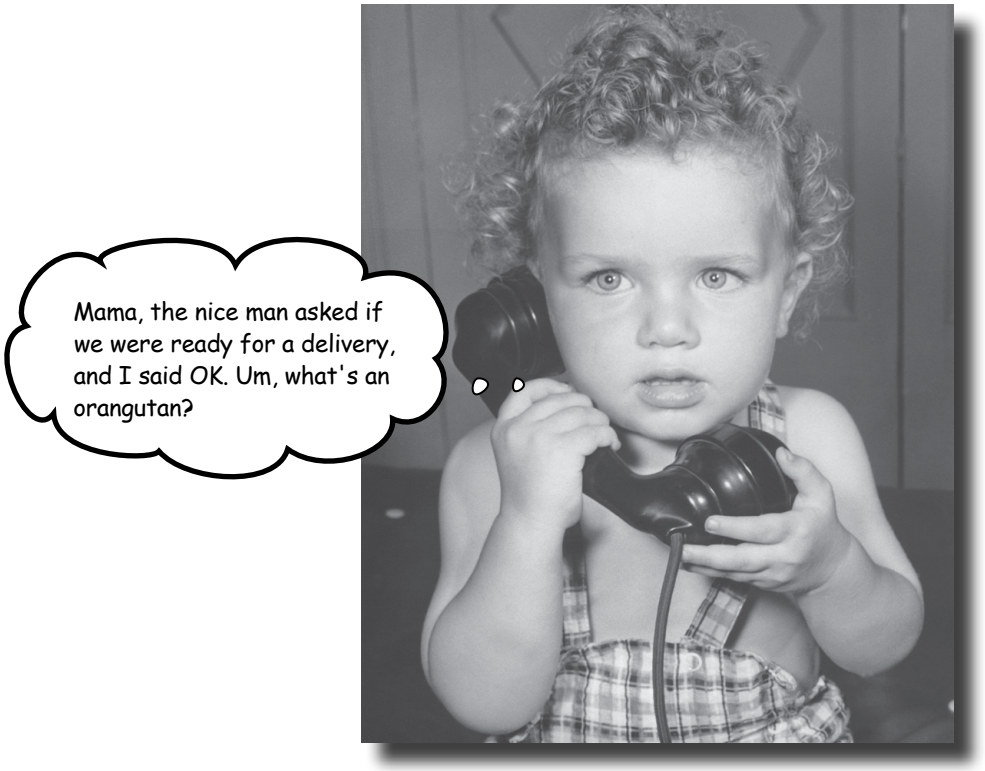


BULLET POINTS

- A hash literal is surrounded by curly braces. It needs to include a key for each value, like this: `{"one" => 1, "two" => 2}`
- When a hash key is accessed that a value has never been assigned to, nil is returned by default.
- Any Ruby expression can be used in conditional statements. Aside from the `false` boolean value, the only other value Ruby will treat as false is `nil`.
- You can use `Hash.new` instead of a hash literal to create a new hash. If you pass an object as an argument to `Hash.new`, that object will be returned by default when any key that hasn't been assigned to is accessed (instead of nil).
- If the key you access isn't exactly equal to the key in the hash, it will be treated as an entirely new key.
- Hashes have an `each` method that works a lot like the `each` method on arrays. The difference is that the block you provide should (normally) accept two parameters (instead of one): one for each key, and one for the corresponding value.
- If you pass a hash as the last argument to a method, Ruby lets you leave the braces off.
- If a hash uses symbols as keys, you can leave the colon off the symbol, and replace => with a colon, like this: `{name: "Kim", age: 28}`
- When defining a function, you can specify that callers should provide keyword arguments. The keywords and values are actually just a hash behind the scenes, but the values are placed into named parameters within the function.
- Keyword arguments can be required, or they can be made optional by defining a default value.

8 references

Crossed Signals



Ever sent an e-mail to the wrong contact? You probably had a hard time sorting out the confusion that ensued. Well, *Ruby objects* are *just like those contacts* in your address book, and *calling methods* on them is like *sending messages* to them. If your address book gets *mixed up*, it's possible to send the wrong message to the wrong object. And you'll have a hard time sorting out the confusion that ensues.

This chapter will help you *recognize the signs* that messages are going to the wrong objects, and help you *get your programs running smoothly* again.

Some confusing bugs

The word continues to spread - if someone has a Ruby problem, your company can solve it. And so people are showing up at your door with some unusual problems...

This astronomer thinks he has a clever way to save some coding... Instead of typing `my_star = CelestialBody.new` and `my_star.type = 'star'` for every star he wants to create, he wants to just *copy* the original star, and set a new name for it.

```
class CelestialBody
  attr_accessor :type, :name
end

altair = CelestialBody.new
altair.name = 'Altair'
altair.type = 'star'
polaris = altair
polaris.name = 'Polaris'
vega = polaris
vega.name = 'Vega'

puts altair.name, polaris.name, vega.name
```

To save time, he wants to copy the previous star...

...And just change the name.

Same here.

```
Vega
Vega
Vega
```

But it looks like the names on all 3 stars are now identical!

But the plan seems to be backfiring. All three of his `CelestialBody` instances are reporting that they have the *same* name!

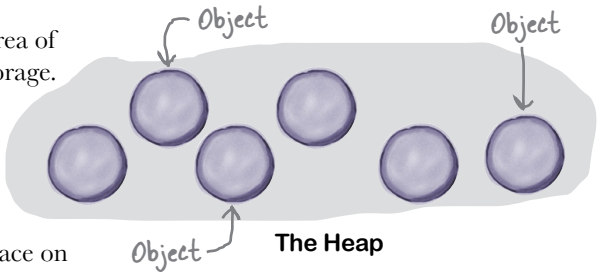
The heap

The bug in the star catalog program stems from an underlying problem: the developer *thinks* he's working with *multiple* objects, when actually he's operating on the *same* object over and over.

To understand how that can be, we're going to need to learn about where objects really live, and how your programs communicate with them.

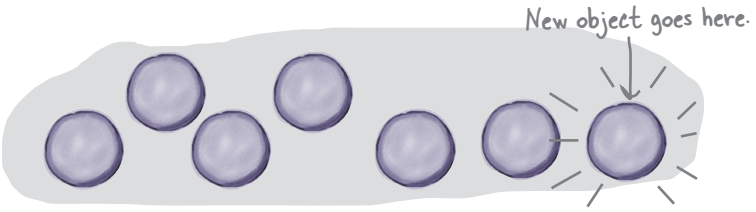
Rubyists often talk about "placing objects in variables", "storing objects in arrays", "storing an object in a hash value", and so forth. But that's just a simplification of what actually happens. Because you can't actually put an object *in* a variable, array, or hash.

Instead, all Ruby objects live on the **heap**, an area of your computer's memory allocated for object storage.



The Heap

When a new object is created, Ruby allocates space on the heap where it can live.



Generally, you don't need to concern yourself with the heap - Ruby manages it for you. The heap grows in size if more space is needed. Objects that are no longer used get cleared off the heap. It's not something you usually have to worry about.

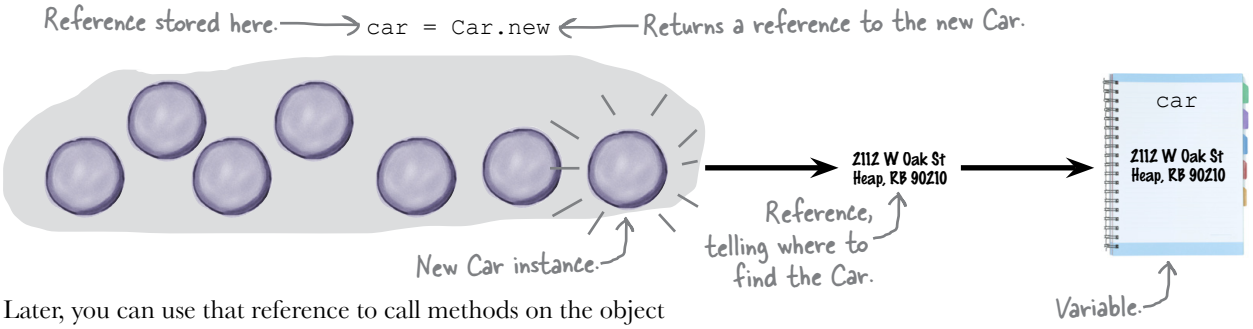
But we *do* need to be able to *retrieve* items that are stored on the heap. And we do that with *references*. Read on to learn more about them.

References

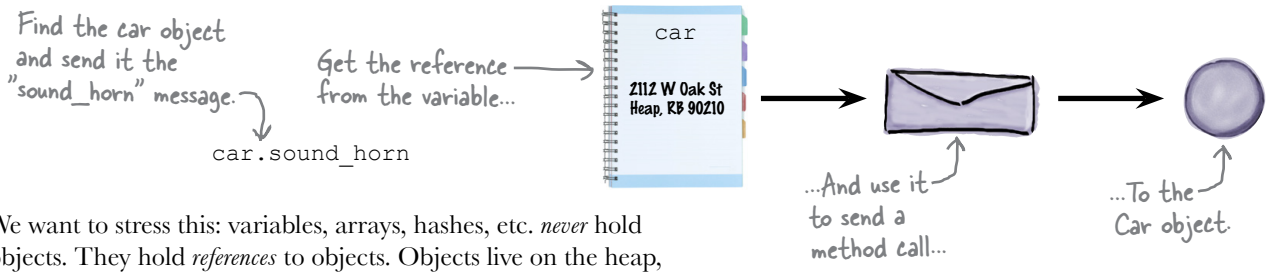
When you want to send a letter to a particular person, how do you get it to them? Each residence in a city has an *address* that mail can be sent to. You simply write the address on an envelope. A postal worker then uses that address to find the residence and deliver the letter.

When a friend of yours moves into a new residence, they give you their address, which you then write down in an address book or other convenient place. This allows you to communicate with them in the future.

Similar to addresses for houses, Ruby uses **references** to locate objects on the heap. When a new object is created, it returns a reference to itself. You store that reference in a variable, array, or other convenient place. Kind of like a house address, the reference tells Ruby where the object "lives" on the heap.



Later, you can use that reference to call methods on the object (which, you might recall, is similar to sending them a message).



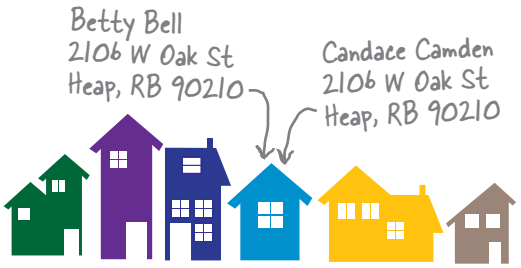
We want to stress this: variables, arrays, hashes, etc. *never* hold objects. They hold *references* to objects. Objects live on the heap, and they are only *accessed* through the references held in variables.

When references go wrong

Andy met not one, but *two* gorgeous women last week: Betty and Candace. Better yet, they both live on his street.

Oak Street in reality

Andy intended to write both their addresses down in his address book. Unfortunately for him, he accidentally wrote the *same* address (Betty's) down for *both* women.



Oak Street according to Andy's address book

Later that week, Betty received *two* letters from Andy:

Now, Betty is angry at Andy, and Candace (who never received a letter) thinks Andy is ignoring her.

What does any of this have to do with fixing our Ruby programs? You're about to find out...

Aliasing

Andy's dilemma can be simulated in Ruby with this simple class, called `LoveInterest`. A `LoveInterest` has an instance method, `request_date`, which will print an affirmative response just once. If the method is called again after that, the `LoveInterest` will report that it's busy.

```
class LoveInterest

  def request_date
    if @busy
      puts "Sorry, I'm busy."
    else
      puts "Sure, let's go!"
      @busy = true
    end
  end

end
```

@busy is nil (and treated as false) until it gets set to something else.

If this is not the first request...

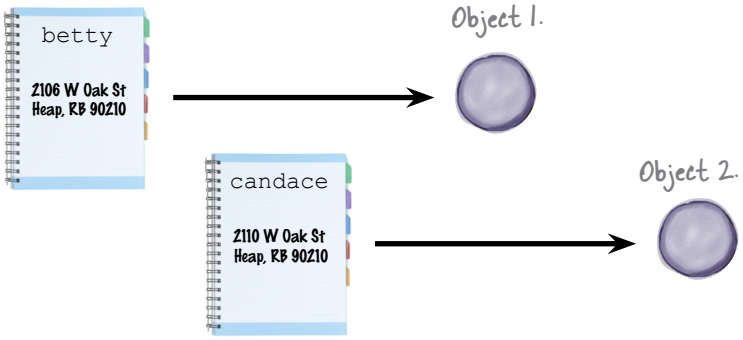
Give a negative response.

Give an affirmative response.

Mark this object as unable to accept any future requests.

Normally, when using this class, we would create two separate objects, and store references to them in two separate variables:

```
betty = LoveInterest.new
candace = LoveInterest.new
```



When we use the two separate references to call `request_date` on the two separate objects, we get two affirmative answers, as we expect.

```
betty.request_date
candace.request_date
```

```
Sure, let's go!
Sure, let's go!
```

We can confirm that we're working with two different objects by using the `object_id` instance method, which almost all Ruby objects have. It returns a unique identifier for each object.

```
p betty.object_id
p candace.object_id
```

```
70115845133840
70115845133820
```

Two different objects.

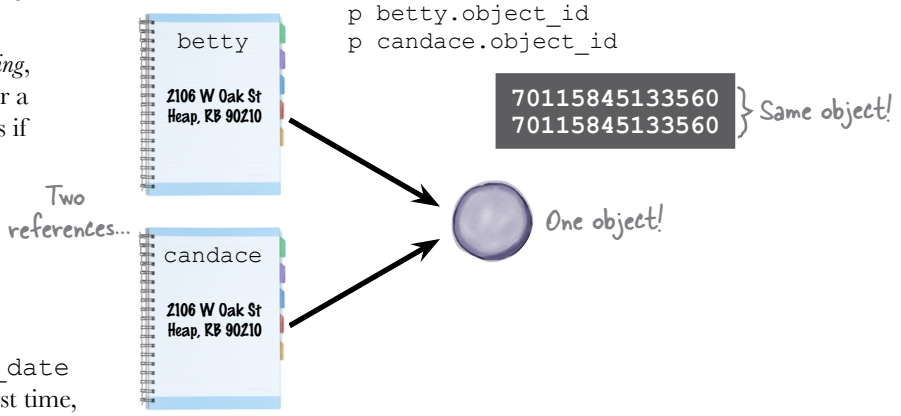
Aliasing (cont.)

But if we *copy* the reference instead, we wind up with two references to the *same* object, under two different *names* (the variables `betty` and `candace`).

This sort of thing is known as *aliasing*, because you have multiple *names* for a single thing. This can be dangerous if you're not expecting it!

```
betty = LoveInterest.new
candace = betty

p betty.object_id
p candace.object_id
```

```
70115845133560
70115845133560
```
Same object!



In this case, the calls to `request_date` both go to the same object. The first time, it responds that it's available, but the second request is rejected.

A second request to the SAME object!

```
betty.request_date
candace.request_date
```

```
Sure, let's go!
Sorry, I'm busy.
```

This aliasing behavior seems *awfully* familiar... Remember the malfunctioning star catalog program? Let's go back and take another look at that next.

Here is a Ruby class:

```
class Counter

  def initialize
    @count = 0
  end

  def increment
    @count += 1
    puts @count
  end

end
```

And here is some code that uses that class:

```
a = Counter.new
b = Counter.new
c = b
d = c

a.increment
b.increment
c.increment
d.increment
```

Guess what the code will output, and write your answer in the blanks.
(We've filled in the first one for you.)

1
.....
.....
.....
.....

Here is a Ruby class:

```
class Counter

  def initialize
    @count = 0
  end

  def increment
    @count += 1
    puts @count
  end

end
```

And here is some Ruby code that uses that class:

```
a = Counter.new
b = Counter.new
c = b
d = c

a.increment
b.increment
c.increment
d.increment
```

Guess what the code will output, and write your answer in the blanks.

1
1
2
3

Fixing the astronomer's program

Now that we've learned about aliasing, let's take another look at the astronomer's malfunctioning star catalog, and see if we can figure out the problem this time...

```
class CelestialBody
  attr_accessor :type, :name
end

altair = CelestialBody.new
altair.name = 'Altair'
altair.type = 'star'
polaris = altair
polaris.name = 'Polaris'
vega = polaris
vega.name = 'Vega'

puts altair.name, polaris.name, vega.name
```

To save time, he wants to copy the previous star...

...And just change the name.

Same here.

```
Vega
Vega
Vega
```

But it looks like the names on all 3 stars are now identical!

If we try calling `object_id` on the objects in the three variables, we'll see that all three variables refer to the *same* object. The same object under three different names... sounds like another case of aliasing!

```
puts altair.object_id
puts polaris.object_id
puts vega.object_id
```

```
70189936850940
70189936850940
70189936850940
```

Same object!

Fixing the astronomer's program (cont.)

By copying the contents of the variables, the astronomer did *not* get three `CelestialBody` instances as he thought. Instead, he's a victim of unintentional aliasing - he got *one* `CelestialBody` with *three* references to it!

Stores a reference to a new CelestialBody.

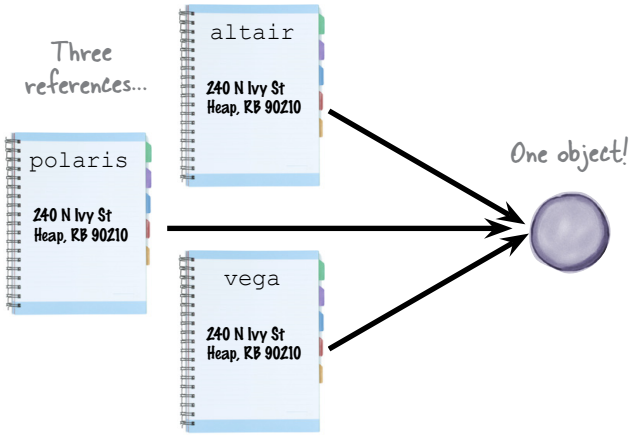
Copies the SAME reference to a new variable!

Copies the same reference to a THIRD variable!

```
altair = CelestialBody.new
altair.name = 'Altair'
altair.type = 'star'
polaris = altair
polaris.name = 'Polaris'
vega = polaris
vega.name = 'Vega'

puts altair.name, polaris.name, vega.name
```

To this poor, bewildered object, the sequence of instructions looked like this:

- "Set your `name` attribute to `'Altair'`, and your `type` attribute is now `'star'`.
- Now set your name to `'Polaris'`.
- Now your name is `'Vega'`.
- Give us your name attribute 3 times.



...The `CelestialBody` dutifully complied, and told us three times that its `name` was now `'Vega'`.

```
Vega
Vega
Vega
```

Fortunately, a fix will be easy. We just need to skip the shortcuts, and actually create *three* `CelestialBody` instances.

Create the first CelestialBody.

Instead of copying the reference, get a reference to a second CelestialBody.

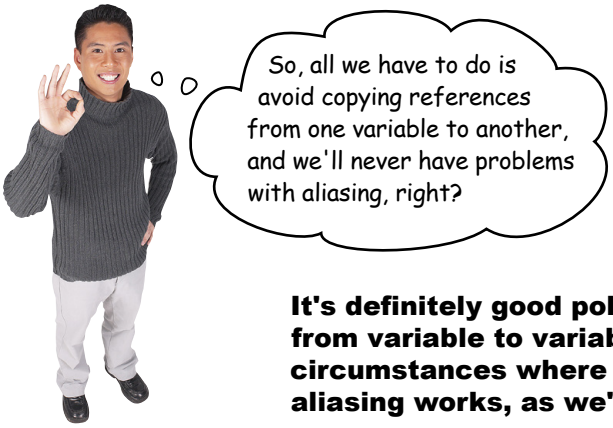
We need to set the type on each object separately.

Get a reference to a third object.

```
altair = CelestialBody.new
altair.name = 'Altair'
altair.type = 'star'
polaris = CelestialBody.new
polaris.name = 'Polaris'
polaris.type = 'star'
vega = CelestialBody.new
vega.name = 'Vega'
vega.type = 'star'

puts altair.name, polaris.name, vega.name
```

```
Altair
Polaris
Vega
```

And as we can see from the output, the problem is fixed!



It's definitely good policy to avoid copying references from variable to variable. But there are other circumstances where you need to be aware of how aliasing works, as we'll see shortly.

Quickly identifying objects with "inspect"

Before we move on, we should mention a shortcut for identifying objects... We've already shown you how to use the `object_id` instance method. If it outputs the same value for the object in two variables, you know they both point to the same object.

```
altair = CelestialBody.new
altair.name = 'Altair'
altair.type = 'star'
polaris = altair
polaris.name = 'Polaris'

puts altair.object_id, polaris.object_id
```

Copies the SAME reference to a new variable!

```
70350315190400
70350315190400
```

The SAME object!

The string returned by the `inspect` instance method also includes a representation of the object ID, in hexadecimal (consisting of the numbers "0" through "9" and the letters "a" through "f"). You don't need to know the details of how hexadecimal works; just know that if you see the *same value* for the object referenced by two variables, you have two aliases for the *same object*. A *different value* means a *different object*.

```
puts altair.inspect, polaris.inspect

vega = CelestialObject.new
puts vega.inspect
```

A hexadecimal representation of the object ID.

The SAME object!

A different object.

```
#<CelestialBody:0x007ff76b17f100 @name="Polaris", @type="star">
#<CelestialBody:0x007ff76b17f100 @name="Polaris", @type="star">
#<CelestialBody:0x007ff76b17edb8>
```

Problems with a hash default object

The astronomer is back, with more problematic code...

He needs his hash to be a mix of planets and moons. Since most of his objects will be planets, he set the hash default object to a `CelestialBody` with a `type` attribute of `"planet"`. (We saw hash default objects last chapter; they let you set an object the hash will return any time you access a key that hasn't been assigned to.)

```
class CelestialBody
  attr_accessor :type, :name
end

default_body = CelestialBody.new
default_body.type = 'planet'
bodies = Hash.new(default_body)
```

Set up a planet.

Make the planet the default value for all unassigned hash keys.

He believes that will let him add planets to the hash simply by assigning names to them. And it seems to work:

```
bodies['Mars'].name = 'Mars'
p bodies['Mars']
```

A CelestialBody with the correct type attribute...

```
#<CelestialBody:0x007fc60d13e6f8 @type="planet", @name="Mars">
```

When the astronomer needs to add a moon to the hash, he can do that, too. He just has to set the `type` attribute in addition to the `name`.

```
bodies['Europa'].name = 'Europa'
bodies['Europa'].type = 'moon'

p bodies['Europa']
```

A CelestialBody with a type of "moon"...

```
#<CelestialBody:0x007fc60d13e6f8 @type="moon", @name="Europa">
```

But then, as he continues adding new `CelestialBody` objects to the hash, it starts behaving strangely...

Problems with a hash default object (cont.)

The problems with using a `CelestialBody` as a hash default object become apparent as more objects as the astronomer tries to add more objects to the hash... When he adds another planet after adding a moon, the planet's `type` attribute is set to `"moon"` as well!

```
bodies['Venus'].name = 'Venus'

p bodies['Venus']
```

This is supposed to be a planet. Why is this set to "moon"?!

```
#<CelestialBody:0x007fc60d13e6f8 @type="moon", @name="Venus">
```

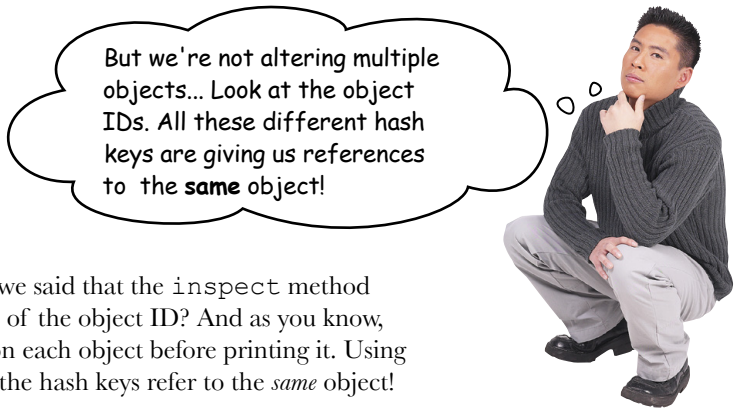
...If he goes back and gets the value for the keys he added previously, *those* objects appear to have been modified as well!

```
p bodies['Mars']
p bodies['Europa']
```

Isn't one of these supposed to be a "moon"?

What happened to the names "Mars" and "Europa"?

```
#<CelestialBody:0x007fc60d13e6f8 @type="moon", @name="Venus">
#<CelestialBody:0x007fc60d13e6f8 @type="moon", @name="Venus">
```



Good observation! Remember we said that the `inspect` method string includes a representation of the object ID? And as you know, the `p` method calls `inspect` on each object before printing it. Using the `p` method shows us that all the hash keys refer to the *same* object!

```
p bodies['Venus']
p bodies['Mars']
p bodies['Europa']
```

These are all the SAME object!

```
#<CelestialBody:0x007fc60d13e6f8 @type="moon", @name="Venus">
#<CelestialBody:0x007fc60d13e6f8 @type="moon", @name="Venus">
#<CelestialBody:0x007fc60d13e6f8 @type="moon", @name="Venus">
```

Looks like we've got a problem with aliasing again! On the next few pages, we'll see how to fix it.

We're actually modifying the hash default object!

The central problem with this code is that we're not actually modifying hash values. Instead, we're modifying the *hash default object*.

We can confirm this using the `default` instance method, which is available on all hashes. It lets us look at the default object after we create the hash.

Let's inspect the default object both before and after we attempt to add a planet to the hash.

```
class CelestialBody
  attr_accessor :type, :name
end

default_body = CelestialBody.new
default_body.type = 'planet'
bodies = Hash.new(default_body)

p bodies.default                    # Inspect the default object.

bodies['Mars'].name = 'Mars'        # Try to add a value to the hash.

p bodies.default                    # Inspect the default object again.
```

The hash default object BEFORE attempting to add a hash value.

```
#<CelestialBody:0x007f868a8274c8 @type="planet">
#<CelestialBody:0x007f868a8274c8 @type="planet", @name="Mars">
```

The hash default object AFTER attempting to add a hash value..

The name got added to the default object instead!

So why is a name being added to the default object? Shouldn't it be getting added to the hash value for `bodies['Mars']`?

If we look at the object IDs for both `bodies['Mars']` and the hash default object, we'll have our answer:

```
p bodies['Mars']
p bodies.default
```

Same object ID!

The SAME object!

```
#<CelestialBody:0x007f868a8274c8 @type="planet", @name="Mars">
#<CelestialBody:0x007f868a8274c8 @type="planet", @name="Mars">
```

When we access `bodies['Mars']`, we're still getting a reference to the hash default object! But why?

A more detailed look at hash default objects

When we introduced the hash default object in the last chapter, we said that you get the default object anytime you access a key *that hasn't been assigned to yet*. Let's take a closer look at that last detail.

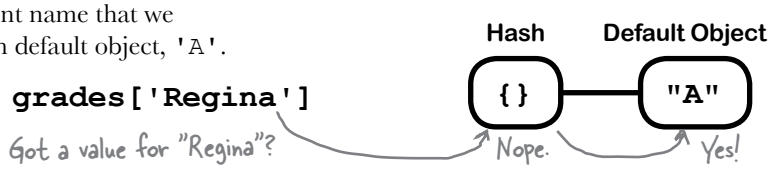
Let's suppose we've created a hash that will hold student names as the keys, and their grades as the corresponding values. We want the default to be a grade of `'A'`.

```
grades = Hash.new('A')
```

At first, the hash is completely empty. Any student name that we request a grade for will come back with the hash default object, `'A'`.

```
p grades['Regina']
```

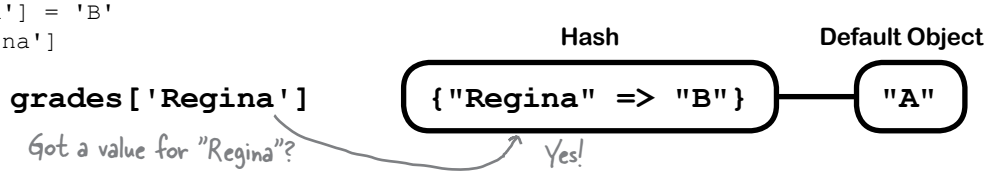
```
'A'
```



When we assign a value to a hash key, we'll get that value back instead of the hash default the next time we try to access it.

```
grades['Regina'] = 'B'
p grades['Regina']
```

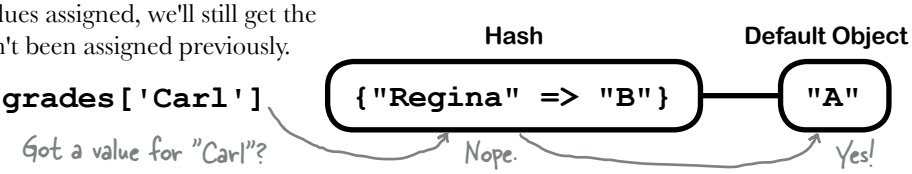
```
"B"
```



Even when some keys have had values assigned, we'll still get the default object for any key that hasn't been assigned previously.

```
p grades['Carl']
```

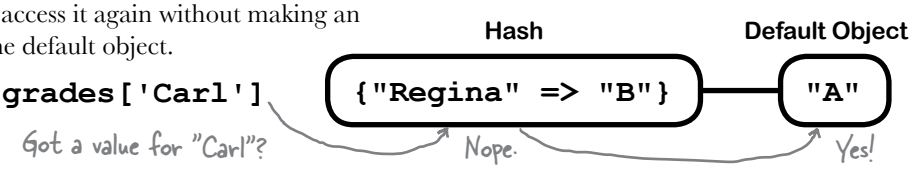
```
"A"
```



But *accessing* a hash value is not the same as *assigning* to it. If you access a hash value once and then access it again without making an assignment, you'll still be getting the default object.

```
p grades['Carl']
```

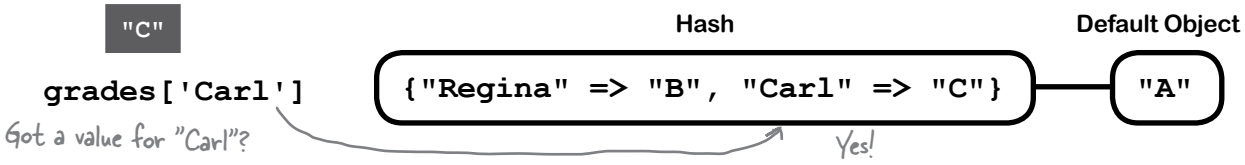
```
"A"
```



Only when a value is *assigned to* the hash (not just *retrieved from* it) will anything other than the default object be returned.

```
grades['Carl'] = 'C'
p grades['Carl']
```

```
"C"
```



Back to the hash of planets and moons

And *that* is why, when we try to set the `type` and `name` attributes of objects in the hash of planets and moons, we wind up altering the default object instead. We're not actually assigning any values to the hash. In fact, if we inspect the hash itself, we'll see that it's totally empty!

```
class CelestialBody
  attr_accessor :type, :name
end

default_body = CelestialBody.new
default_body.type = 'planet'
bodies = Hash.new(default_body)

bodies['Mars'].name = 'Mars'
bodies['Europa'].name = 'Europa'
bodies['Europa'].type = 'moon'
bodies['Venus'].name = 'Venus'

p bodies
```

`{}` ← Empty!

I thought we **were** assigning values to the hash. Aren't those assignment statements right there?

Isn't this assigning to the hash?

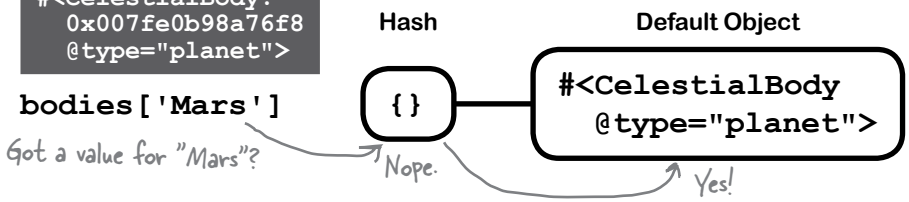
```
bodies['Mars'].name = 'Mars'
bodies['Europa'].name = 'Europa'
bodies['Europa'].type = 'moon'
bodies['Venus'].name = 'Venus'
```

Actually, those are calls to the `name=` and `type=` attribute writer methods on the hash default object. Don't mistake them for assignment to the hash.

When we access a key for which no value has been assigned, we get the default object back.

```
default_body = CelestialBody.new
default_body.type = 'planet'
bodies = Hash.new(default_body)

p bodies['Mars']
```

```
#<CelestialBody:
  0x007fe0b98a76f8
  @type="planet">
```

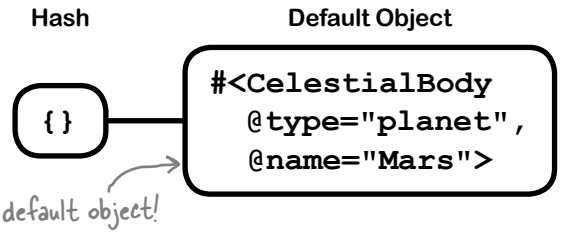


The statement below is *not* an assignment to the hash. It attempts to *access* a value for the key `'Mars'` from the hash (which is still empty). Since there is no value for `'Mars'`, it gets a reference to the default object, *which it then modifies*.

```
bodies['Mars'].name = 'Mars'
```

Accesses the default object.

Modifies the default object.



And since there's *still* nothing assigned to the hash, the *next* access gets a reference to the default object as well, and so on.

Fortunately, we have a solution for you...

Our wish list for hash defaults

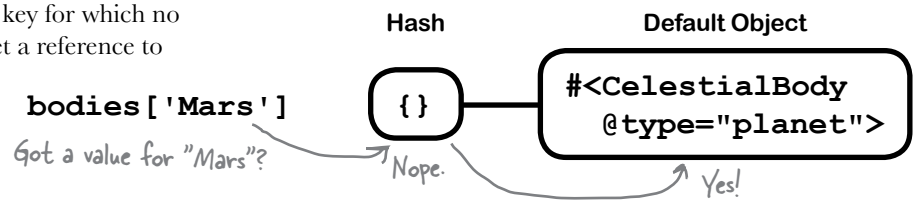
We've determined that this code doesn't *assign* a value to the hash, it just *accesses* a value. It gets a reference to the default object, which it then (unintentionally) modifies.

```
default_body = CelestialBody.new
default_body.type = 'planet'
bodies = Hash.new(default_body)

bodies['Mars'].name = 'Mars'
```

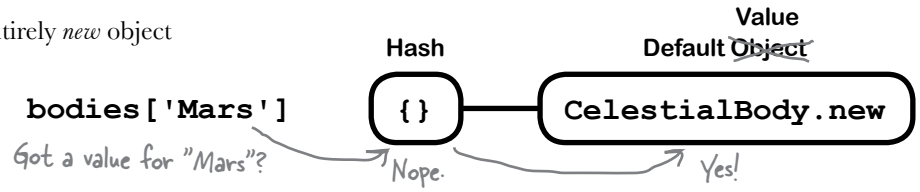
Gets a reference to the default object.

Modifies the default object!

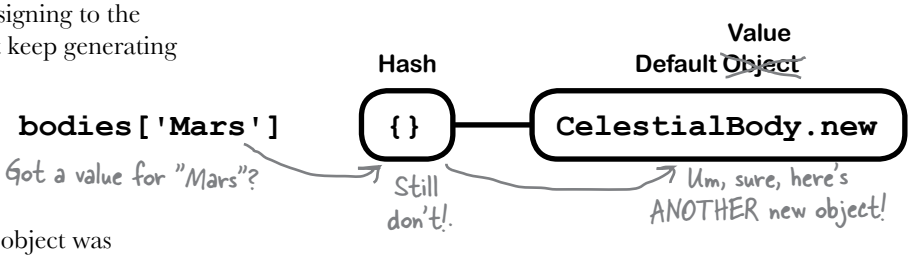
Right now, when we access a hash key for which no value has been assigned, we just get a reference to the hash default object.



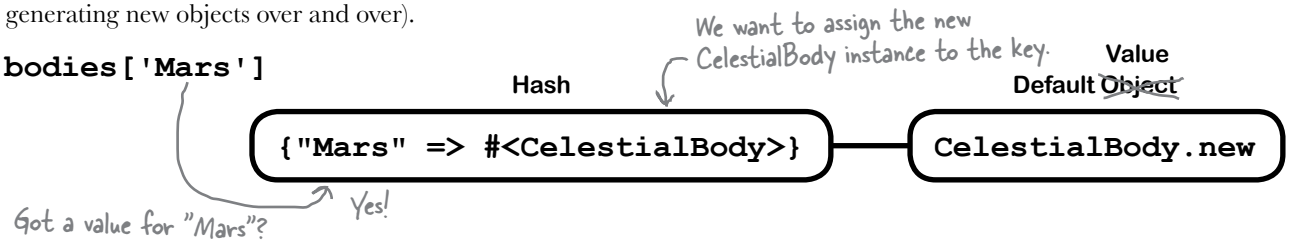
What we *really* want is to get an entirely *new* object for each unassigned hash key.



Of course, if we did that *without* assigning to the hash, then later accesses would just keep generating new objects over and over...



So it would also be nice if the new object was assigned to the hash for us, so that later accesses would get the same object again (instead of generating new objects over and over).



Hashes have a feature that can do *all* this for us!

Hash default blocks

Instead of passing an argument to `Hash.new` to be used as a hash default *object*, you can pass a *block* to `Hash.new` to be used as the hash default *block*. When a key is accessed for which no value has been assigned:

- The block is called.
- The block receives references to the hash and the current key as block parameters. These can be used to assign a value to the hash.
- The block return value is returned as the current value of the hash key.

Those rules are a bit complex, so we'll go over them in more detail in the next few pages. But for now, let's take a look at your first hash default block:

```
bodies = Hash.new do |hash, key|
  body = CelestialBody.new
  body.type = "planet"
  hash[key] = body
  body
end
```

Creates the hash.

When the block is called later, it will receive a reference to the hash and the key being accessed.

Here we set up the object which will become the value for this key.

Assign the object to the current hash key.

Return the object.

If we access keys on *this* hash, we get separate objects for each key, just like we always intended.

This code is identical to what we used a couple pages ago!

```
bodies['Mars'].name = 'Mars'
bodies['Europa'].name = 'Europa'
bodies['Europa'].type = 'moon'
bodies['Venus'].name = 'Venus'
```

```
p bodies['Mars']
p bodies['Europa']
p bodies['Venus']
```

Three separate objects.

bodies['Mars'] →
bodies['Europa'] →
bodies['Venus'] →

```
#<CelestialBody:0x007fe701896580 @type="planet", @name="Mars">
#<CelestialBody:0x007fe7018964b8 @type="moon", @name="Europa">
#<CelestialBody:0x007fe7018963a0 @type="planet", @name="Venus">
```

Better yet, the first time we access any key, a value is automatically assigned to the hash for us!

Values have been assigned to the hash!

```
p bodies
```

```
{"Mars"=>#<CelestialBody:0x007fe701896580 @type="planet", @name="Mars">,
 "Europa"=>#<CelestialBody:0x007fe7018964b8 @type="moon", @name="Europa">,
 "Venus"=>#<CelestialBody:0x007fe7018963a0 @type="planet", @name="Venus">}
```

Now that we know it will work, let's take a closer look at the components of that block...

Hash default blocks: Assigning to the hash

In most cases, you'll want the value created by your hash default block to be assigned to the hash. A reference to the hash and the current key are passed to the block, in order to allow you to do so.

When the block is called later, it will receive a reference to the hash and the key being accessed.

```
bodies = Hash.new do |hash, key|
  body = CelestialBody.new
  body.type = "planet"
  hash[key] = body
  body
end
```

Assign the object to the current hash key.

When we assign values to the hash in the block body, things work like we've been expecting all along. A new object is generated for each new key you access. On subsequent accesses, we get the same object back again, with any changes we've made intact.

Generates a new object.

Gives us the same object as the line above.

Changes we make will be saved.

```
p bodies['Europa']
p bodies['Europa']
bodies['Europa'].type = 'moon'
p bodies['Europa']
```

All the same object.

```
#<CelestialBody:0x007fb6389eed00 @type="planet">
#<CelestialBody:0x007fb6389eed00 @type="planet">
#<CelestialBody:0x007fb6389eed00 @type="moon">
```

Type attribute is intact.

Watch it!

Don't forget to assign a value to the hash!

If you forget, the generated value will just be thrown away. The hash key still won't have a value, and the hash will just keep calling the block over and over to generate new defaults.

We SHOULD assign to the hash here. If we don't....

We'll get a different object each time we access this key!

Changes we make will be discarded!

```
bodies = Hash.new do |hash, key|
  body = CelestialBody.new
  body.type = "planet"
  body
end

p bodies['Europa']
p bodies['Europa']
bodies['Europa'].type = 'moon'
p bodies['Europa']
```

All different objects!

```
#<CelestialBody:0x007ff95507ee90 @type="planet">
#<CelestialBody:0x007ff95507ecd8 @type="planet">
#<CelestialBody:0x007ff95507eaf8 @type="planet">
```

Type is still at the default!

Hash default blocks: Block return value

When you access an unassigned hash key for the first time, the hash default block's return value is returned as the value for the key.

```
bodies = Hash.new do |hash, key|
  body = CelestialBody.new
  body.type = "planet"
  hash[key] = body
  body
end

p bodies['Mars']
```

This return value... ← `body`

Is what we get here! ← `p bodies['Mars']`

```
#<CelestialBody:0x007fef7a9132c0 @type="planet">
```

As long as you assign a value to the key within the block body, the hash default block won't be invoked for subsequent accesses of that key; instead, you'll get whatever value was assigned.

Watch it!

Make sure the block return value matches what you're assigning to the hash!

Otherwise, you'll get one value when you first access the key, and a completely different value on subsequent accesses.

```
bodies = Hash.new do |hash, key|
  body = CelestialBody.new
  body.type = "planet"
  hash[key] = body
  "I'm a little teapot"
end
p bodies['Mars']
p bodies['Mars']
```

The value returned from the block!

The value assigned to the hash!

```
"I'm a little teapot"
#<CelestialBody:0x007fcf830ff000 @type="planet">
```

Generally speaking, you won't need to work very hard to remember this rule. As we'll see on the next page, setting up an appropriate return value for your hash default block happens quite naturally...

Hash default blocks: A shortcut

Thus far, we've been returning a value from the hash default block on a separate line:

```
bodies = Hash.new do |hash, key|
  body = CelestialBody.new
  body.type = "planet"
  hash[key] = body
  body
end

p bodies['Mars']
```

Separate block return value.

```
#<CelestialBody:0x007fef7a9132c0 @type="planet">
```

But Ruby offers a shortcut that can reduce the amount of code in your default block a bit...

You've already learned that the value of the last expression in a block is treated as the block's return value... What we *haven't* mentioned is that in Ruby, the value of an assignment expression is the same as the value being assigned.

```
p my_hash = {}
p my_array = []
p my_integer = 20
p my_hash['A'] = ['Apple']
p my_array[0] = 245
```

```
{}
[]
20
["Apple"]
245
```

Values of expressions same as values assigned.

So, we can use just an assignment statement in a hash default block, and it will return the assigned value.

```
greetings = Hash.new do |hash, key|
  hash[key] = "Hi, #{key}"
end

p greetings["Kayla"]
```

```
"Hi, Kayla"
```

And, of course, it will add the value to the hash as well.

```
p greetings
```

```
{"Kayla"=>"Hi, Kayla"}
```

So in the astronomer's hash, instead of adding a separate line with a return value, we can just let the value of the assignment expression provide the return value for the block.

```
bodies = Hash.new do |hash, key|
  body = CelestialBody.new
  body.type = "planet"
  hash[key] = body
end

p bodies['Mars']
```

Let this be the block return value.

```
#<CelestialBody:0x007fa769a3f2d8 @type="planet">
```

The three code snippets below are all *supposed* to make a hash of arrays with foods grouped by the first letter of their name, but only one actually works. Match each snippet with the output it would produce.

(We've filled in the first one for you.)

A

```
foods = Hash.new([])
foods['A'] << "Apple"
foods['A'] << "Avocado"
foods['B'] << "Bacon"
foods['B'] << "Bread"
p foods['A']
p foods['B']
p foods
```

B

```
foods = Hash.new { |hash, key| [] }
foods['A'] << "Apple"
foods['A'] << "Avocado"
foods['B'] << "Bacon"
foods['B'] << "Bread"
p foods['A']
p foods['B']
p foods
```

C

```
foods = Hash.new { |hash, key| hash[key] = [] }
foods['A'] << "Apple"
foods['A'] << "Avocado"
foods['B'] << "Bacon"
foods['B'] << "Bread"
p foods['A']
p foods['B']
p foods
```

.....

```
[]
[]
{}
```

A .....

```
["Apple", "Avocado", "Bacon", "Bread"]
["Apple", "Avocado", "Bacon", "Bread"]
{}
```

.....

```
["Apple", "Avocado"]
["Bacon", "Bread"]
{"A"=>["Apple", "Avocado"], "B"=>["Bacon", "Bread"]}
```

Exercise Solution

The three code snippets below are all *supposed* to make a hash of arrays with foods grouped by the first letter of their name, but only one actually works. Match each snippet with the output it would produce.

A

```
foods = Hash.new([])
foods['A'] << "Apple"
foods['A'] << "Avocado"
foods['B'] << "Bacon"
foods['B'] << "Bread"
p foods['A']
p foods['B']
p foods
```

This ONE array will be used as the default value for all hash keys!

All of these will get added to the SAME array!

B

```
foods = Hash.new { |hash, key| [] }
foods['A'] << "Apple"
foods['A'] << "Avocado"
foods['B'] << "Bacon"
foods['B'] << "Bread"
p foods['A']
p foods['B']
p foods
```

Returns a new, empty array each time the block is called, but doesn't add it to the hash!

Each string is added to a new array. The array is then discarded!

C

```
foods = Hash.new { |hash, key| hash[key] = [] }
foods['A'] << "Apple"
foods['A'] << "Avocado"
foods['B'] << "Bacon"
foods['B'] << "Bread"
p foods['A']
p foods['B']
p foods
```

Assigns a new array to the hash, under the current key.

Added to a new array.

Added to same array as "Apple".

Added to a new array.

Added to same array as "Bacon".

B

```
[]
[]
{}
```

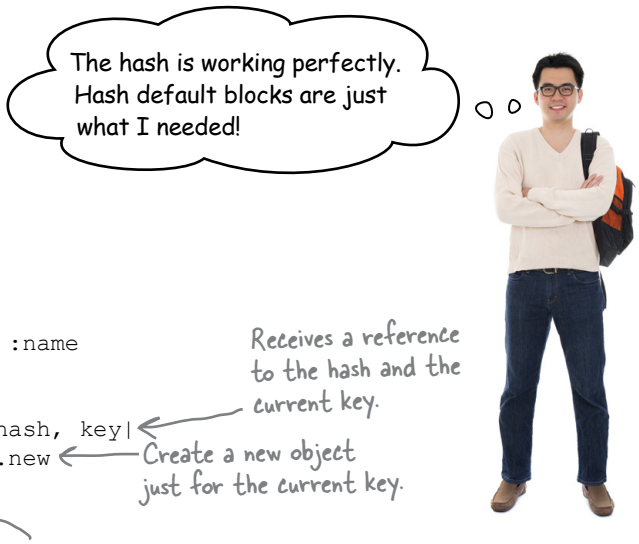
A

```
["Apple", "Avocado", "Bacon", "Bread"]
["Apple", "Avocado", "Bacon", "Bread"]
{}
```

C

```
["Apple", "Avocado"]
["Bacon", "Bread"]
{"A"=>["Apple", "Avocado"], "B"=>["Bacon", "Bread"]}
```

The astronomer's hash: our final code



Here's our final code for the hash default block:

```
class CelestialBody
  attr_accessor :type, :name
end

bodies = Hash.new do |hash, key|
  body = CelestialBody.new
  body.type = "planet"
  hash[key] = body
end

bodies['Mars'].name = 'Mars'
bodies['Europa'].name = 'Europa'
bodies['Europa'].type = 'moon'
bodies['Venus'].name = 'Venus'

p bodies
```

Receives a reference to the hash and the current key.

Create a new object just for the current key.

Assigns to the hash AND returns the new value.

These lines all work as expected, now!

(Output aligned for easier reading.)

Each hash value is a separate object.

Type defaults to "planet", but can be overridden.

Names are all intact.

```
{"Mars"   =>#<CelestialBody:0x007fcde388aaa0 @type="planet", @name="Mars"   >,
 "Europa"=>#<CelestialBody:0x007fcde388a9d8 @type="moon",   @name="Europa">,
 "Venus" =>#<CelestialBody:0x007fcde388a8c0 @type="planet", @name="Venus" >}
```

Here's what we did to get this program working:

- We use a hash default block to create a *unique* object for each hash key. (This is unlike a hash default object, which gives references to *one* object as the default for *all* keys.)
- Within the block, we assign the new object to the current hash key.
- The new object becomes the value of the assignment expression, which also becomes the block's return value. So the first time a given hash key is accessed, they get the new object as the corresponding value.

Using hash default objects safely

I have one more question. Why would anyone use a hash default object when you can use a hash default block instead?

Hash default objects work very well if you use a number as the default.

I should only use numbers? Then why did Ruby let us use a `CelestialBody` as a default object earlier, without even a warning?

Okay, it's a little more complicated than that. Hash default objects work very well if you don't change the default, and if you assign values back to the hash. It's just that numbers make it easy to follow these rules.

Take this example, which counts the number of times letters occur in an array. (It works just like the vote counting code from last chapter.)

```
letters = ['a', 'c', 'a', 'b', 'c', 'a']

counts = Hash.new(0)

letters.each do |letter|
  counts[letter] += 1
end

p counts
```

If this value is unassigned, gets the hash default but does NOT modify it.

Assigns the incremented value back to the hash.

```
{"a"=>3, "c"=>2, "b"=>1}
```

Using a hash default object here works because we follow the above two rules...

Hash default object rule #1: Don't modify the default object

If you're going to use a hash default object, it's important not to modify that object. Otherwise, you'll get unexpected results the next time you access the default. We saw this happen when we used a default object (instead of a default block) for the astronomer's hash, and it caused havoc:

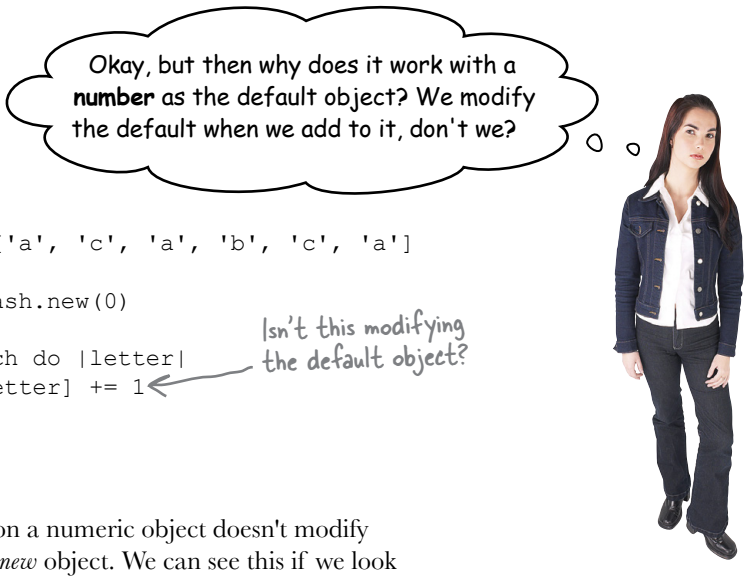
```
default_body = CelestialBody.new
default_body.type = 'planet'
bodies = Hash.new(default_body)
```

Sets the hash's default object.

```
bodies['Mars'].name = 'Mars'
```

Gets a reference to the default object.

Modifies the default object!




```
letters = ['a', 'c', 'a', 'b', 'c', 'a']

counts = Hash.new(0)

letters.each do |letter|
  counts[letter] += 1
end
```

Isn't this modifying the default object?

In Ruby, doing math operations on a numeric object doesn't modify that object; it returns an entirely *new* object. We can see this if we look at object IDs before and after an operation.

```
number = 0
puts number.object_id
number = number + 1
puts number.object_id
```

```
1
3
```

Two different objects! (Object IDs for integers are much lower than for other objects, but that's an implementation detail, so don't worry about it. The key point is, they're different.)

In fact, numeric objects are *immutable*: they don't *have* any methods that modify the object's state. Any operation that might change the number gives you back an entirely new object.

That's what makes numbers safe to use as hash default objects; you can be certain that the default number won't be changed accidentally.

Numbers make good hash default objects because they are immutable.

Hash default object rule #2: Assign values to the hash

If you're going to use a hash default object, it's also important to ensure you're actually assigning values to the hash. As we saw with the astronomer's hash, sometimes it can look like you're assigning to the hash when you're not...

```
default_body = CelestialBody.new
default_body.type = 'planet'
bodies = Hash.new(default_body)

bodies['Mars'].name = 'Mars'

p bodies
```

A call to an attribute writer method. This does NOT assign to the hash!

```
{}
```

The hash is still empty, actually!

When we use a *number* as a default object, though, it's much more natural to actually assign values to the hash. (Because numbers are immutable, we *can't* store the incremented values *unless* we assign them to the hash!)

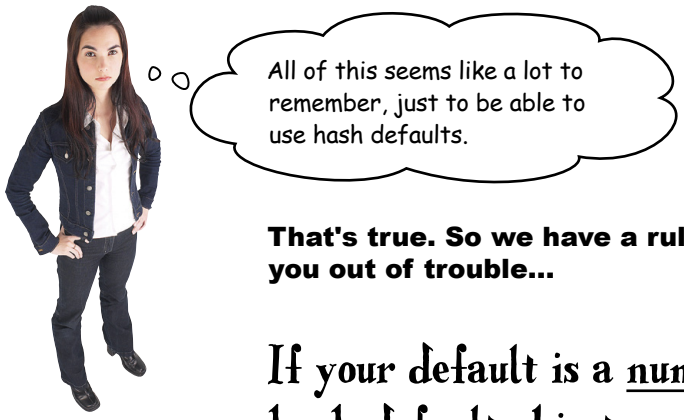
```
hash = Hash.new(0)

hash['a'] += 1
hash['c'] += 1

p hash.default
p hash
```

The hash default object is unchanged.

```
0
{"a"=>1, "c"=>1}
```

We assigned the values to the hash!

The rule of thumb for hash defaults



That's true. So we have a rule of thumb that will keep you out of trouble...

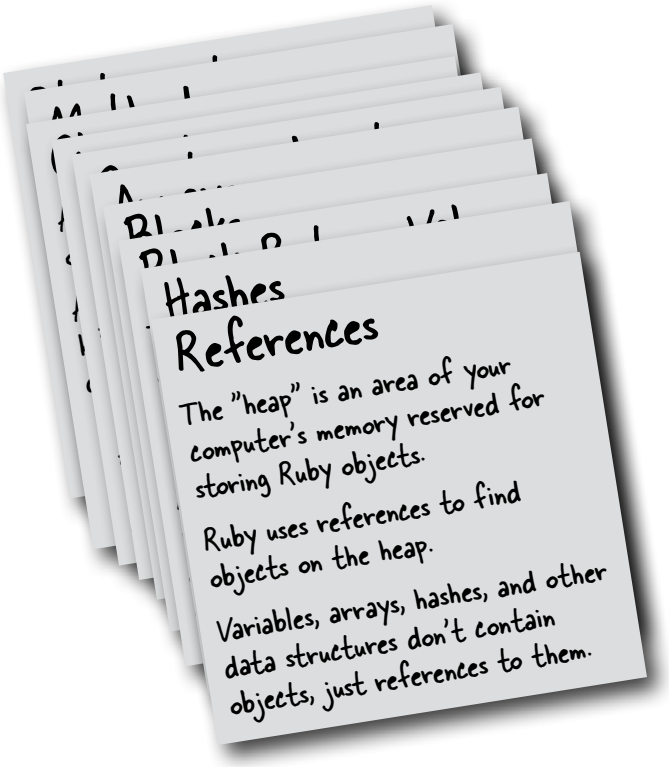
If your default is a number, you can use a hash default object.
If your default is anything else, you should use a hash default block.

As you gain more experience with references, all of this will become second nature, and you can break this rule of thumb when the time is right. Until then, this should prevent most problems you'll encounter.

Understanding Ruby references and the issue of aliasing won't help you write more powerful Ruby programs. It *will* help you quickly find and fix problems when they arise, however. Hopefully this chapter has helped you form a basic understanding of how references work, and will let you avoid trouble in the first place.

Your Ruby Toolbox

That's it for Chapter 8! You've added references to your tool box.



BULLET POINTS

- If you need to store more objects, Ruby will increase the size of the heap for you. If you're no longer using objects, Ruby will delete them from the heap for you.
- Aliasing is the copying of a reference to an object, and it can cause bugs if you do it unintentionally.
- Most Ruby objects have an object_id instance method, which returns a unique identifier for the object. It can be used to determine whether you have multiple references to a single object.
- The string returned by the inspect method also includes a representation of the object ID.
- If you set a default object for a hash, all unassigned hash keys will return references to that single default object.
- For this reason, it's best to only use immutable objects (objects that can't be modified), such as numbers, as hash default objects.
- If you need any other kind of object as a hash default, it's better to use a hash default block, so that a unique object is created for each key.
- Hash default blocks receive a reference to the hash and the current key as block parameters. In most cases, you'll want to use these parameters to assign a new object as a value for the given hash key.
- The hash default block's return value is treated as the initial default value for the given key.
- The value of a Ruby assignment expression is the same as the value being assigned. So if an assignment expression is the last expression in a block, the value assigned becomes the block's return value.