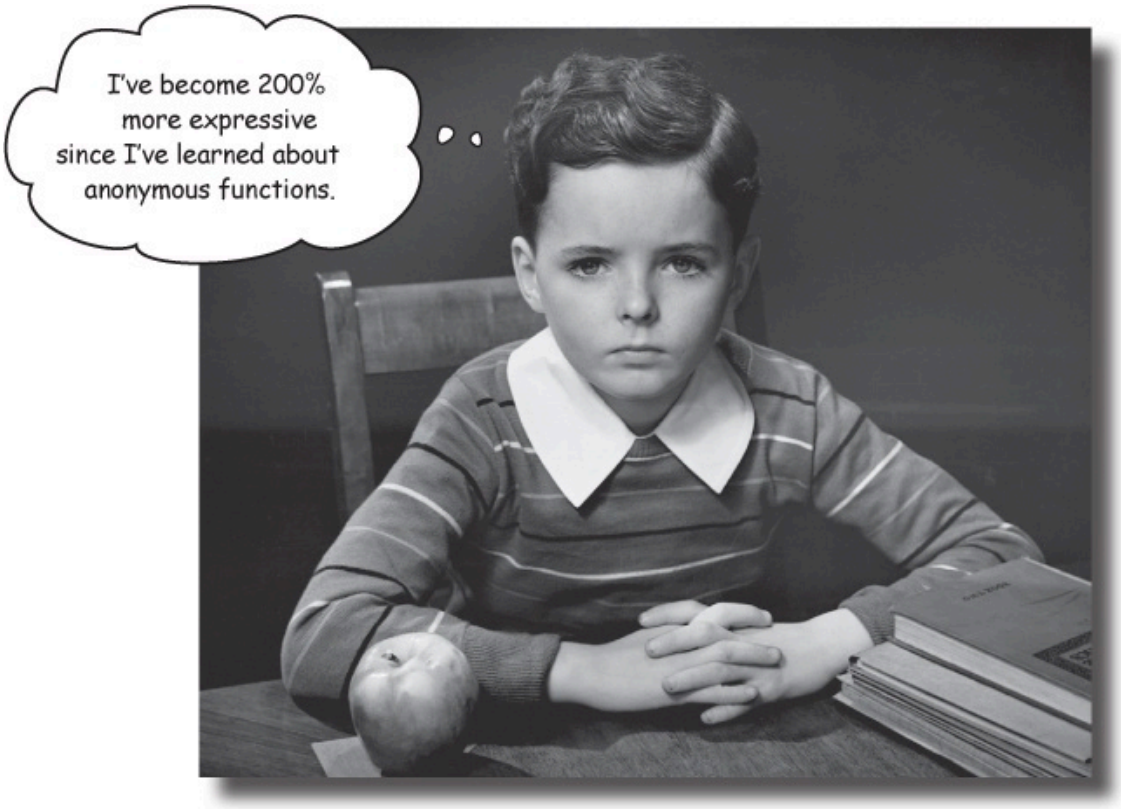
Chapter 11. Serious functions

Anonymous Functions, Scope and Closures



You've put functions through their paces, but there's more to learn. In this chapter we take it further; we get hard-core. We're going to show you how to **really handle** functions. This won't be a super long chapter, but it will be intense, and at the end you're going to be more expressive with your JavaScript than you thought possible. You're also going to be ready to take on a coworker's code, or jump into an open source JavaScript library, because we're going to cover some common coding idioms and conventions around functions. And if you've never heard of an **anonymous function** or a **closure**, boy are you in the right place.

NOTE

And if you have heard of a closure, but don't quite know what it is, you're even more in the right place!

Taking a look at the other side of functions...

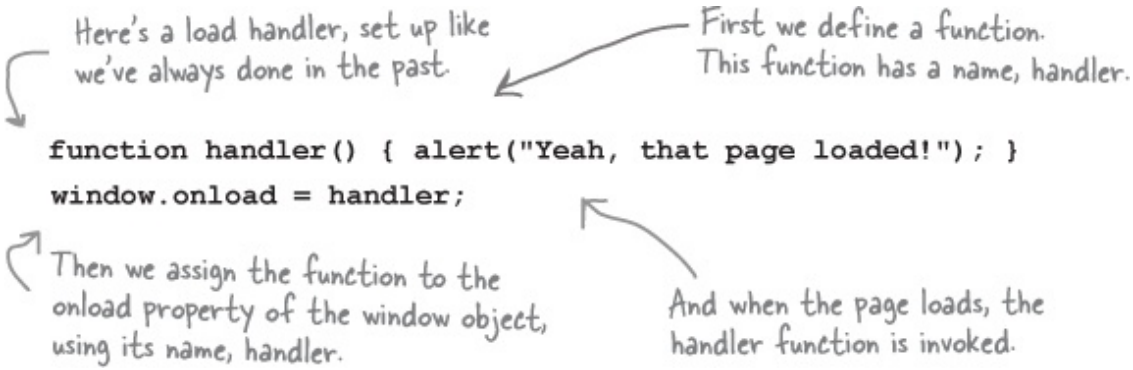
You've already seen two sides of functions—you've seen the formal, declarative side of function declarations, and you've seen the looser, more expressive side of function expressions. Well, now it's time to introduce you to another interesting side of functions: *the anonymous side.*

By anonymous we're referring to functions *that don't have names.* How can that happen? Well, when you define a function with a function declaration, your function will *definitely have a name*. But when you define a function using a function expression, *you don't have to give that function a name*.

You're probably saying, sure, that's an interesting fact, maybe it's possible, but so what? By using anonymous functions we can often make our code

less verbose, more concise, more readable, more efficient, and even more maintainable.

So let's see how to create and use anonymous functions. We'll start with a piece of code we've seen before, and see how an anonymous function might help out:



SHARPEN YOUR PENCIL

Use your knowledge of functions and variables and check off the true statements below.

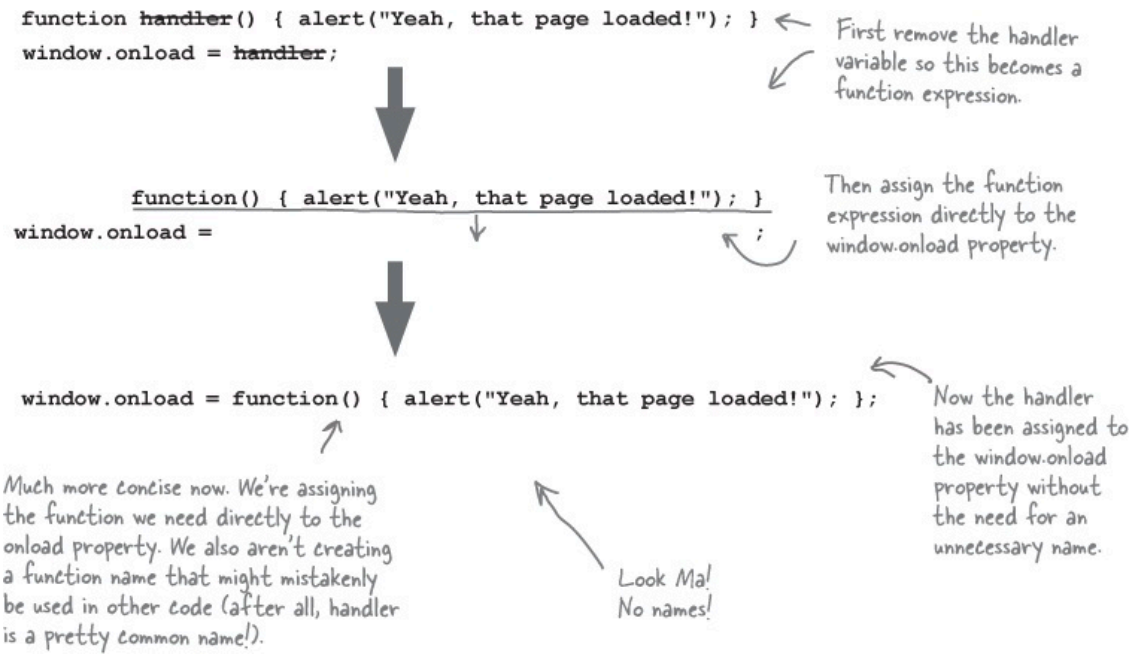
- [ ] The handler variable holds a function reference.
- [ ] When we assign handler to window.onload, we're assigning it a function reference.
- [ ] The only reason the handler variable exists is to assign it to window.onload.
- [ ] We'll never use handler again as it's code that is meant to run only when the page first loads.
- [ ] Invoking onload handlers twice is not a great idea—doing so could cause issues given these handlers usually do some initialization for the entire page.
- [ ] Function expressions create function references.
- [ ] Did we mention that when we assign handler to window.onload, we're assigning it a function reference?

How to use an anonymous function

So, we're creating a function to handle the load event, but we know it's a "one time" function because the load event only happens once per page load. We can also observe that the `window.onload` property is being assigned a function reference—namely, the function reference in `handler`. But because `handler` is a one time function, that name is a bit of a waste,

because all we do is assign the reference in it to the `window.onload` property.

Anonymous functions give us a way to clean up this code. An anonymous function is just a function expression without a name that's used where we'd normally use a function reference. But to make the connection, it helps to see how we use a function expression in code in an anonymous way:



BRAIN POWER

Are there places in your previous code that you've seen anonymous functions and hadn't realized it?

Hint: are they hiding somewhere in your objects?

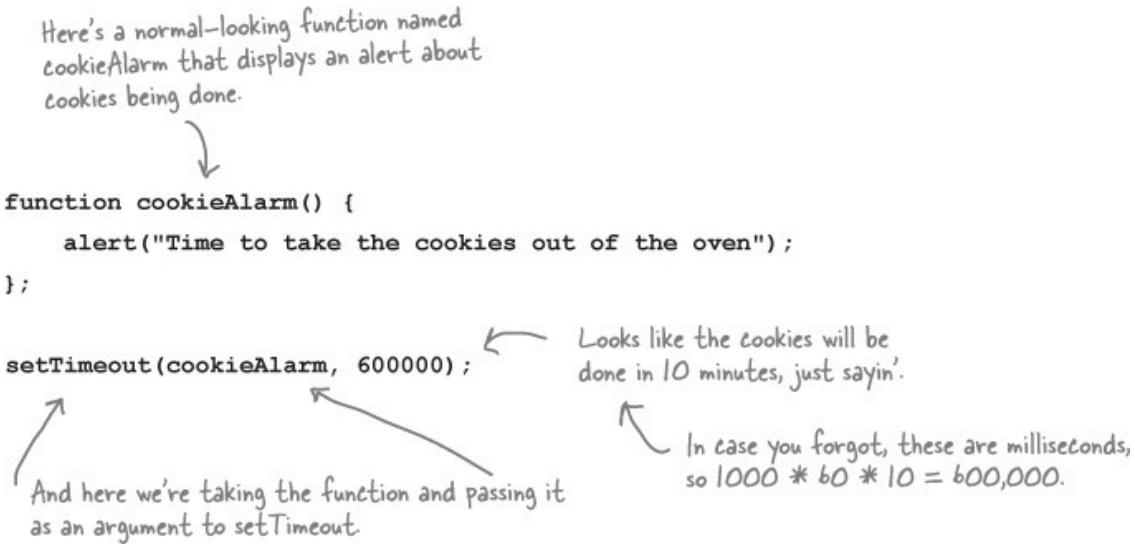
SHARPEN YOUR PENCIL

There are a few opportunities in the code below to take advantage of anonymous functions. Go ahead and rework the code to use anonymous functions wherever possible. You can scratch out the old code and write in new code where needed. Oh, and one more task: circle any anonymous functions that are already being used in the code.

```
window.onload = init;
var cookies = {
    instructions: "Preheat oven to 350...",
    bake: function(time) {
              console.log("Baking the cookies.");
              setTimeout(done, time);
          }
};
function init() {
    var button = document.getElementById("bake");
    button.onclick = handleButton;
}
function handleButton() {
    console.log("Time to bake the cookies.");
    cookies.bake(2500);
}
function done() {
    alert("Cookies are ready, take them out to cool.");
    console.log("Cooling the cookies.");
    var cool = function() {
        alert("Cookies are cool, time to eat!");
    };
    setTimeout(cool, 1000);
}
```

We need to talk about your verbosity, again

Okay, we hate to bring it up again because you've come a long way with functions—you know how to pass functions around, assign them to variables, pass them to functions, return them from functions—but, well, you're still being a little more verbose than you have to (you could also say you're not being as expressive as you could be). Let's see an example:



While this code looks fine, we can make it a bit tighter using anonymous functions. How? Well, think about the `cookieAlarm` variable in the call to `setTimeout`. This is a variable that references a function, so when we invoke `setTimeout`, a function reference is passed. Now, using a variable that references a function is one way to get a function reference, but just like with the `window.onload` example a couple of pages back, you can use a function expression too. Let's rewrite the code with a function expression instead:

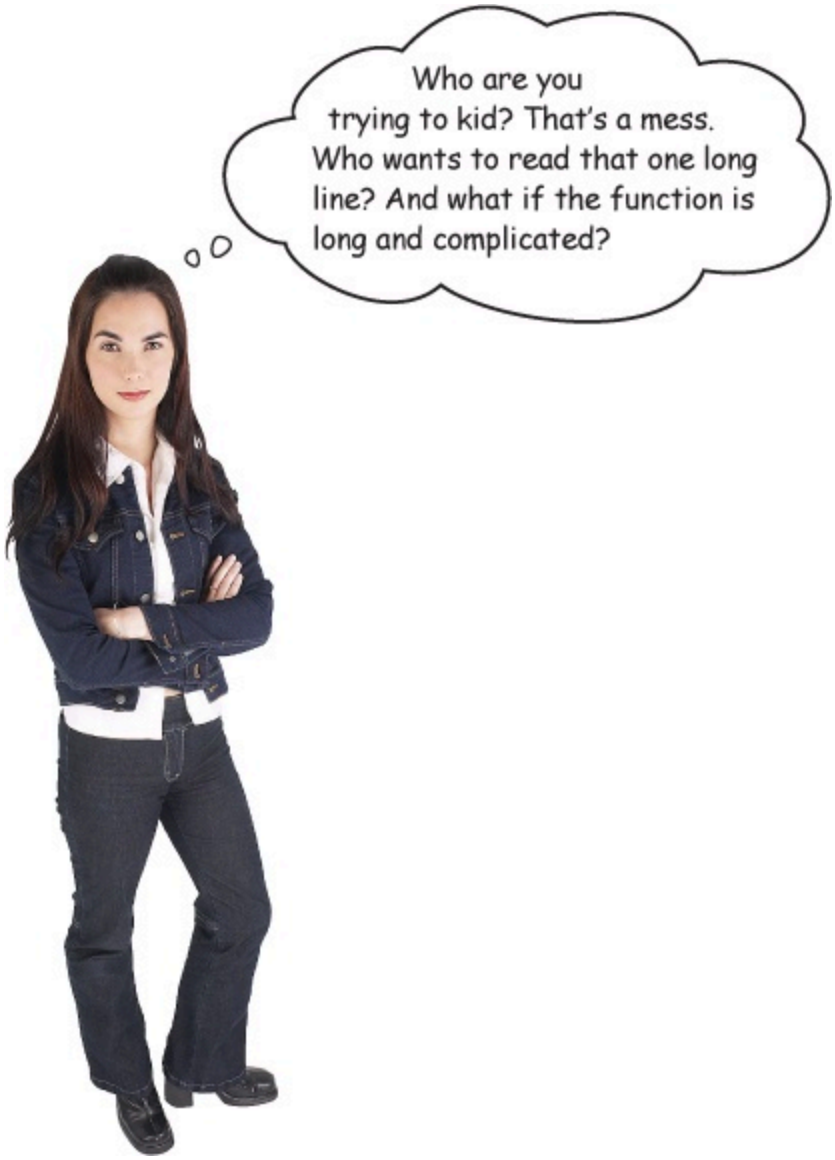
Now instead of a variable, we're just putting the function, inline, in the call to setTimeout.

Pay careful attention to the syntax here. We write the entire function expression, which ends in a right bracket, and then like any argument, we follow it with a comma before adding the next argument.

```
setTimeout(function() { alert("Time to take the cookies out of the oven");}, 600000);
```

We specify the name of the function we're calling, setTimeout, followed by a parenthesis and then the first argument, a function expression.

Here's the second argument, after the function expression.



For a short piece of code, a one liner is just fine. But, beyond that, you're right, it would be rather silly. But as you know, we can use lots of whitespace with JavaScript, so we can insert all the spaces and returns we need to make things more readable. Here's our reformatting of the

All we've done is insert some whitespace—that is, some spaces and returns here and there.

```
setTimeout(function() {
              alert("Time to take the cookies out of the oven");
           }, 600000);
```

We're glad you raised this issue because the code is a lot more readable this way.

That's a mouthful, but you've got it. This is really one of the keys to understanding that functions are first class values. If your code expects a function reference, then you can always put a function expression in its place—because it evaluates to a function reference. As you just saw, if a function is expected as an argument, no problem, you can pass it a function expression (which, again, evaluates to a reference before it is passed). If you need to return a function from within a function, same thing—you can just return a function expression.

EXERCISE

Let's make sure you have the syntax down for passing anonymous function expressions to other functions. Convert this code from one that uses a variable (in this case vaccine) as an argument to one that uses an anonymous function expression.

```
function vaccine(dosage) {
    if (dosage > 0) {
        inject(dosage);
    }
}

administer(patient, vaccine, time);
```

NOTE

Write your version here. And check your answer before moving on!

Q: **Q: Using these anonymous functions like this seems really esoteric. Do I really need to know this stuff?**

A: **A:** *You do. Anonymous function expressions are used frequently in JavaScript code, so if you want to be able to read other people's code, or understand JavaScript libraries, you're going to need to know how these work, and how to recognize them when they're being used.*

Q: **Q: Is using an anonymous function expression really better? I think it just complicates the code and makes the code hard to follow and read.**

A: **A:** *Give it some time. Over time, you'll be able to parse code like this more easily when you see it, and there really are lots of cases where this syntax decreases code complexity, makes the code's intention more clear, and cleans up your code. That said, overuse of this technique can definitely lead to code that is quite hard to understand. But stick with it and it'll get easier to read and more useful as you get the hang of it. You're going to encounter lots of code that makes heavy use of anonymous functions, so it's a good idea to incorporate this technique into your code toolbelt.*

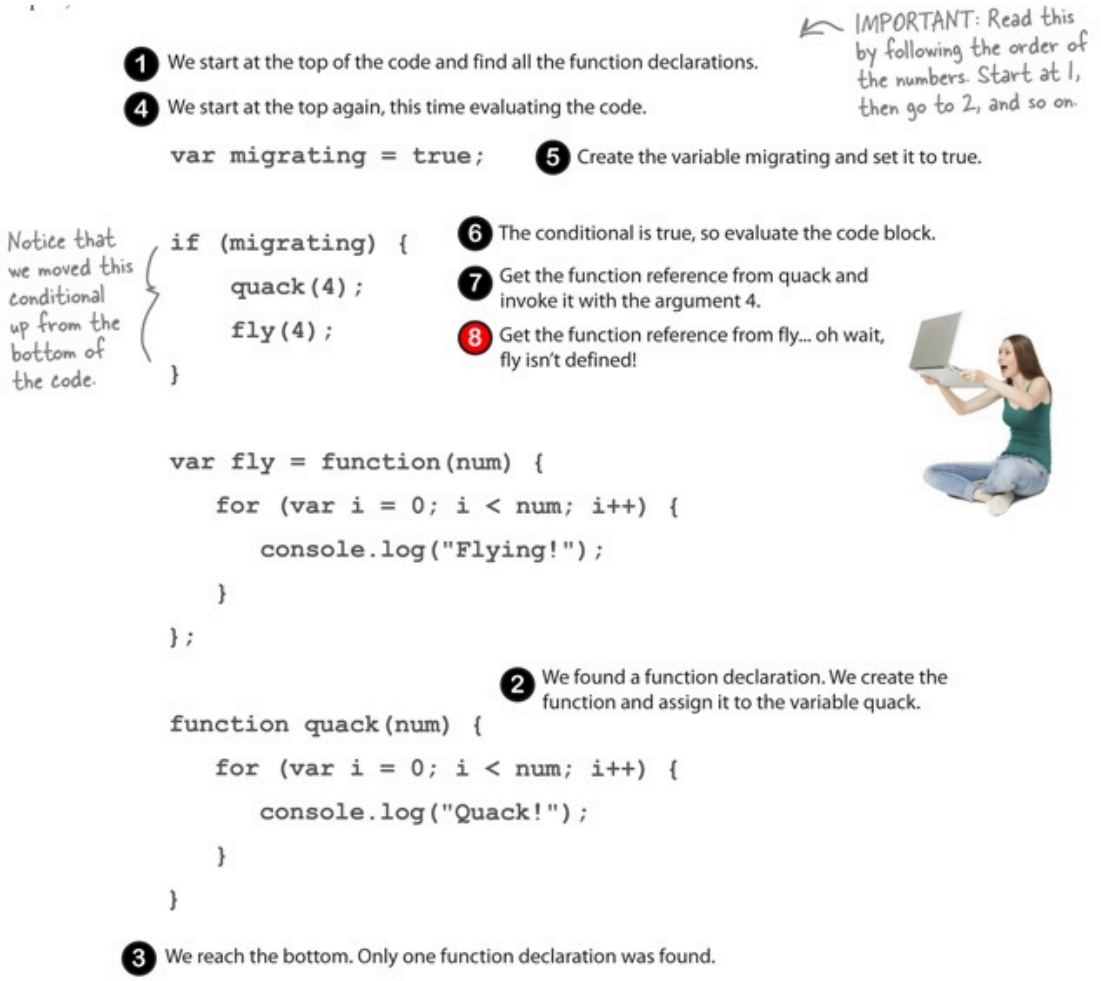
Q: **Q: If first class functions are so useful, how come other languages don't have them?**

A: **A:** *Ah, but they do (and even the ones that don't are considering adding them). For instance, languages like Scheme and Scala have fully first class functions like JavaScript does. Other languages, like PHP, Java (in the newest version), C#, and Objective C have some or most of the first class features that JavaScript does. As more people are recognizing the value of having first class functions in a programming language, more languages are supporting them. Each language does it a little differently, however, so be prepared for a variety of approaches as you explore this topic in other languages.*

When is a function defined? It depends...

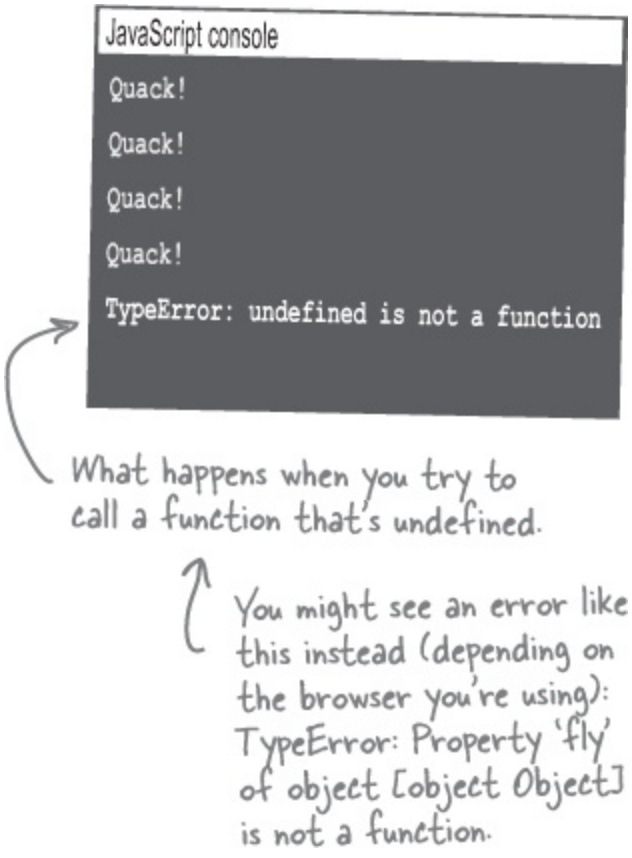
There's one fine point related to functions that we haven't mentioned yet. Remember that the browser takes two passes through your JavaScript code: in the first pass, all your function declarations are parsed and the functions defined; in the second pass, the browser executes your code top down, which is when function expressions are defined. Because of this, functions created by declarations are defined *before* functions that are created using function expressions. And this, in turn, determines where and when you can invoke a function in your code.

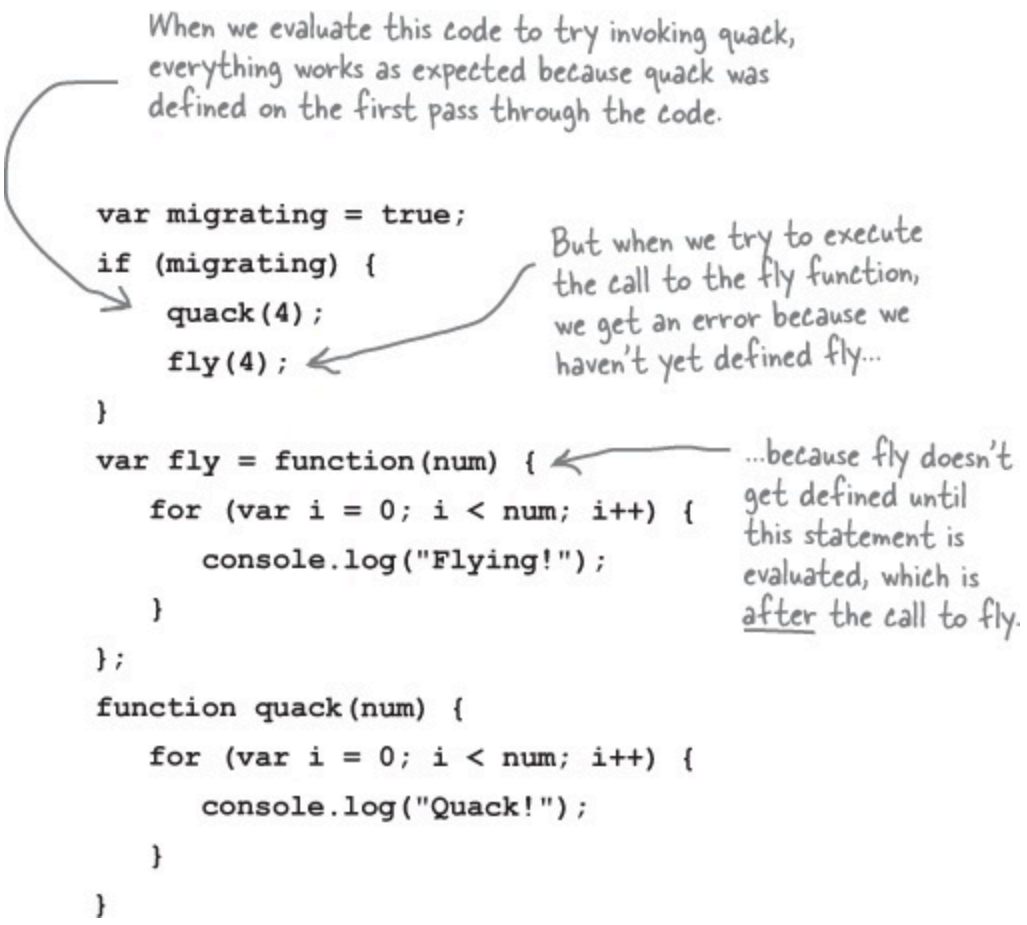
To see what that really means, let's take a look at a concrete example. Here's our code from the last chapter, rearranged just a bit. Let's evaluate it:



What just happened? Why wasn't fly defined?

Okay, we know the `fly` function is undefined when we try to invoke it, but why? After all, `quack` worked just fine. Well, as you've probably guessed by now, unlike `quack`—which is defined on the first pass through the code because it is a function declaration—the `fly` function is defined along with the normal top-to-bottom evaluation of the code. Let's take another look:





So what does this all mean? For starters, it means that you can place function declarations anywhere in your code—at the top, at the bottom, in the middle—and invoke them wherever you like. Function declarations at the top level of your code create functions that are defined everywhere in your code (this is known as *hoisting*).

Function expressions are obviously different because they aren't defined until they are evaluated. So, even if you assign the function expression to a global variable, like we did with `fly`, you can't use that variable to invoke a function until after it's been defined.

Now in this example, both of our functions have *global scope*—meaning both functions are visible everywhere in your code once they are defined. But we also need to consider nested functions—that is functions defined within other functions—because it affects the scope of those functions. Let's take a look.

How to nest functions

It's perfectly legal to define a function within another function, meaning you can use a function declaration or expression inside another function.

How does this work? Here's the short answer: the only difference between a function defined at the top level of your code and one that's defined within another function is just a matter of scope. In other words, placing a function in another function affects where the function is visible within your code.

To understand this, let's expand our example a little by adding some nested function declarations and expressions.

```
var migrating = true;
var fly = function(num) {
   var sound = "Flying";
   function wingFlapper() {
      console.log(sound);
   }
   for (var i = 0; i < num; i++) {
      wingFlapper();
   }
};
function quack(num) {
   var sound = "Quack";
   var quacker = function() {
      console.log(sound);
   };
   for (var i = 0; i < num; i++) {
      quacker();
   }
}
if (migrating) {
    quack(4);
    fly(4);
}
```

Here we're adding a function declaration with the name wingFlapper inside the fly function expression.

And here we're calling it.

Here we're adding a function expression assigned to the quacker variable inside the quack function declaration.

And here we're calling it.

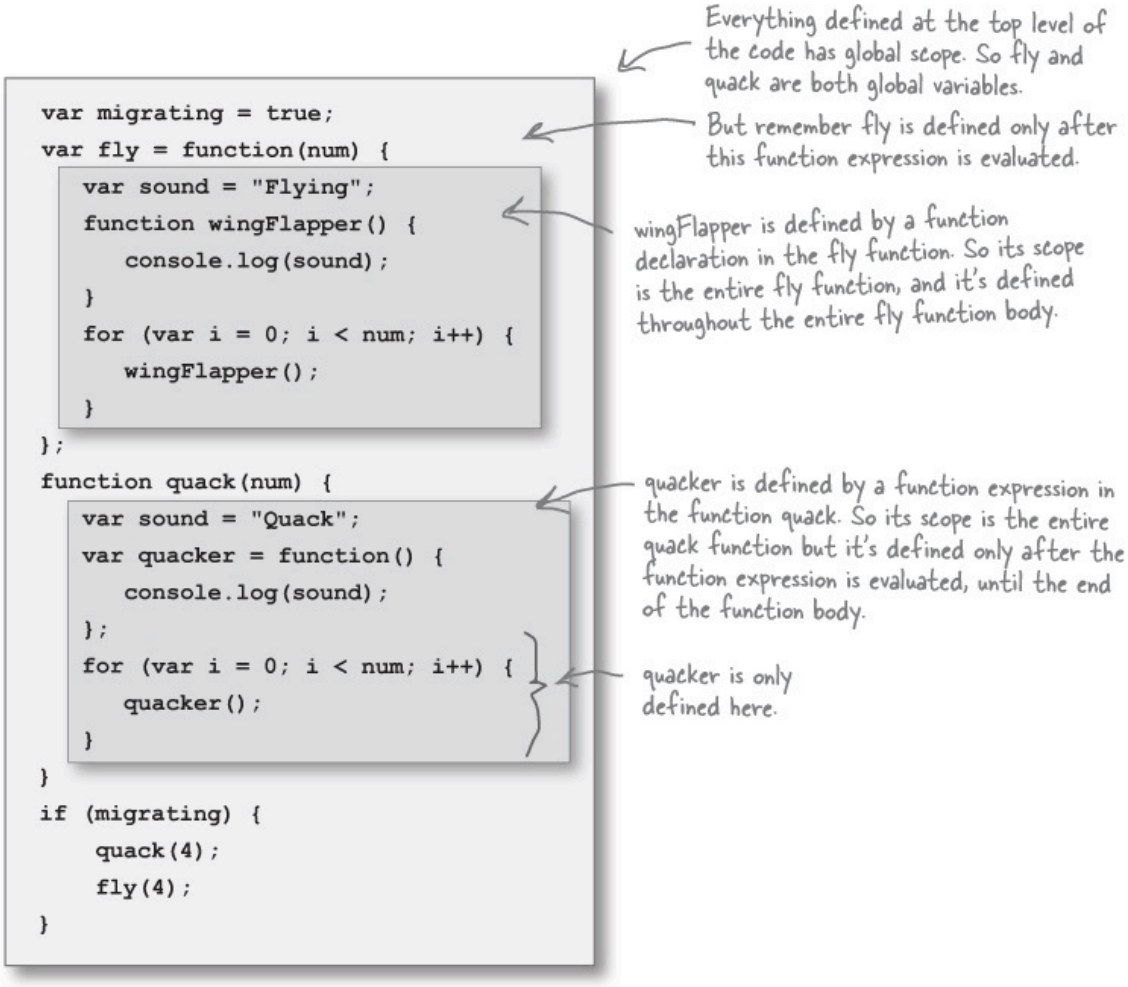
We've moved this code back to the bottom so we no longer get that error when we call fly.

EXERCISE

In the code above, take a pencil and mark where you think the scope of the fly, quack, wingFlapper and quacker functions are. Also, mark any places you think the functions might be in scope but undefined.

How nesting affects scope

Functions defined at the top level of your code have global scope, whereas functions defined within another function have local scope. Let's make a pass over this code and look at the scope of each function. While we're at it, we'll also look at where each function is defined (or, not `undefined`, if you prefer):



Notice that the rules for when you can refer to a function are the same within a function as they are at the top level. That is, within a function, if you define a nested function *with a declaration*, that nested function is defined everywhere within the body of the function. On the other hand, if you create a nested function using a *function expression*, then that nested function is defined only after the function expression is evaluated.

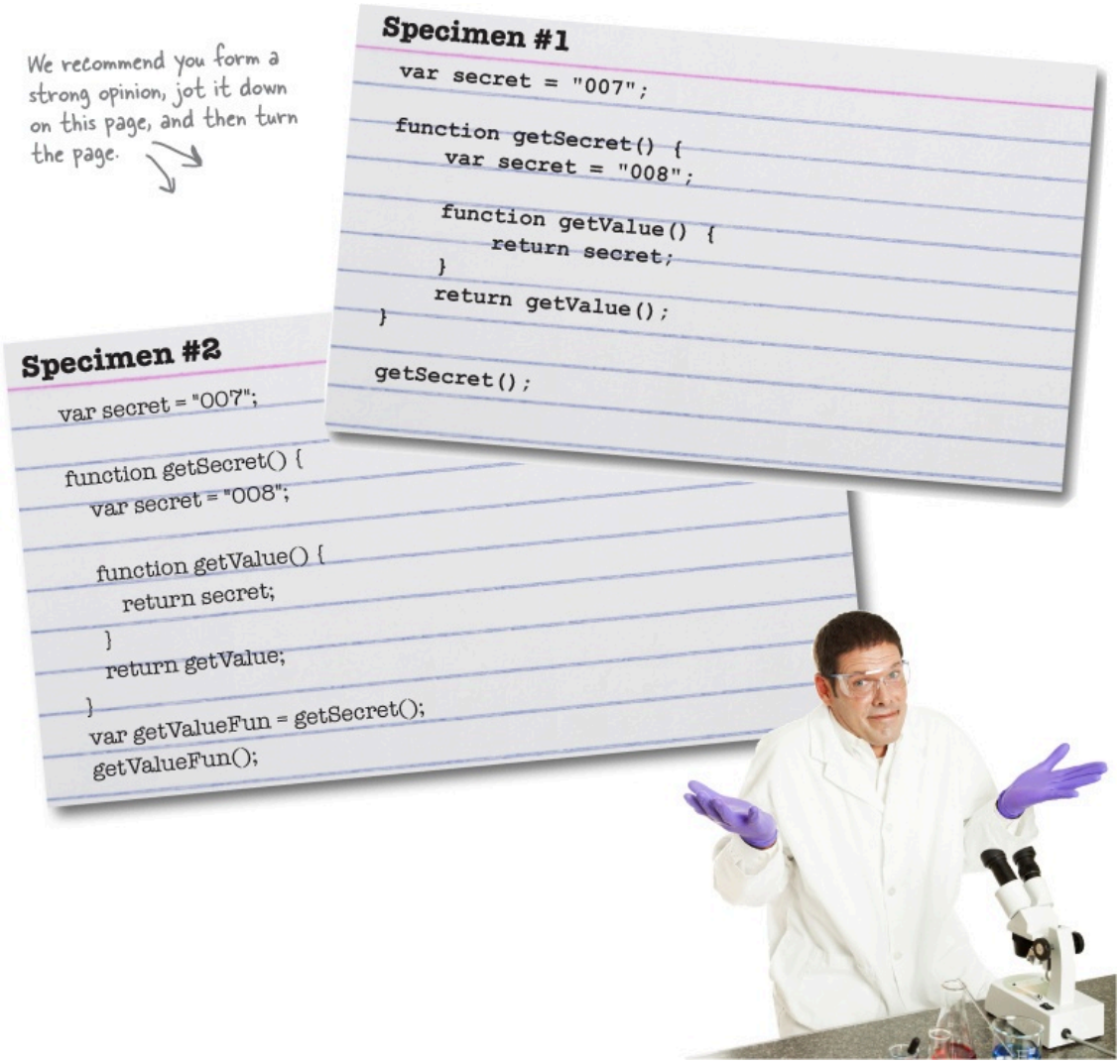
THERE ARE NO DUMB QUESTIONS

Q: **Q: When we pass a function expression to another function, that function must get stored in a parameter, and then treated as a local variable in the function we passed it to. Is that right?**

A: **A:** *That's exactly right. Passing a function as an argument to another function copies the function reference we're passing into a parameter variable in the function we've called. And just like any other parameter, a parameter holding a function reference is a local variable.*

EXTREME JAVASCRIPT CHALLENGE

We need a first class functions expert and we've heard that's you! Below you'll find two pieces of code, and we need your help figuring out what this code does. We're stumped. To us, these look like nearly identical pieces of code, except that one uses a first class function and the other doesn't. Knowing everything we do about JavaScript scope, we expected Specimen #1 to evaluate to 008 and Specimen #2 to evaluate to 007. But they both result in 008! Can you help us figure out why?



NOTE

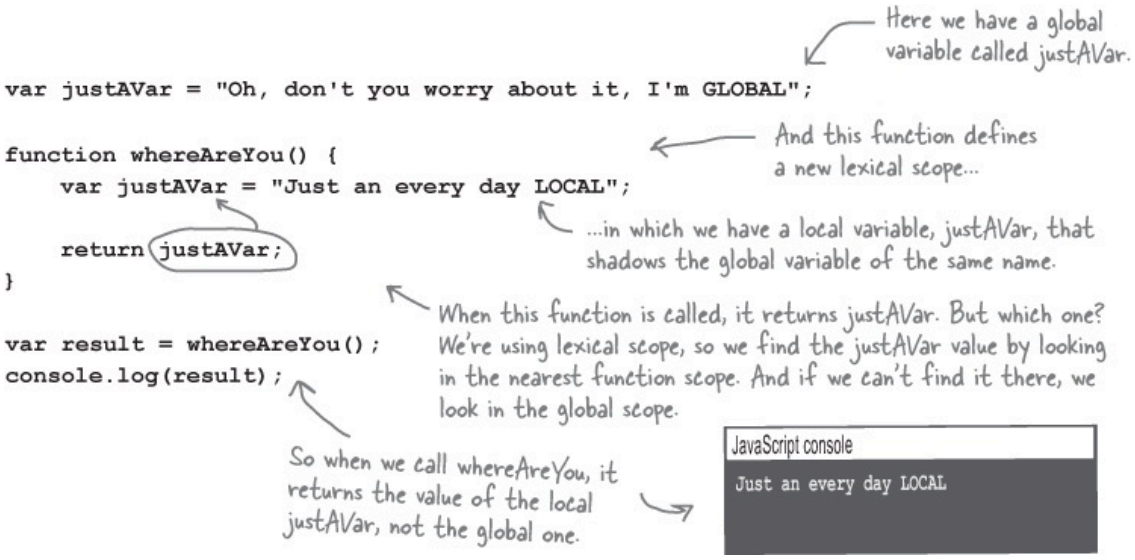
Don't look at the solution at the end of the chapter just yet; we'll revisit this challenge a little bit later.

A little review of lexical scope

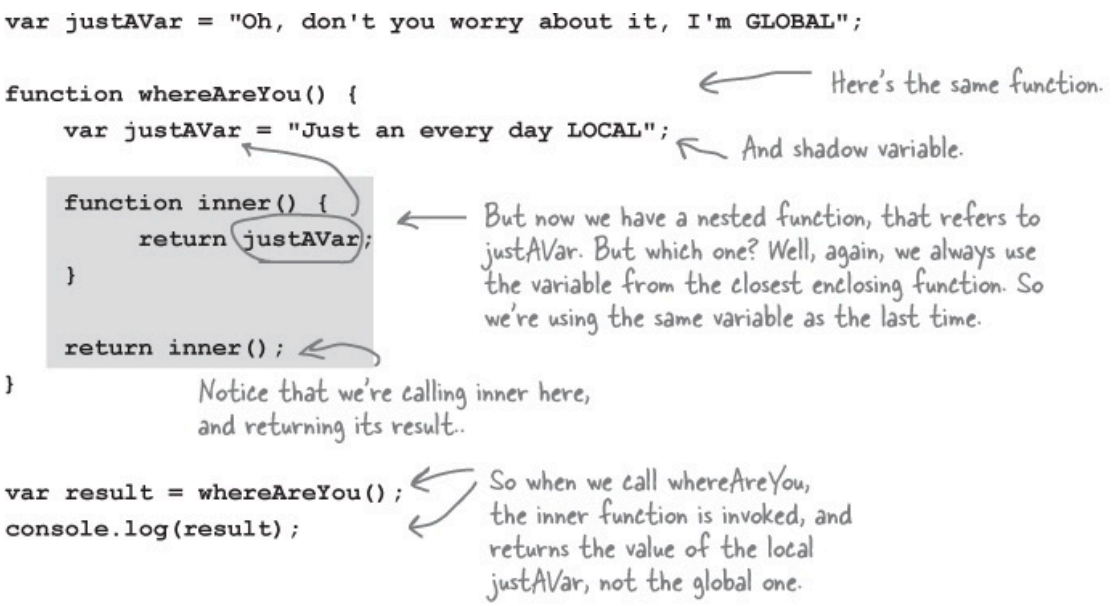
NOTE

Lexical just means you can determine the scope of a variable by reading the structure of the code, as opposed to waiting until the code runs to figure it out.

While we're on the topic of scope, let's quickly review how lexical scope works:



Now let's introduce a nested function:



JAVASCRIPT CONSOLE

```
Just an every day LOCAL
```

Where things get interesting with lexical scope

Let's make one more tweak. Watch this step carefully; it's a doozy:

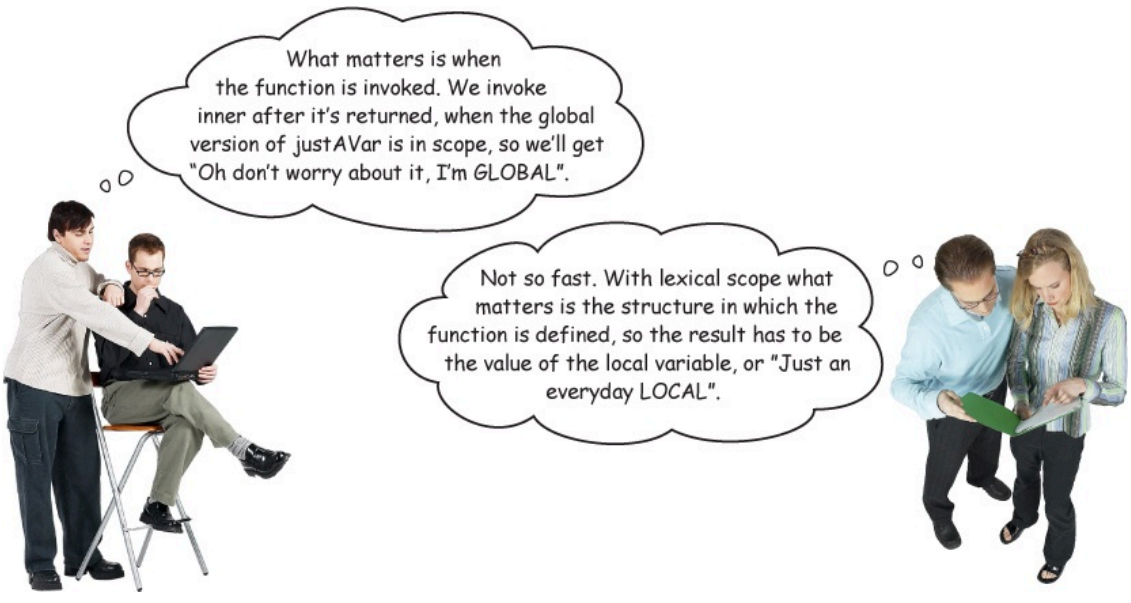
```
var justAVar = "Oh, don't you worry about it, I'm GLOBAL";

function whereAreYou() {
    var justAVar = "Just an every day LOCAL";

    function inner() {
        return justAVar;
    }

    return inner;
}

var innerFunction = whereAreYou();
var result = innerFunction();
console.log(result);
```

No changes at all here, same variables and functions.

But rather than invoking inner, we return the inner function.

So when we call whereAreYou, we get back a reference to inner function, which we assign to the innerFunction variable. Then we invoke innerFunction, capture its output in result and display the result.

So when inner is invoked here (as innerFunction), which justAVar is used? The local one, or the global one?



Frank: What do you mean you're right? That's like defying the laws of physics or something. The local variable doesn't even exist anymore... I mean, when a variable goes out of scope it ceases to exist. It's derezzed! Didn't you see TRON!?

Judy: Maybe in your weak little C++ and Java languages, but not in JavaScript.

Jim: Seriously, how is that possible? The `whereAreYou` function has come and gone, and the local version of `justAVar` couldn't possibly exist anymore.

Judy: If you'd listen to what I just told you... In JavaScript that's not how it works.

Frank: Well, throw us a bone Judy. How does it work?

Judy: When we define the `inner` function, the local `justAVar` is in the scope of that function. Now lexical scope says how we define things is

what matters, so if we're using lexical scope, then *whenever* `inner` is invoked, it assumes it still has that local variable around if it needs it.

Frank: Yeah, but like I already said, that's like defying the laws of physics. The `whereAreYou` function that defined the local version of the `justAVar` variable is over. It doesn't exist any more.

Judy: True. The `whereAreYou` function is done, but the scope is still around for `inner` to use.

Jim: How is that?

Judy: Well, let's see what REALLY happens when we define and return a function...

NOTE

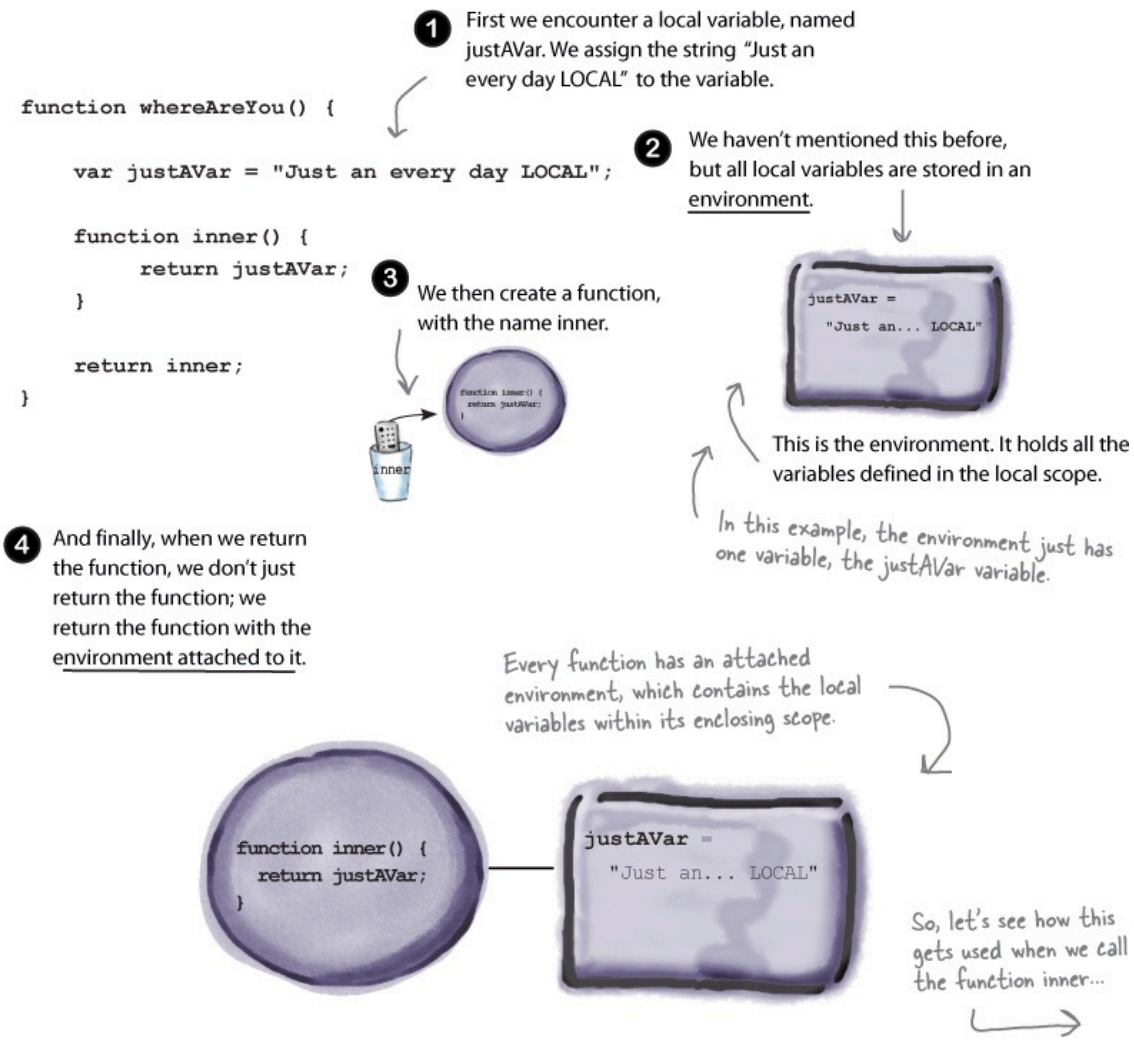
EDITOR'S NOTE: Did Joe change his shirt between pages!?

Functions Revisited

We have a bit of a confession to make. Up until now we haven't told you *everything* about a function. Even when you asked "What does a function reference actually point to?" we kinda skirted the issue. "Oh just think of it like a crystallized function that holds the function's code block," we said.

Well now it's time to show you everything.

To do that, let's walk through what really happens at runtime with this code, starting with the `whereAreYou` function:

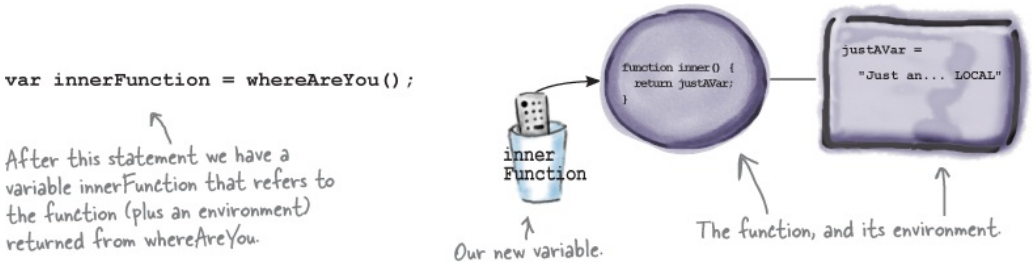


Calling a function (revisited)

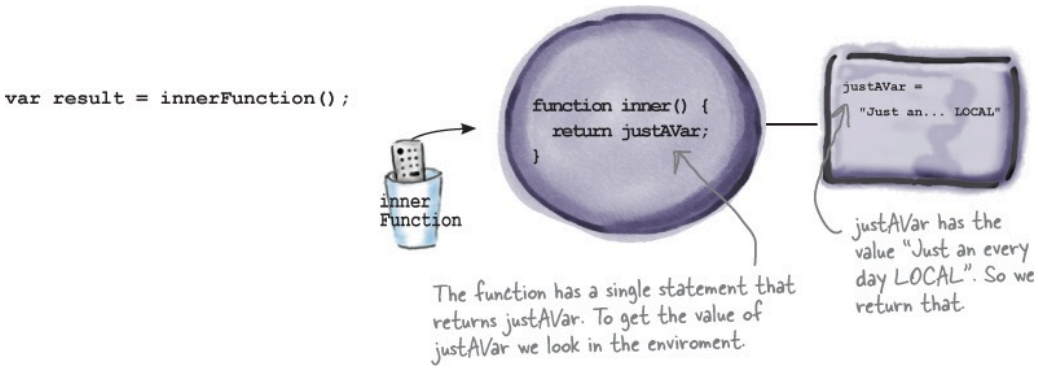
Now that we have the `inner` function, and its environment, let's invoke `inner` and see what happens. Here's the code we want to evaluate:

```
var innerFunction = whereAreYou();
var result = innerFunction();
console.log(result);
```

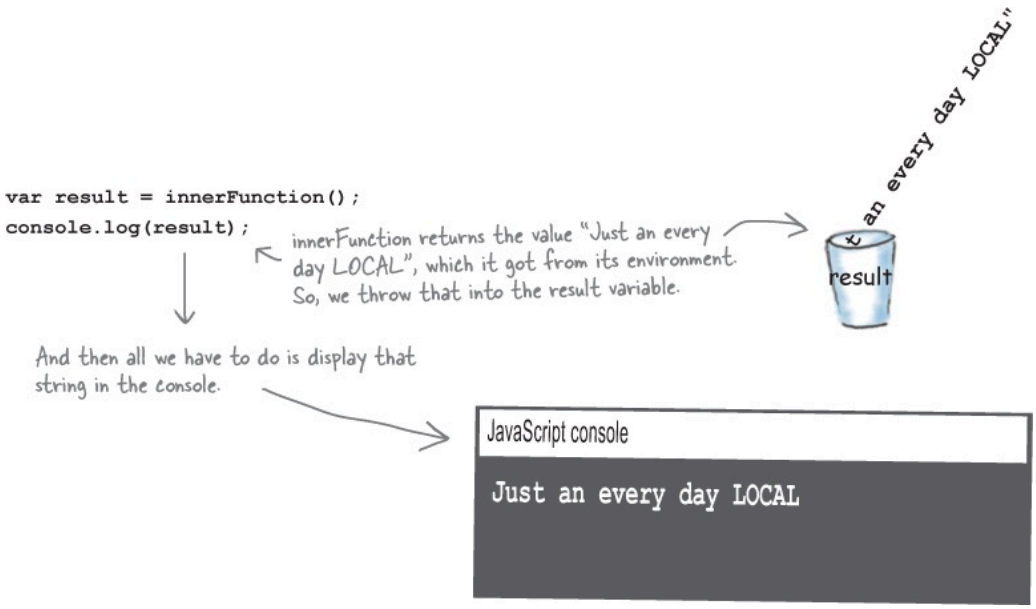
1. **First, we call whereAreYou. We already know that returns a function reference. So we create a variable innerFunction and assign it that function. Remember, that function reference is linked to an environment.**

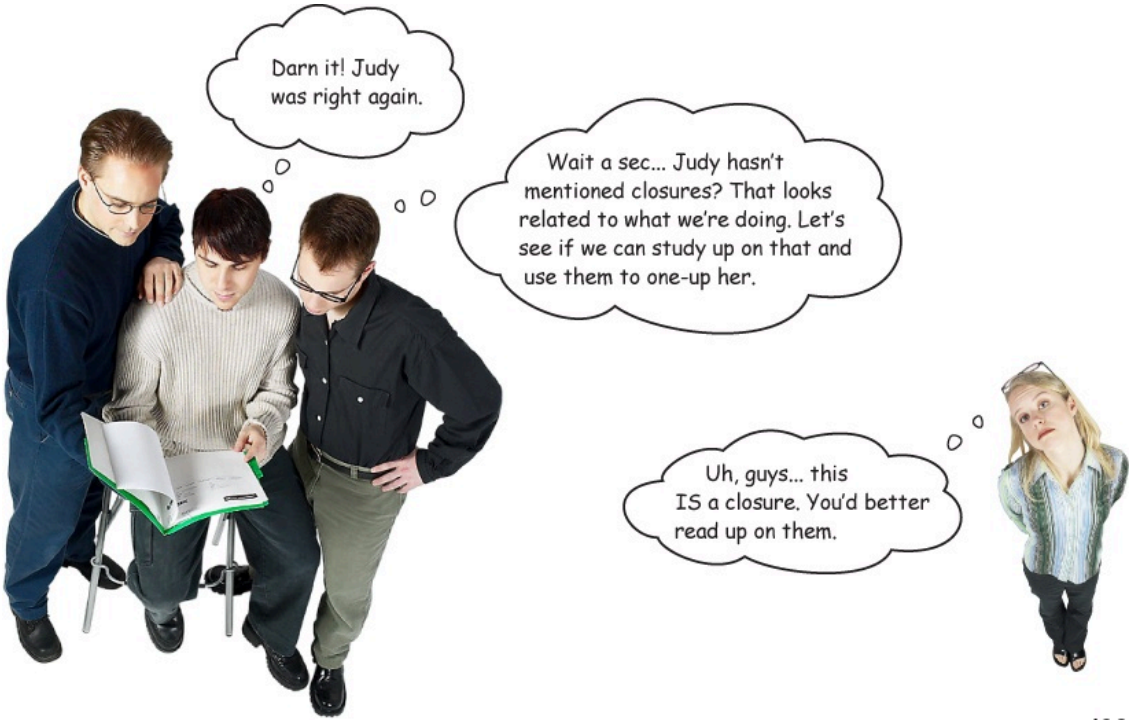


2. **Next we call innerFunction. To do that we evaluate the code in the function's body, and do that in the context of the function's environment, like this:**



3. **Last, we assign the result of the function to the result variable, and then display it in the console.**




Darn it! Judy was right again.
Wait a sec... Judy hasn't mentioned closures? That looks related to what we're doing. Let's see if we can study up on that and use them to one-up her.
Uh, guys... this IS a closure. You'd better read up on them.

Q: **Q: When you say that lexical scope determines where a variable is defined, what do you mean?**

A: **A:** *By lexical scope we mean that JavaScript's rules for scoping are based purely on the structure of your code (not on some dynamic runtime properties). This means you can determine where a variable is defined by simply examining your code's structure. Also remember that in JavaScript only functions introduce new scope. So, given a reference to a variable, look for where that variable is defined in a function from the most nested (where it's used) to the least nested until you find it. And if you can't find it in a function, then it must be global, or undefined.*

Q: **Q: If a function is nested way down many layers, how does the environment work then?**

A: **A:** *We used a simplistic way of showing the environment to explain it, but you can think of each nested function as having its own little environment with its own variables. Then, what we do is create a chain of the environments of all the nested functions, from inner to outer.*

So, when it comes to finding a variable in the environment, you start at the closest one, and then follow the chain until you find your variable. And, if you don't find it, you look in the global environment.

Q: **Q: Why are lexical scoping and function environments good things? I would have thought the answer in that code example would be "Oh, don't you worry about it, I'm GLOBAL". That makes sense to me. The real answer seems confusing and counterintuitive.**

A: **A:** *We can see how you might think that, but the advantage of lexical scope is that we can always look at the code to determine the scope that's in place when a variable is defined, and figure out what its value should be from that. And, as we've seen, this is true even if you return a function and invoke it much later in a place totally outside of its original scope.*

Now there is another reason you might consider this a good thing, and that is the kind of things we can do in code with this

capability. We're going to get to that in just a bit.

Q: **Q: Do parameter variables get included in the environment too?**

A: **A:** *Yes. As we've said before, you can consider parameters to be local variables in your functions, so they are included in the environment as well.*

Q: **Q: Do I need to understand how the environment works in detail?**

A: **A:** *No. What you need to understand is the lexical scoping rules for JavaScript variables, and we've covered that. But now you know that if you have a function that is returned from within a function, it carries its environment around with it.*

Remember that JavaScript functions are always evaluated in the same scoping environment in which they were defined. Within a function, if you want to determine where a variable is coming from, search in its enclosing functions, from the most nested to the least.

What the heck is a closure?

Sure, everyone talks about closures as *the must have* language feature, but how many people actually get what they are or how to use them? Darn few. It's the language feature everyone wants to understand and the feature every traditional language wants to add.

Here's the problem. According to many well-educated folks in the business, *closures are hard*. But that's really not a problem for you. Want to know why? No, no, it's not because this is a "brain friendly book" and no, it's not because we have a killer application that needs to be built to teach closures to you. It's because *you just learned them*. We just didn't call them closures.

So without further ado, we give you the super-formal definition.

NOTE

CLOSURE, NOUN: A closure is a function together with a referencing environment.

> **If you've been trained well in this book you should be thinking at this point, "Ah, this is the 'get a big raise' knowledge."**

Okay, we agree that definition isn't totally illuminating. But why is it called *closure*? Let's quickly walk through that, because—seriously—this could be one of those make-or-break job interview questions, or the thing that gets you that raise at some point in the future.

To understand the word *closure*, we need to understand the idea of "closing" a function.

SHARPEN YOUR PENCIL

Here's your task: (1) find all the **free variables** in the code below and circle them. A free variable is one that isn't defined in the local scope. (2) Pick one of the environments on the right that **closes the function**. By that we mean that it provides values for all the free variables.

```
function justSayin(phrase) {
    var ending = "";
    if (beingFunny) {
       ending = " -- I'm just sayin!";
    } else if (notSoMuch) {
       ending = " -- Not so much.";
    }
    alert(phrase + ending);
}
```

Circle the free variables in this code. Free variables are not defined in the local scope.

```
beingFunny = true;
notSoMuch = false;
inConversationWith = "Paul";
```

```
beingFunny = true;
justSayin = false;
oocoder = true;
```

```
notSoMuch = true;
phrase = "Do do da";
band = "Police";
```

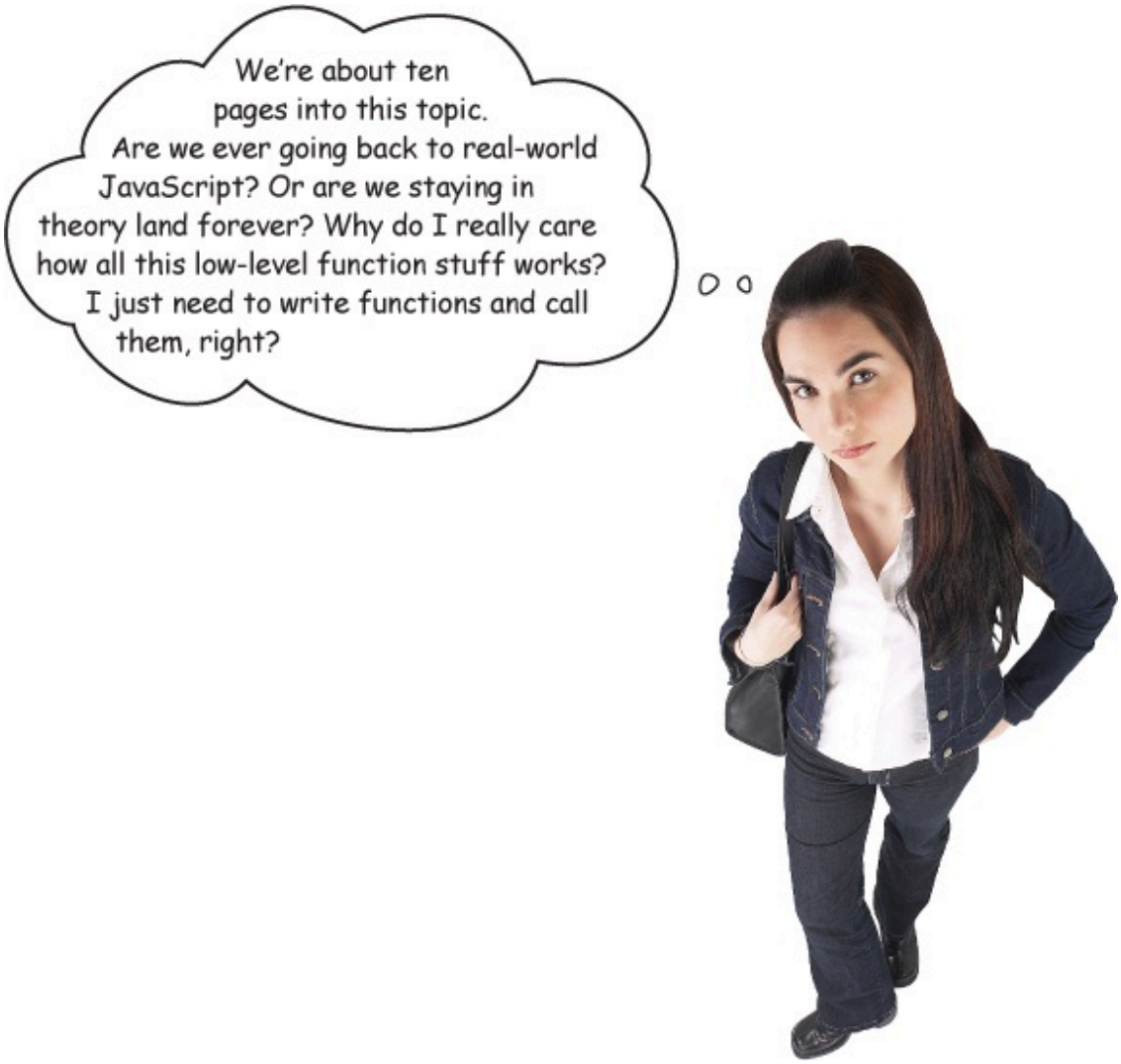
Pick one of these that closes the function.

Closing a function

You probably figured this out in the previous exercise, but let's run through it one more time: a function typically has *local variables* in its code body (including any parameters it has), and it also might have variables that aren't defined locally, which we call *free variables*. The name

free comes from the fact that within the function body, free variables aren't bound to any values (in other words, they're not declared locally in the function). Now, when we have an environment that has a value for each of the free variables, we say that we've *closed* the function. And, when we take the function and the environment together, we say we have a *closure*.

A closure results when we combine a function that has free variables with an environment that provides variable bindings for all those free variables.



If closures weren't so darned useful, we'd agree. We're sorry we had to drag you through the learning curve on closures but we assure you, it is well worth it. You see, closures aren't just some theoretical functional programming language construct; they're also a powerful programming technique. Now that you've got how they work down (and we're not kidding that understanding closures is what's going to raise your cred among your managers and peers) it's time to learn how to use them.

And here's the thing: they're used all over the place. In fact they're going to become so second nature to you that you'll find yourself using them liberally in your code. Anyway, let's get to some closure code and you'll see what we're talking about.

Using closures to implement a magic counter

Ever think of implementing a counter function? It usually goes like this:

```
var count = 0;

function counter() {
    count = count + 1;
    return count;
}
```

We have a global variable count.

Each time we call counter, we increment the global count variable, and return the new value.

And we can use our counter like this:

```
console.log(counter());
console.log(counter());
console.log(counter());
```

So we can count and display the value of the counter like this.

JAVASCRIPT CONSOLE

```
1
2
3
```

The only issue with this is that we have to use a global variable for `count`, which can be problematic if you're developing code with a team (because people often use the same names, which end up clashing).

What if we were to tell you there is a way to implement a counter with a totally local and protected `count` variable? That way, you'll have a counter that no other code can ever clash with, and the only way to increment the counter value is through the function (otherwise known as a closure).

To implement this with a closure, we can reuse most of the code above. Watch and be amazed:

```
function makeCounter() {
    var count = 0;

    function counter() {
        count = count + 1;
        return count;
    }
    return counter;
}
```

Here, we're putting the count variable in the function makeCounter. So now count is a local variable, not a global variable.

Now, we create the counter function, which increments the count variable.

And return the counter function.

This is the closure. It holds count in its environment.

Think this magic trick will work? Let's try it and see...

Test drive your magic counter

We added a bit of testing code to test the counter. Give it a try!

```
function makeCounter() {
    var count = 0;

    function counter() {
        count = count + 1;
        return count;
    }
    return counter;
}
var doCount = makeCounter();
console.log(doCount());
console.log(doCount());
console.log(doCount());
```

JAVASCRIPT CONSOLE

```
1

2

3
```

Our counter works... we get solid counting results.

Looking behind the curtain...

Let's step through the code to see how the counter works.

1. We call makeCounter, which creates a counter function and returns it along with an environment containing the free variable, count. In other words, it creates a closure. The function returned from makeCounter is stored in doCount.
2. We call the function doCount. This executes the body of the counter function.
3. When we encounter the variable count, we look it up in the environment, and retrieve its value. We increment count, save the new value back into the environment, and return that new value to where doCount was called.
4. We repeat steps 2 and 3 each time we call doCount.

EXERCISE

It's your turn. Try creating the following closures. We realize this is not an easy task at first, so refer to the answer if you need to. The important thing is to work your way through these examples, and get to the point where you fully understand them.

First up for 10pts: makePassword takes a password as an argument and returns a function that accepts a password guess and returns true if the guess matches the password (sometimes you need to read these closure descriptions a few times to get them):

```
function makePassword(password) {
    return ____________________________ {
        return (passwordGuess === password);
    };
}
```

Next up for 20pts: the multN function takes a number (call it n) and returns a function. That function itself takes a number, multiplies it by n and returns the result.

```
function multN(n) {
    return ____________________________ {
        return _______________;
    };
}
```

Last up for 30 pts: This is a modification of the counter we just created. makeCounter takes no arguments, but defines a count variable. It then creates and returns an object with one method, increment. This method increments the count variable and returns it.

Creating a closure by passing a function expression as an argument

Returning a function from a function isn't the only way to create a closure. You create a closure *whenever* you have a reference to a function that has free variables, and that function is executed outside of the context in which it was created.

Another way we can create a closure is to pass a function to a function. The function we pass will be executed in a completely different context than the one in which it was defined. Here's an example:

Here, we're passing a function expression that contains a free variable, `doneMessage`, to the function `setTimeout`. As you know, what happens is we evaluate the function expression to get a function reference, which is then passed to `setTimeout`. The `setTimeout` method holds on to this function (which is a function plus an environment—in other words, a closure) and then 1000 milliseconds later it calls that function.

And again, the function we're passing into `setTimeout` is a closure because it comes along with an environment that binds the free variable, `doneMessage`, to the string "Cookies are done!".

BRAIN POWER

What would happen if our code looked like this instead?

```
function handler() {
    alert(doneMessage);
}
function makeTimer(doneMessage, n) {
    setTimeout(handler, n);
}
makeTimer("Cookies are done!", 1000);
```

BRAIN POWER 2

Revisit the code in **Finishing the image game** in **Chapter 9**. Can you modify your code to use a closure, and eliminate the need for the third argument to setTimeout?

The closure contains the actual environment, not a copy

One thing that often misleads people learning closures is that they think the environment in the closure must have a copy of all the variables and their values. It doesn't. In fact, the environment references the live variables being used by your code, so if a value is changed by code outside your closure function, that new value is seen by your closure function when it is evaluated.

Let's modify our example to see what that means.

1. When we call setTimeout and pass to it the function expression, a closure is created containing the function along with a reference to the environment.

```
setTimeout(function() {
    alert(doneMessage);
}, n);
```

2. Then, when we change the value of doneMessage to “OUCH!” outside of the closure, it’s changed in the same environment that is used by the closure.

```
doneMessage = "OUCH!";
```

3. 1000 milliseconds later, the function in the closure is called. This function references the doneMessage variable, which is now set to “OUCH!” in the environment, so we see “OUCH!” in the alert.

Creating a closure with an event handler

Let's look at one more way to create a closure. We'll create a closure with an event handler, which is something you'll see fairly often in JavaScript code. We'll start by creating a simple web page with a button and a `<div>` element to hold a message. We'll keep track of how many times you click the button and display the tally in the `<div>`.

Here's the HTML and a tiny bit of CSS to create the page. Go ahead and add the HTML and CSS below into a file named "divClosure.html".

Next, let's write the code. Now, you could write the code for this example without using a closure at all, but as you'll see, by using a closure, our code is more concise, and even a bit more efficient.

Click me! without a closure

Let's first take a look at how you'd implement this example *without* a closure.

Click me! with a closure

The version without a closure looks perfectly reasonable, except for that global variable which could potentially cause trouble. Let's rewrite the code using a closure and see how it compares. We'll show the code here, and take a closer look after we test it.

Test drive your button counter 

Okay, let's bring the HTML and the code together in your "divClosure.html" file and give this a test run. Go ahead and load the page and then click on the button to increment the counter. You should see the message update in the `<div>`. Look at the code again, and make sure you think you know how this all works. After you've done so, turn the page and we'll walk through it together.

How the Click me! closure works

To understand how the closure works, let’s follow along with the browser once again, as it evaluates this code...

EXTREME JAVASCRIPT CHALLENGE REVISITED

We need a closures expert and we've heard that's you! Now you know how closures work, can you figure out why both specimens below evaluate to 008? To figure it out, write any variables that are captured in the environments for the functions below. Note that it's perfectly fine for an environment to be empty. Check your answer at the end of the chapter.

Specimen #1

```
var secret = "007";

function getSecret() {
    var secret = "008";

    function getValue() {
        return secret;
    }
    return getValue();
}
getSecret();
```

Specimen #2

```
var secret = "007";

function getSecret() {
    var secret = "008";

    function getValue() {
        return secret;
    }
    return getValue;
}
```

```
var getValueFun = getSecret();
getValueFun();
```

SHARPEN YOUR PENCIL

First, check out this code:

Your task is to figure out not just what this code computes, but *how* it computes. To do that, go in reverse. That is, take out the anonymous function, assign it to a variable, and then use that variable where the function expression used to be. Is the code more obvious now? So, what does it do?

BULLET POINTS

- An **anonymous function** is a function expression that has no name.
- Anonymous functions can make your code more concise.
- A **function declaration** is defined before the rest of your code is evaluated.
- A **function expression** is evaluated at runtime with the rest of your code, and so is not defined until the statement in which it appears is evaluated.
- You can pass a function expression to another function, or return a function expression from a function.
- A function expression evaluates to a **function reference**, so you can use a function expression anywhere you can use a function reference.
- **Nested functions** are functions defined inside another function.
- A nested function has local scope, just like other local variables.
- **Lexical scope** means that we can determine the scope of a variable by reading our code.
- To bind the value of a variable in a nested function, use the value that's defined in the closest enclosing function. If no value is found, then look in the global scope.
- **Closures** are a function along with a referencing environment.
- A closure captures the value of variables in scope at the time the closure is created.
- **Free variables** in the body of a function are variables that are not bound in the body of that function.
- If you execute a function closure in a different context in which it was created, the values of free variables are determined by the referencing environment.
- Closures are often used to capture state for event handlers.

JAVASCRIPT CROSS

Time for another crossword puzzle to burn some JavaScript into those neuron pathways.

Across	Down
4. A function declaration nested in another function has _____ scope. 6. When we tried to call fly before it was defined, we got this kind of error. 9. wingFlapper is a _____ function. 12. We often use setTimeout to create a timer for making _____. 13. A function expression assigned to a variable at the top level of your code has _____ scope. 14. To get a raise, you should understand how _____ work. 16. A _____ variable is one that's not defined in the local scope. 17. We changed the value of doneMessage to _____ in the closure. 18. An environment that provides values for all free variables _____ a function.	1. _____ is always right. 2. ____ changed his shirt between pages. 3. Movie the word "derezzed" was used in. 5. An _____ function is a function expression that has no name. 7. A function with an _____ attached to it is called a closure. 8. A function expression evaluates to a function_____. 10. We passed a function _____ to set the cookie alarm. 11. Parameters are _____ variables, so they're included in the environment where variables are defined. 15. _____ scope means you can understand the scope of your variables by reading the structure of your code.

SHARPEN YOUR PENCIL SOLUTION

There are a few opportunities in the code below to make the code more concise by using anonymous functions. Go ahead and rework the code to use anonymous functions wherever possible. You can scratch out the old code and write in new code where needed. Oh, and one more task: circle any anonymous functions that are already being used in the code. Here's our solution.

EXERCISE SOLUTION

Let's make sure you have the syntax down for passing anonymous function expressions to other functions. Convert this code from one that uses a variable (in this case vaccine) as a parameter to one that uses an anonymous function. Here's our solution.

EXERCISE SOLUTION

It's your turn. Try creating the following closures. We realize this is not an easy task at first, so refer to the answer if you need to. The important thing is to work your way through these examples, and get to the point where you fully understand them.

Here are our solutions:

First up for 10pts: makePassword takes a password as an argument and returns a function that accepts a password guess and returns true if the guess matches the password (sometimes you need to read these closure descriptions a few times to get them): The solutions continue on the next page...

Next up for 20pts: the multN function takes a number (call it n) and returns a function. That function itself takes a number, multiplies it by n and returns the result.

Last up for 30 pts: This is a modification of the counter we just created. makeCounter takes no arguments, but defines a count variable. It then creates and returns an object with one method, increment. This method increments the count variable and returns it.

SHARPEN YOUR PENCIL SOLUTION

Use your knowledge of functions and variables and check off the true statements below. Here's our solution:

- [ ] The handler variable holds a function reference.
- [x] When we assign handler to window.onload, we're assigning it a function reference.
- [ ] The only reason the handler variable exists is to assign it to window.onload.
- [x] We'll never use handler again as it's code that is meant to run only when the page first loads.
- [ ] Invoking onload handlers twice is not a great idea—doing so could cause issues given these handlers usually do some initialization for the entire page.
- [x] Function expressions create function references.
- [ ] Did we mention that when we assign handler to window.onload, we're assigning it a function reference?

SHARPEN YOUR PENCIL SOLUTION

Here's your task: (1) find all the **free variables** in the code below and circle them. A free variable is one that isn't defined in the local scope. (2) Pick one of the environments on the right that **closes the function**. By that we mean that it provides values for all the free variables. Here's our solution.

EXTREME JAVASCRIPT CHALLENGE SOLUTION

We need a closures expert and we've heard that's you! Now you know how closures work, can you figure out why both specimens below evaluate to 008? To figure it out, write any variables that are captured in the environments for the functions below. Note that it's perfectly fine for an environment to be empty. Here's our solution.

Specimen #1

Specimen #2

SHARPEN YOUR PENCIL SOLUTION

Here's our solution for this brain twister!

```
(function(food) {
    if (food === "cookies") {
        alert("More please");
    } else if (food === "cake") {
        alert("Yum yum");
    }
})("cookies");
```

Your task is to figure out not just what it computes, but how it computes. To do that, go in reverse, that is, take out the anonymous function, assign it to a variable, and then replace the previous function with the variable. Is the code more obvious now? So what does it do?

JAVASCRIPT CROSS SOLUTION