Modern JavaScript

DEVELOP AND DESIGN

Larry Ullman

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Peachpit Press

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This book is dedicated to Doug and Christina,
and to their family and friends,
for the extraordinary, life-changing gift.

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INTRODUCTION

JavaScript is one of the most widely used programming languages today, found on almost every Web page (certainly all the new ones). Over the past ten years, between economic changes and expansions in how JavaScript is used, more and more Web developers and designers are expected to know this language. These facts make it all the more ironic that so few people respect JavaScript as the true programming language that it is. Furthermore, many books still present JavaScript in a legacy manner, as a technology to be used piecemeal to implement gimmicks and distractions. This book was written to address these problems, presenting JavaScript in a way that you can easily understand, actually master, and appropriately utilize as a productive asset in today's dynamic Web sites.

WHO THIS BOOK IS FOR

This book was written primarily with two types of readers in mind:

- Those who don't know JavaScript at all (and perhaps have never done any programming)
- Those who may have played with JavaScript some, but don't have a solid understanding of why one does what one does in the language.

You may be a Web developer who has written code in other languages but merely dabbled with JavaScript. Or, you may be a Web designer, with a graphical focus but an increasing need to learn JavaScript. Whatever the case, if you have a sincere interest in understanding modern JavaScript and knowing how to use it, well, then this book is for you.

WHAT YOU WILL LEARN

By reading this book, and trying the many examples, you will come to comprehend what JavaScript is and how to reliably program with it, regardless of the task. The book's content is organized in three sections.

PART 1: GETTING STARTED

The first part of the book starts with JavaScript's history and its role in today's Web. You'll also learn the fundamental terms and concepts, particularly when it comes to using JavaScript with HTML in a Web page. The last chapter in Part 1 thoroughly covers the types of tools you'll need to develop, design, debug, and test JavaScript code.

PART 2: JAVASCRIPT FUNDAMENTALS

The bulk of the book is in this second part, which teaches the core components of the language. These fundamentals include the kinds of data you'll work with, operators and control structures, defining your own functions, handling events, and Ajax. Two chapters focus on the browser and HTML forms.

PART 3: NEXT STEPS

All books have their limits, and this book purposefully stops short of trying to cover everything, or attempting to turn you into a true JavaScript "ninja." But in the third part of the book, you will be introduced to what your next logical steps should be in your development as a JavaScript programmer. One chapter is on frameworks, another is on advanced JavaScript concepts, and a third walks through a real-world integration of JavaScript and PHP for a practical Web application.

THE CORRESPONDING WEB SITE

My Web site can be found at `www.LarryUllman.com`. To find the materials specific to this book, click on *Books By Topic* at the top of the page, and then select *JavaScript > Modern JavaScript: Develop and Design*. On the first page that comes up you will find all of the code used in the book. There are also links to errata (errors found) and more information that pertains directly to this book.

The whole site is actually a WordPress blog and you'll find lots of other useful information there, in various categories. The unique tag for this book is *jsdd*, meaning that `www.larryullman.com/tag/jsdd/` will list everything on the site that might be useful and significant to you. While you're at the site, I recommend that you also sign up for my free newsletter, through which I share useful resources, answer questions, and occasionally give away free books.

The book has a corresponding support forum at `www.LarryUllman.com/forums/`. You are encouraged to ask questions there when you need help. You can also follow up on the "Review and Pursue" sections through the forums.

LET'S GET STARTED

With a quick introduction behind you (and kudos for giving it a read), let's get on with the show. In very first chapter, you'll learn quite a bit about JavaScript as a language and the changing role it has had in the history of Web development. There's no programming to be done there, but you'll get a sense of both the big picture and the current landscape, which are important in going forward.

WELCOME TO JAVASCRIPT

A great thing about programming with JavaScript is that most, if not all, of the tools you'll need are completely free. That's particularly reassuring, as you'll want a lot of the following items in order to develop using JavaScript in a productive and reliable way. Chapter 3, Tools of the Trade, goes into the following categories in much more detail.

BROWSERS

Presumably, you already have at least one Web browser, but you'll want several. All the key modern browsers are free and should be used: Chrome, Firefox, Safari, Opera, and even Internet Explorer.

TEXT EDITOR

To write JavaScript code, you can use almost any text editor, although some are clearly better than others. The quick recommendations are Notepad++ on Windows and BBEdit or TextMate on Mac OS X.

IDE

If you prefer an all-in-one tool to a text editor, select an Integrated Development Environment (IDE). The free Aptana Studio is wonderful and runs on most platforms; fine commercial alternatives exist, too.

DEBUGGER

Debugging is a big facet of all programming, and better debugging tools means less stress and a faster development time. Firebug is the clear champion here, although many browsers now have sufficiently good debugging tools built in.

WEB SERVER

Examples in two chapters require a PHP-enabled Web server, plus a MySQL database. If you don't have a live Web site with these already, you can download and install the free XAMPP for Windows or MAMP for Mac OS X.

4

SIMPLE **VARIABLE TYPES**

All programming comes down to taking *some action* with *some data*. In this chapter, the focus is on the data side of the equation, represented by variables. Even if you've never done any programming, you're probably familiar with the concept of a variable: a temporary storage container. This chapter starts with the basics of variables in JavaScript, and then covers number, string, and Boolean variables. Along the way you'll find plenty of real-world code, representing some of the actions you will take with these simple variable types.

BASICS OF VARIABLES

I think it's easiest to grasp variables by starting with so-called "simple" variables, also called "primitive" variable types. By *simple*, I mean variables that only store a single piece of information at a time. For example, a numeric variable stores just a single number; a string, just a sequence of zero or more quoted characters. Simple variables will be the focus in this chapter, with more advanced alternatives—such as arrays and objects—coming in Chapter 6, Complex Variable Types.

To be completely accurate, it's the *values* in JavaScript that are typed, not the variables. Further, many values in JavaScript can be represented as either a *literal* or an *object*. But I don't want to overwhelm you with technical details already, especially if they won't impact your actual programming. Instead, let's focus on this line of code:

```
var myVar = 'easy peasy';
```

TIP: Remember that you can practice much of the JavaScript in this chapter using your browser's console window.

That's a standard and fundamental line of JavaScript programming, declaring a variable named `myVar`, and assigning to it the string *easy peasy*. The next few pages will look at the four components of this one line in detail:

- `var`, used to declare a variable
- the variable's name
- `=`, the assignment operator
- the variable's value

DECLARING VARIABLES

To declare a variable is to formally announce its existence. In many languages, such as C and ActionScript, you must declare a variable prior to referencing it. JavaScript does not *require* you to declare variables, you can just immediately begin referencing them, as in:

```
quantity = 14;
```

(The semicolon is used to terminate a statement. It's not required, but you should always use it.)

Now, to clarify, you don't *have to* declare variables in JavaScript, but *you actually should*. To do that, use the `var` keyword:

```
var fullName;
```

or

```
var fullName = 'Larry Ullman';
```

The distinction between using `var` and not using `var` has to do with the variable's *scope*, a topic that will mean more once you begin defining your own functions (see Chapter 7, Creating Functions). Undeclared variables—those referenced for the first time without using `var`—will have *global* scope by default, and global variables are frowned upon (see the sidebar for more).

Also understand that whether or not you assign a value to the variable when it's declared has no impact on its scope. Both lines above used to declare the `fullName` variable result in a variable with the same scope.

As discussed in Chapter 1, (Re-)Introducing JavaScript, JavaScript is a *weakly typed language*, meaning that variables are not strictly confined to one type or another. Neither of the above uses of `fullName` decree that the variable is a string. With either of those lines of code, this next line will not cause a syntax error:

```
fullName = 2;
```

That line would most likely cause a logical or run-time error, as other code would expect that `fullName` is a string, but the larger point is that a JavaScript variable isn't typed but has a type based upon its value. If `fullName` stores a quoted sequence of zero or more characters, then `fullName` is said to be a string; if `fullName` stores 2, then it's said to be a number.

Note that each variable is only declared once, but you can use `var` to declare multiple variables at the same time:

```
var firstName, lastName;
```

You can even declare multiple variables at the same time while simultaneously assigning values:

```
var firstName = 'Larry', lastName = 'Ullman';
```

GLOBAL **VARIABLES**

All variables have a *scope*, which is the realm in which they exist. As you'll see in Chapter 7, variables declared within a function have *function-level* scope: They only exist within that function. Other languages, but not JavaScript (currently), have *block-level* scope, where a variable can be declared and only exist between a pair of curly braces. Variables declared outside of any function, or referenced without any use of `var`, have *global* scope. There are a few reasons to avoid using global variables.

First, as a general rule of programming, applications should only do the bare minimum of what's required. If a variable does not absolutely need to be global, it shouldn't be. Second, global variables can have an adverse effect on performance, because the application will have to constantly maintain that variable's existence, even when the variable is not being used. By comparison, function variables will only exist during that function's execution (i.e., when the function is called). Third, global variables can cause run-time and logical errors should they conflict with other global variables. This can happen if your code has a variable with the same name as a poorly designed library you might also be including in the same page.

All this being said, understand that for the next few chapters, you will occasionally be using global variables in your code. This is because variables declared outside of any function, even when using the `var` keyword, will also have global scope, and you won't have user-defined functions yet. Still, while it's best not to use global variables, using them is not a terrible, horrible thing, and it's much better to *knowingly* create a global variable than to *accidentally* do so.

You'll rarely see this done in the book, as I will want to better focus on each variable declaration, but lines like that one are common in real-world JavaScript code.

As a final note on the var keyword, you should always declare your variables as soon as possible in your code, within the scope in which they are needed. Variables declared outside of any functions should be declared at the top of the code; variables declared within a function definition should be declared as the first thing within that function's code. The technical reason for this is because of something called "hoisting," but declaring variables as soon as possible is also standard practice in languages without hoisting issues.

VARIABLE NAMES

In order to create a variable, you must give it a name, also called an *identifier*. The rules for names in JavaScript are:

- The name must start with a letter, the underscore, or a dollar sign.
- The rest of the name can contain any combination of letters, underscores, and numbers (along with some other, less common characters).
- You cannot use spaces, punctuation, or any other characters.
- You cannot use a reserved JavaScript word.
- Names are case-sensitive.

This last rule is an important one, and can be a frequent cause of problems. The best way to minimize problems is to use a consistent naming scheme. With an object-oriented language like JavaScript, it's conventional to use "camel-case" syntax, where words within a name are broken up by a capital letter:

- `fullName`
- `streetAddress`
- `monthlyPayment`

In procedural programming languages, the underscore is often used to break up words. In procedural PHP, for example, I would write `$full_name` and `$street_address`. In JavaScript, camel-case is conventional, but the most important criterion is that you choose a style and stick with it.

As a final note, you should not use an existing variable's name for your variable. For example, when JavaScript runs in the browser, the browser will provide some variables, such as `document` and `window`. Both of these are quite important, and you wouldn't want to override them by creating your own variables with those names. You don't need to memorize a list of browser-provided variables, however; just try to be unique and descriptive with your variable names (e.g., `theDocument` and `theWindow` would work fine).

ASSIGNING VALUES

As you probably already know or guessed from what you've seen in this book or online, a single equals sign is the assignment operator, used to assign a value on the right to the variable on the left. Here is the declaration of, and assignment to, a numeric variable:

```
var rate;
rate = 5.25;
```

This can be condensed into a single line:

```
var rate = 5.25;
```

That one line not only declares a variable, but *initializes* it: provides an initial value. You do not have to initialize variables when you declare them, but sometimes it will make sense to.

SIMPLE VALUE TYPES

JavaScript recognizes several "simple" types of values that can be assigned to variables, starting with numbers, strings, and Booleans. A number is exactly what you'd expect: any quantity of digits with or without a single decimal point. Numeric values are never quoted and may contain digits, a single decimal point, a plus or minus, and possibly the letter "e" (for exponential notation). Numeric values do not contain commas, as would be used to indicate thousands.

A string is any sequence of zero or more quoted characters. You can use single or double quotation marks, but you must use the same type to end the string as you used to begin it:

- 'This is a string.'
- "This is also a string."

If you need to include a single or double quotation mark within the string, you can either use the other mark type to delineate the string or *escape* the potentially problematic character by prefacing it with a backslash:

- "I've got an idea."
- 'Chapter 4, "Simple Variable Types"'

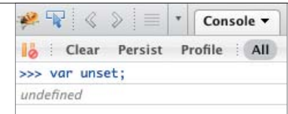


FIGURE 4.1 Because this variable has not yet been assigned a value, its value is `undefined`.

- 'I\'ve got an idea.'
- "Chapter 4, \"Simple Variable Types\""

What will not work is:

- 'I've got an idea.'
- "Chapter 4, "Simple Variable Types""

Note that a string does not need to have any characters in it: Both '' and "" are valid strings, called *empty* strings.

JavaScript also has Boolean values: `true` and `false`. As JavaScript is a case-sensitive language, you must use *true* and *false*, not *True* or *TRUE* or *False* or *FALSE*.

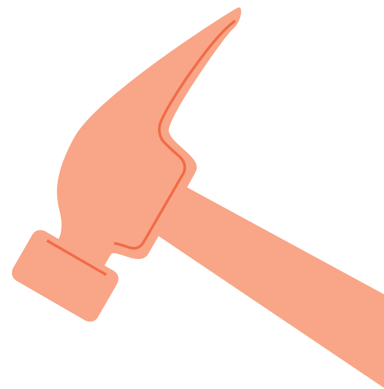
Two more simple, yet special, values are `null` and `undefined`. Again, these are case-sensitive words. The difference between them is subtle. `null` is a defined non-value and is best used to represent the consequence of an action that has no result. For example, the result of a working Ajax call could be `null`, which is to say that no data was returned.

Conversely, `undefined` is no set value, which is normally the result of inaction. For example, when a variable is declared without being assigned a value, its value will be `undefined` (**Figure 4.1**):

```
var unset; // Currently undefined.
```

Similarly, if a function does not actively return a value, then the returned value is `undefined` (you'll see this in Chapter 7).

Both `null` and `undefined` are not only different from each other, but different from `false`, which is a known and established negative value. As you'll see in Chapter 5, Using Control Structures, when used as the basis of a condition, both `null` and `undefined` are treated as FALSE, as are the number 0 and the empty string. Still, there are differences among them.



TIP: As a reminder, the combination of two slashes together (//) creates a comment in JavaScript.

WORKING WITH NUMBERS

Unlike a lot of languages, JavaScript only has a single number type, used to represent any numerical value, from integers to doubles (i.e., decimals or real numbers) to exponent notation. You can rest assured in knowing that numbers in JavaScript can safely represent values up to around 9 quadrillion!

Let's look at everything you need to know about numbers in JavaScript, from the arithmetic operators to formatting numbers, to using the `Math` object for more sophisticated purposes.

ARITHMETIC OPERATORS

You've already been introduced to one operator: a single equals sign, which is the assignment operator. JavaScript supports the standard arithmetic operators, too (**Table 4.1**).

TABLE 4.1 Arithmetic Operators

SYMBOL	MEANING
+	Addition
-	Subtraction
*	Multiplication
/	Division
%	Remainder

The modulus operator, in case you're not familiar with it, returns the remainder of a division. For example:

```
var remainder = 7 % 2; // 1;
```

One has to be careful when applying the modulus operator to negative numbers, as the remainder itself will also be negative:

```
var remainder = -7 % 2; // -1
```

These arithmetic operators can be combined with the assignment operator to both perform a calculation and assign the result in one step:

```
var cost = 50; // Dollars
cost *= 0.7373; // Converted to euros
```

You'll frequently come across the increment and decrement operators: ++ and --. The increment operator adds one to the value of the variable; the decrement operator subtracts one:

```
var num = 1;
num++; // 2
num--; // 1
```

These two operators can be used in both *prefix* and *postfix* manners (i.e., before the variable or after it):

```
var num = 1;
num++; // num now equals 2.
++num; // num is now 3.
--num; // num is now 2.
```

A difference between the postfix and prefix versions is a matter of *operator precedence*. The rules of operator precedence dictate the order operations are executed in a multi-operation line. For example, basic math teaches that multiplication and division have a higher precedence than addition and subtraction. Thus:

```
var num = 3 * 2 + 1; // 7, not 9
```

Table 4.2 lists the order of precedence in JavaScript, from highest to lowest, including some operators not yet introduced (I've also omitted a couple of operators that won't be discussed in this book). There's also an issue of *associativity* that I've omitted, as that would be just one more thing you'd have to memorize. In fact, instead of trying to memorize that table, I recommend you use parentheses to force, or just clarify, precedence, without relying upon mastery of these rules. For example:

```
var num = (3 * 2) + 1; // Still 7.
```

That syntax, while two characters longer than the earlier version, has the same net effect but is easier to read and undeniably clear in intent.

Some of the operators in Table 4.2 are *unary*, meaning they apply to only one operand (such as ++ and --); others are binary, applying to two operands (such as addition). In Chapter 5, you'll learn how to use the one *trinary* operator, which has three operands.

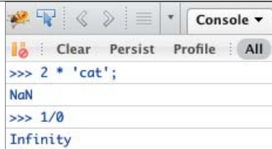


FIGURE 4.2 The result of invalid mathematical operations will be the special values `NaN` and `Infinity`.

TABLE 4.2 Operator Precedence

PRECEDENCE	OPERATOR	NOTE
1	. []	member operators
1	new	creates new objects
2	()	function call
3	++ --	increment and decrement
4	!	logical not
4	+ -	unary positive and negative
4	typeof void delete	
5	* / %	multiplication, division, and modulus
6	+ -	addition and subtraction
8	< <= > >=	comparison
9	== != === !==	equality
13	&&	logical and
14	||	logical or
15	?:	conditional operator
16	= += -= *= /= %= <<= >>= >>>= &= ^= |=	assignment operators

The last thing to know about performing arithmetic in JavaScript is if the result of the arithmetic is invalid, JavaScript will return one of two special values:

- `NaN`, short for *Not a Number*
- `Infinity`

For example, you'll get these results if you attempt to perform arithmetic using strings or when you divide a number by zero, which surprisingly doesn't create an error (**Figure 4.2**). In Chapter 5, you'll learn how to use the `isNaN()` and `isFinite()` functions to verify that values are numbers safe to use as such.

CREATING CALCULATORS

At this point in time, you have enough knowledge to begin using JavaScript to perform real-world mathematical calculations, such as the kinds of things you'd put on a Web site:

- Mortgage and similar loan calculators
- Temperature and other unit conversions
- Interest or investment calculators

For this particular example, let's create an e-commerce tool that will calculate the total of an order, including tax, and minus any discount (**Figure** 4.3). The most relevant HTML is:

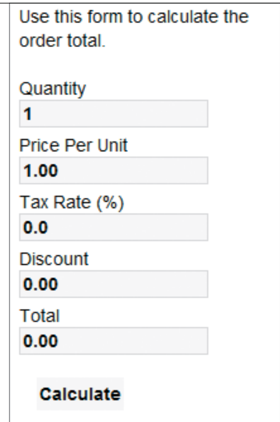


FIGURE 4.3 A simple calculator.

```
<div><label for="quantity">Quantity</label><input type="number"
→ name="quantity" id="quantity" value="1" min="1" required></div>
<div><label for="price">Price Per Unit</label><input type="text"
→ name="price" id="price" value="1.00" required></div>
<div><label for="tax">Tax Rate (%)</label><input type="text"
→ name="tax" id="tax" value="0.0" required></div>
<div><label for="discount">Discount</label><input type="text"
→ name="discount" id="discount" value="0.00" required></div>
<div><label for="total">Total</label><input type="text" name="total"
→ id="total" value="0.00"></div>
<div><input type="submit" value="Calculate" id="submit"></div>
```

That would go in a page named `shopping.html`, which includes the `shopping.js` JavaScript file, to be written in subsequent steps. You'll notice that the HTML form makes use of the HTML5 number input type for the quantity, with a minimum value. The other types are simply text, as the number type doesn't deal well with decimals. Each input is given a default value, and set as required. Remember that as Chapter 2, JavaScript in Action, explains, browsers that don't support HTML5 will treat unknown types as text elements and ignore the unknown properties. The final text element will be updated with the results of the calculation.

To create a calculator:

1. Create a new JavaScript file in your text editor or IDE, to be named `shopping.js`.

2. Begin defining the `calculate()` function:

```
function calculate() {
    'use strict';
```

   This function will be called when the user clicks the submit button. It does the actual work.

3. Declare a variable for storing the order total:

```
var total;
```

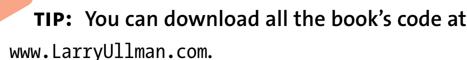
   As mentioned previously, you should generally declare variables as soon as you can, such as the first line of a function definition. Here, a variable named `total` is declared but not initialized.

4. Get references to the form values:

```
var quantity = document.getElementById('quantity').value;
var price = document.getElementById('price').value;
var tax = document.getElementById('tax').value;
var discount = document.getElementById('discount').value;
```

   In these four lines of code, the values of the various form elements are assigned to local variables. Note that in the Chapter 2 example, variables were assigned references to the form elements, and then the element values were later checked. Here, the value is directly assigned to the variable.

   At this point in time, one would also perform validation of these values, prior to doing any calculations. But as Chapter 5 more formally covers the knowledge needed to perform validation, I'm skipping this otherwise needed step in this example.



TIP: You can download all the book's code at `www.LarryUllman.com`.

5. Calculate the initial total:

```
total = quantity * price;
```

The `total` variable is first assigned the value of the quantity times the price, using the multiplication operator.

6. Factor in the tax rate:

```
tax /= 100;

tax++;

total *= tax;
```

There are a couple of ways one can calculate and add in the tax. The first, shown here, is to change the tax rate from a percent (say 5.25%) to a decimal (0.0525). Next, add one to the decimal (1.0525). Finally, multiply this number times the total. You'll see that the division-assignment, incrementation, and multiplication-assignment operators are used here as shorthand. This code could also be written more formally:

```
tax = tax/100;

tax = tax + 1;

total = total * tax;
```

You could also make use of precedence and parentheses to perform all these calculations in one line.

An alternative way to calculate the tax would be to convert it to decimal, multiply that value times the total, and then add that result to the total.

7. Factor in the discount:

```
total -= discount;
```

The discount is just being subtracted from the total.

8. Display the total in the form:

```
document.getElementById('total').value = total;
```

The `value` attribute can also be used to *assign* a value to a text form input. Using this approach, you can easily reflect data back to the user. In later chapters, you'll learn how to display information on the HTML page using DOM manipulation, rather than setting the values of form inputs.

9. Return `false` to prevent submission of the form:

```
return false;
```

The function must return a value of `false` to prevent the form from actually being submitted (to the page named by the form's `action` attribute).

10. Complete the function:

```
} // End of calculate() function.
```

11. Define the `init()` function:

```
function init() {
    'use strict';
    var theForm = document.getElementById('theForm');
    theForm.onsubmit = calculate;
} // End of init() function.
```

The `init()` function will be called when the window triggers a load event (see Step 12). The function needs to add an event listener to the form's submission, so that when the form is submitted, the `calculate()` function will be called. To do that, the function gets a reference to the form, by calling the `document` object's `getElementById()` method, providing it with the unique ID value of the form. Then the variable's `onsubmit` property is assigned the value *calculate*, as explained in Chapter 2.

12. Add an event listener to the window's load event:

```
window.onload = init;
```

This code was also explained in Chapter 2. It says that when the window has loaded, the `init()` function should be called.

Use this form to calculate the order total.

Quantity
12
Price Per Unit
1.99
Tax Rate (%)
5.25
Discount
3.00
Total
22.133699999999997

Calculate

Use this form to calculate the order total.

Quantity
cat
Price Per Unit
1.99
Tax Rate (%)
5.25
Discount
3.00
Total
NaN

Calculate

FIGURE 4.4 The result of the total order calculation.

FIGURE 4.5 Performing arithmetic with invalid values, such as a quantity of *cat*, will result in a total of `NaN`.

It's a minor point, as you can organize your scripts in rather flexible ways, but this line is last as it references the `init()` function, defined in Step 12, so that definition should theoretically come before this line. That function references `calculate()`, so the `calculate()` function's definition is placed before the `init()` function definition. You don't have to organize your code this way, but I prefer to.

13. Save the file as `shopping.js`, in a `js` directory next to `shopping.html`, and test in your Web browser (**Figure 4.4**).

    Play with the numbers, including invalid values (**Figure 4.5**), and retest the calculator until you're comfortable with how arithmetic works in JavaScript.

FORMATTING NUMBERS

Although the previous example is perfectly useful, and certainly a good start, there are several ways in which it can be improved. For example, as written, no checks are made to ensure that the user enters values in all the form elements, let alone that those values are numeric (Figure 4.5) or, more precisely, positive numbers. That knowledge will be taught in the next chapter, which discusses conditionals, comparison operators, and so forth. Another problem, which can be addressed here, is that you can't expect someone to pay, say, 22.1336999 (Figure 4.4). To improve the professionalism of the calculator, formatting the calculated total to two decimal points would be best.

A number in JavaScript is not just a number, but is also an object of type `Number`. As an object, a number has built-in methods, such as `toFixed()`. This method returns a number with a set number of digits to the right of a decimal point:

```
var num = 4095.3892;
num.toFixed(3); // 4095.389
```

Note that this method only returns the formatted number; it does not change the original value. To do that, you'd need to assign the result back to the variable, thereby replacing its original value:

```
num = num.toFixed(3);
```

If you don't provide an argument to the `toFixed()` method, it defaults to 0:

```
var num = 4095.3892;
num.toFixed(3); // 4095
```

The method can round up to 20 digits.

Similar to `toFixed()` is `toPrecision()`. It takes an argument dictating the total number of significant digits, which may or may not include those after the decimal.

Let's apply this information to the calculator in order to add some better formatting to the total.

To format a number:

1. Open `shopping.js` in your text editor or IDE, if it is not already.
2. After factoring in the discount, but before showing the total amount, format the total to two decimals:

   ```
   total = total.toFixed(2);
   ```

   This one line will take care of formatting the decimal places. Remember that the returned result must be assigned back to the variable in order for it to be represented upon later uses.

   Alternatively, you could just call `total.toFixed(2)` when assigning the value to the total form element.

FIGURE 4.6 The same input as in Figure 4.4 now generates a more appropriate result.

FIGURE 4.7 The area of a circle, πr2, is calculated using the Math.PI constant.

3. Save the file, reload the HTML page, and test it in your Web browser (**Figure 4.6**).

An even better way of formatting the number would be to add commands indicating thousands, but that requires more logic than can be understood at this point in the book.

THE MATH OBJECT

You just saw that numbers in JavaScript can also be treated as objects of type Number, with a couple of built-in methods that can be used to manipulate them. Another way to manipulate numbers in JavaScript involves the Math object. Unlike Number, you do not create a variable of type Math, but use the Math object directly. The Math object is a global object in JavaScript, meaning it's always available for you to use.

The Math object has several predefined *constants*, such as π, which is 3.14... and E, which is 2.71... A constant, unlike a variable, has a fixed value. Conventionally, constants are written in all uppercase letters, as shown. Referencing an object's constant uses the same dot syntax as you would to reference one of its methods: Math.PI, Math.E, and so forth. Therefore, to calculate the area of a circle, you could use (**Figure 4.7**):

```
var radius = 20;
var area = Math.PI * radius * radius;
```

Use this form to calculate the volume of a sphere.

Radius

12

Volume

7238.2295

Calculate

FIGURE 4.8 This calculator determines and displays the volume of a sphere given a specific radius.

The `Math` object also has several predefined methods, just a few of which are:

- `abs()`, which returns the absolute value of a number
- `ceil()`, which rounds up to the nearest integer
- `floor()`, which rounds down to the nearest integer
- `max()`, which returns the largest of zero or more numbers
- `min()`, which returns the smallest of zero or more numbers
- `pow()`, which returns one number to the power of another number
- `round()`, which returns a number rounded to the nearest integer
- `random()`, which returns a pseudo-random number between 0 (inclusive) and 1 (exclusive)

There are also several trigonometric methods like `sin()` and `cos()`.

Another way of writing the formula for determining the area of a circle is:

```
var radius = 20;
var area = Math.PI * Math.pow(radius, 2);
```

To apply this new information, let's create a new calculator that calculates the volume of a sphere, based upon a user-entered radius. That formula is:

$$volume = 4/3 * \pi * radius^3$$

Besides using the π constant and the `pow()` method, this next bit of JavaScript will also apply the `abs()` method to ensure that only a positive radius is used for the calculation (**Figure 4.8**). The relevant HTML is:

```
<div><label for="radius">Radius</label><input type="text"
→ name="radius" id="radius" required></div>
<div><label for="volume">Volume</label><input type="text"
→ name="volume" id="volume"></div>
<div><input type="submit" value="Calculate" id="submit"></div>
```

The HTML page includes the `sphere.js` JavaScript file, to be written in subsequent steps.

To calculate the volume of a sphere:

1. Create a new JavaScript file in your text editor or IDE, to be named `sphere.js`.

2. Begin defining the `calculate()` function:

   ```
   function calculate() {
       'use strict';
       var volume;
   ```

   Within the function, a variable named `volume` is declared, but not initialized.

3. Get a reference to the form's radius value:

   ```
   var radius = document.getElementById('radius').value;
   ```

   Again, this code closely replicates that in `shopping.js`, although there's only one form value to retrieve.

4. Make sure that the radius is a positive number:

   ```
   radius = Math.abs(radius);
   ```

   Applying the `abs()` method of the `Math` object to a number guarantees a positive number without having to use a conditional to test for that.

5. Calculate the volume:

   ```
   volume = (4/3) * Math.PI * Math.pow(radius, 3);
   ```

   The volume of a sphere is four-thirds times π times the radius to the third power. This one line performs that entire calculation, using the `Math` object twice. The division of four by three is wrapped in parentheses to clarify the formula, although in this case the result would be the same without the parentheses.

6. Format the volume to four decimals:

   ```
   volume = volume.toFixed(4);
   ```

   Remember that the `toFixed()` method is part of `Number`, which means it's called from the `volume` variable, not from the `Math` object.

7. Display the volume:

```
document.getElementById('volume').value = volume;
```

This code is the same as in the previous example, but obviously referencing a different form element.

8. Return `false` to prevent the form's submission, and complete the function:

```
    return false;
} // End of calculate() function.
```

9. Add an event listener to the form:

```
function init() {
    'use strict';
    document.getElementById('calcForm').onsubmit = calculate;
} // End of init() function.
window.onload = init;
```

This is the same code used in `shopping.js`. As in that example, when the form is submitted, the `calculate()` function will be called.

10. Save the file as `sphere.js`, in a `js` directory next to `sphere.html`, and test it in your Web browser.

WORKING WITH STRINGS

Strings and numbers are two of the most common types used in JavaScript, and both are easy to comprehend and use. You've seen the fundamentals when it comes to numbers—and there's not all that much to it, really, so now it's time to look at strings in more detail.

CREATING STRINGS

Informally, you've already witnessed how strings are created: just quote anything. As with a number, once you have a string value, you also have predefined methods that can be used to manipulate that value. Unlike numbers, though, strings have a

lot more methods, and even a property you'll commonly use: `length`. The `length` property stores the number of characters found in the string, including empty spaces:

```
var fullName = 'Larry Ullman';
fullName.length; // 12
```

If you're following this book sequentially, you'll have already seen this in Chapter 2:

```
var email = document.getElementById('email');
if ( (email.value.length > 0) { ...
```

What you're actually seeing here is the beauty of object-oriented programming: A string is a string, with all the functionality that comes with it, regardless of how the string was created. The assignment to the `email` variable starts with the `document` object, which is a representation of the page's HTML. That object has a `getElementById()` method, which returns an HTML element. The specific element returned by that line is a text input, in other words, a text object. This is assigned to `email`. That object has a `value` property for finding the text input's value (or for setting its value). Since the value returned by that property is a string, you can then refer to its `length` property. Thanks to the ability to chain object notation, this could be reduced to one line:

```
if ( (document.getElementById('email').value.length > 0) { ...
```

DECONSTRUCTING STRINGS

Once you've created a string, you can deconstruct it—break it into pieces—in a number of ways. As a string is just a sequence of `length` characters, you can reference individual characters using the `charAt()` method. This method takes an *index* as its first argument, an index being the position of the character in the string. The trick to using indexes is that they begin at 0, not 1 (this is common to indexes of all types across all programming languages). Thus, the first character of string `fullName` can be retrieved using `fullName.charAt(0)`. And a string's last character will be indexed at `length - 1`:

```
var fullName = 'Larry Ullman';
fullName.charAt(0); // L
fullName.charAt(11); // n
```

Sometimes you don't want to know what character is at a specific location in the string, but rather if a character is found in the string at all. For this need, use the `indexOf()` method. This method returns the indexed position where the character is first found:

```
var fullName = 'Larry Ullman';
fullName.indexOf('L'); // 0
fullName.indexOf('a'); // 1
fullName.indexOf(' '); // 5
```

The first argument can be more than a single character, letting you see if entire words are found within the string. In that case, the method returns the indexed position where the word begins in the string:

```
var language = 'JavaScript';
language.indexOf('Script'); // 4
```

The `indexOf()` method takes an optional second argument, which is a location to begin searching in the string. By default, this is `0`:

```
var language = 'JavaScript';
language.indexOf('a'); // 1
language.indexOf('a', 2); // 3
```

However you use `indexOf()`, if the character or characters—the *needle*—is not found within the string (the *haystack*), the method returns `-1`. Also, `indexOf()` performs a case-sensitive search:

```
var language = 'JavaScript';
language.indexOf('script'); // -1
```

Another way to look for needles within a string haystack is to use `lastIndexOf()`, which goes backward through the string. Its second argument is also optional, and indicates the starting point, but the search again goes backward from that starting point, not forward:

```
var fullName = 'Larry Ullman';
fullName.indexOf('a'); // 1
```

```
fullName.lastIndexOf('a'); // 10
fullName.lastIndexOf('a', 5); // 1
```

To pull a substring out of a string, there's the `slice()` method. Its first argument is the index position to begin at. Its optional second argument is the indexed position where to stop. Without this second argument, the substring will continue until the end of the string:

```
var language = 'JavaScript';
language.slice(4); // Script
language.slice(0,4); // Java
```

A nice trick with `slice()` is that you can provide a negative second argument, which indicates the index at which to stop, counting backward from the end of the string. If you provide a negative starting point, the slice will begin at that indexed position, counting backward from the end of the string:

```
var language = 'JavaScript';
language.slice(0,-6); // Java
language.slice(-6); // Script
```

However you use `slice()`, this method only returns a new string, without affecting the value of the original.

JavaScript also has a `substring()` method, which uses the same arguments as `slice()`, but it has some unexpected behaviors, and it's recommended that you use `slice()` instead.

JavaScript has another string method for retrieving substrings: the aptly named `substr()`. Its first argument is the starting index for the substring, but the second is the number of characters to be included in the substring, not the terminating index. In theory, you can provide negative values for each, thereby changing both the starting and ending positions to be relative to the end of the string, but Internet Explorer doesn't accept negative starting positions.

NOTE: **In Chapter 6, you'll learn about the** `split()` **method, which breaks a string into an array of strings.**

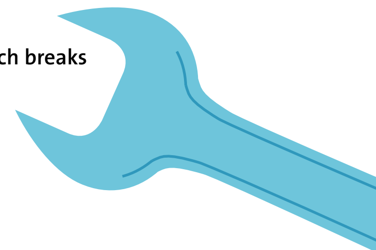


FIGURE 4.9 The HTML form, as it works in Internet Explorer.

To test using `slice()`, let's create some JavaScript code that limits the amount of data that can be submitted by a textarea. For the time being, a second textarea will show the restricted string; in Chapter 8, Event Handling, you'll learn how to dynamically restrict the amount of text entered in a text area in real time. The relevant HTML for this example is:

```
<div><label for="comments">Comments</label><textarea name="comments"
→ id="comments" maxlength="100" required></textarea></div>
<div><label for="count">Character Count</label><input type="number"
→ name="count" id="count"></div>
<div><label for="result">Result</label><textarea name="result"
→ id="result"></textarea></div>
<div><input type="submit" value="Submit" id="submit"></div>
```

The HTML form has one textarea for the user's input, a text input indicating the number of characters used, and another textarea showing the truncated result. To make the truncated text more professional, it'll be broken on the final space before the character limit (**Figure 4.9**), rather than having the text broken midword. The page, named `text.html`, includes the `text.js` JavaScript file, to be written in subsequent steps.

To deconstruct strings:

1. Create a new JavaScript file in your text editor or IDE, to be named `text.js`.

2. Begin defining the `limitText()` function:

   ```
   function limitText() {
       'use strict';
       var limitedText;
   ```

   The `limitedText` variable will be used to store the edited version of the user-supplied text.

3. Retrieve the original text:

   ```
   var originalText = document.getElementById('comments').value;
   ```

   The original text comes from the first textarea in the form and is assigned to `originalText` here.

4. Find the last space before the one-hundredth character in the original text:

```
var lastSpace = originalText.lastIndexOf(' ', 100);
```

To find the last occurrence of a character in a string, use the `lastIndexOf()` method, applied to the original string. This script is not looking for the absolute last space, though, just the final space before the hundredth character, so 100 is provided as the second argument to `lastIndexOf()`, meaning that the search will begin at the index of 100 and work backward.

5. Trim the text to that spot:

```
limitedText = originalText.slice(0, lastSpace);
```

Next, a substring from `originalText` is assigned to `limitedText`, starting at the beginning of the string—index of 0—and stopping at the previously found space.

6. Show the user the number of characters submitted:

```
document.getElementById('count').value = originalText.length;
```

To indicate that the user submitted too much data, the original character count will be shown in a text input.

7. Display the limited text:

```
document.getElementById('result').value = limitedText;
```

The value of the second textarea is updated with the edited string.

8. Return `false` and complete the function:

```
    return false;
} // End of limitText() function.
```

TIP: It'd be more professional to break the text on a space or comma or the end of a sentence, but that capability is beyond this point in the book.

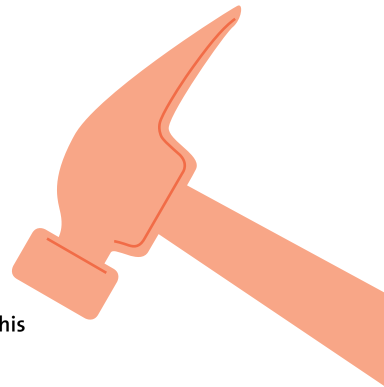


FIGURE 4.10 In Chrome, which supports the textarea's `maxlength` attribute, only 100 characters can be submitted, but the partial word is still chopped off.

9. Add an event listener to the form:

```
function init() {
    'use strict';
    document.getElementById('calcForm').onsubmit = limitText;
} // End of init() function.
window.onload = init;
```

   This is the same basic code used in the previous example. When the form is submitted, the `limitText()` function will be called.

10. Save the file as `text.js`, in a `js` directory next to `text.html`, and test it in your Web browser (Figure 4.9).

   Try using different strings (**Figure 4.10**), and retest, to make sure it's working as it should.

MANIPULATING STRINGS

The most common way to manipulate a string is to change its value using *concatenation*. Concatenation is like addition for strings, adding more characters onto existing ones. In fact, the concatenation operator in JavaScript is also the arithmetic addition operator:

```
var message = 'Hello';
message = message + ', World! ';
```

As with the arithmetic addition, you can combine the plus sign with the assignment operator (=) into a single step:

```
var message = 'Hello';
message += ', World! ';
```

This functionality is duplicated by the `concat()` method, although it's less commonly used. This method takes one or more strings to be appended to the string:

```
var address = '100 Main Street';
address.concat(' Anytown', ' ST', ' 12345', ' US');
```

CONSTANTS

Many programming languages have the concept of a *constant*: a single value that cannot be changed (depending upon how and where the constant was created, and depending upon the language, the constant can have other qualities, too). In theory, JavaScript has the ability to create a constant, using this code:

```
const NAME = value;
```

The same naming rules as those for variables apply to constants, but constants are conventionally written in all uppercase letters, using underscores to separate words. Regardless, the `const` keyword is not supported across all browsers; specifically, Internet Explorer doesn't recognize it. There are ways to fake a constant, but that requires code well beyond what you would know at this point. The end result is that you shouldn't plan on creating your own constants in JavaScript code.

On the other hand, many built-in JavaScript objects have their defined constants, like the `Number` object's `MAX_VALUE`. This constant represents the maximum value that a number can have in the given environment. You'd refer to it using `Number.MAX_VALUE`.

Two methods exist to simply change the case of the string's characters: `toLowerCase()` and `toUpperCase()`. You can apply these to a string prior to using one of the previously mentioned methods, in order to fake case-insensitive searches:

```
var language = 'JavaScript';
language.indexOf('script'); // -1, aka not found
language.toLowerCase().indexOf('script'); // 4
```

Added to JavaScript in version 1.8.1 is the `trim()` method, which removes extra spaces from both ends of a string. It's supported in more current browsers—Chrome, Firefox 3.5 and up, IE9 and above, Safari 5 and up, and Opera 10.5 and above, but isn't available on older ones.

Note that, as with `slice()` and the other methods already covered, `toLowerCase()`, `toUpperCase()`, and `trim()` do not affect the original string, they only return a modified version of that string. Concatenation, however, does alter the original.

First Name
Larry
Last Name
Ullman
Formatted Name
Ullman, Larry
Submit

FIGURE 4.11 The values entered in the first two inputs are concatenated together to create a formatted name.

To test this new information, this next example will take a person's first and last names, and then format them as *Surname, First Name* (**Figure 4.11**). The relevant HTML is:

```
<div><label for="firstName">First Name</label><input type="text"
→ name="firstName" id="firstName" required></div>
<div><label for="lastName">Last Name</label><input type="text"
→ name="lastName" id="lastName" required></div>
<div><label for="result">Formatted Name</label><input type="text"
→ name="result" id="result" required></div>
<div><input type="submit" value="Submit" id="submit"></div>
```

This would go into an HTML page named `names.html`, which includes the `names.js` JavaScript file, to be written in subsequent steps. By this point in the chapter, this should be a simple and obvious exercise for you.

To manipulate strings:

1. Create a new JavaScript file in your text editor or IDE, to be named `names.js`.

2. Begin defining the `formatNames()` function:

   ```
   function formatNames() {
       'use strict';
       var formattedName;
   ```

   The `formattedName` variable will be used to store the formatted version of the user's name.

3. Retrieve the user's first and last names:

   ```
   var firstName = document.getElementById('firstName').value;
   var lastName = document.getElementById('lastName').value;
   ```

4. Create the formatted name:

   ```
   formattedName = lastName + ', ' + firstName;
   ```

   To create the formatted name, assign to the `formattedName` variable the `lastName` plus a comma plus a space, plus the `firstName`. There are other ways of performing this manipulation, such as:

```
formattedName = lastName;
formattedName += ', ';
formattedName += firstName;
```

That code would probably perform worse, though, than the one-line option.

5. Display the formatted name:

```
document.getElementById('result').value = formattedName;
```

6. Return `false` and complete the function:

```
    return false;
} // End of formatNames() function.
```

7. Add an event listener to the form:

```
function init() {
    'use strict';
    document.getElementById('calcForm').onsubmit = formatNames;
} // End of init() function.
window.onload = init;
```

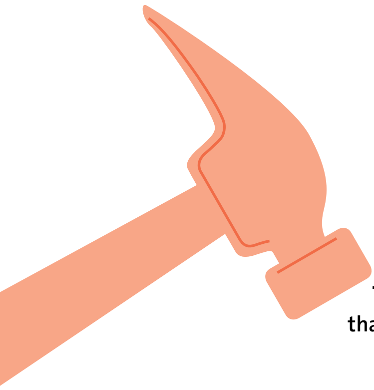
When the form is submitted, the `formatNames()` function will be called.

8. Save the file as `names.js`, in a `js` directory next to `names.html`, and test it in your Web browser (Figure 4.11).

ESCAPE SEQUENCES

Another thing to understand about strings in JavaScript is that they have certain meaningful *escape sequences*. You've already seen two examples of this: to use a type of quotation mark (single or double) within a string delimited by that same type, the inserted quotation mark must be prefaced with a backslash:

- 'I\'ve got an idea.'
- "Chapter 4, \"Simple Variable Types\""



Three other meaningful escape sequences are:

- `\n`, a new line
- `\r`, a carriage return
- `\\`, a literal backslash

Note that these work within either single or double quotation marks (unlike, for example, in PHP, where they only apply within double quotation marks).

TIP: When a user presses Enter or Return within a textarea, that translates to `\n` in a corresponding JavaScript string.

PERFORMING TYPE CONVERSIONS

Because JavaScript is weakly typed, different value types can be used together without causing formal errors. In, say, ActionScript, the following would cause an error:

```
var cost:int = 2;
cost += ' dollars';
```

But in JavaScript, you can do that without the browser complaining. That being said, although you *can* use different types together without causing formal errors, it's quite possible to end up with logical errors, which is to say *bugs*, if you're not careful. One complication stems from the fact that the addition operator in math is the same as the concatenation operator for strings. When you add a string to a number, or add a number to a string, JavaScript will convert the number to a string and then concatenate the two. For example, say the shopping example added a shipping value to the total:

```
var shipping = document.getElementById('shipping').value;
total = quantity * price;
tax /= 100;
tax++;
total *= tax;
total += shipping;
```

FIGURE 4.12 Adding the string '5.00' to the total has the impact of concatenation, converting the `total` number into an unusable string.

FIGURE 4.13 How the `parseInt()` function extracts numbers from strings.

By the time JavaScript gets to the final line, `total` is a number, but `shipping` is a string, because it comes from a form's text input. That final line won't have the effect of mathematically adding the shipping to the total but rather concatenating the shipping onto the total (**Figure 4.12**).

This issue doesn't apply to other operators, though. For example, subtraction converts a string to a number and then performs the math, as the shopping example already demonstrated.

To perform math using strings, without worrying about creating bugs, you can forcibly convert the string to a number. There are many ways of doing so, starting with `parseFloat()` and `parseInt()`. These are "top-level" functions, which is to say they are not associated with any object and can be called directly. The first function always returns a floating-point number (aka, a decimal), and the latter, an integer. Both functions take the value to be converted as its first argument. The `parseInt()` function takes the *radix* as the second. The radix is the number's base, as in base-8 (aka, octal), base-10 (decimal), and base-16 (hexadecimal). Although the second argument is optional, you should always provide it to be safe, and will normally use a value of 10:

```
total += parseFloat(shipping, 10);
```

To best use these functions, you should have an understanding of how they work. Both functions begin at the start of the string and extract a number until an invalid numeric character is encountered. If no valid number can be pulled from the start of the value, both functions return `NaN` (**Figure 4.13**):

```
parseInt('20', 10);
parseInt('20.0', 10);
parseInt('20 ducklings', 10);
parseInt('I saw 20 ducklings.', 10);
```

OBJECTS VS. LITERALS

A point that this chapter has thus far ignored is that values can be represented in two ways: as *objects* or as *literals*. All of the examples in this chapter are literals, such as these:

- 2
- 'JavaScript'
- false

This is the most common way for creating simple variable types, but you can create numbers, strings, and Booleans as formal objects, too:

```
var number = new Number(2);

var fullName = new String('JavaScript');

var flag = new Boolean(false);
```

In that code, the corresponding global function—`String`, `Number`, and `Boolean`—is used to create and return an object of the given type.

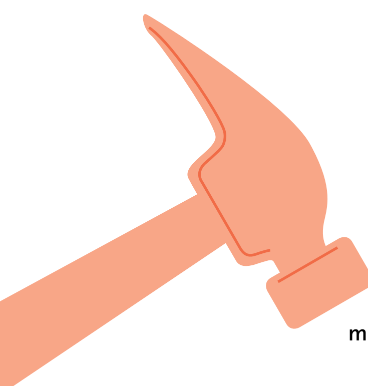
Besides being more complicated to write, creating simple types as objects will actually have slightly worse performance and have some unexpected behaviors. And you can continue to use literals as if they were objects, as many of the examples in this chapter have shown, without formally creating the object. In such cases, when needed, JavaScript will convert the literal value to a corresponding object, call the object's method, and then remove the temporary object.

A trickier way to convert a string to a number is to prepend it with a +:

```
total += +shipping;
```

or

```
total += +(shipping);
```



TIP: You can also convert a string to a number by multiplying it by 1.

Using this unary operator is the fastest solution, in terms of how quickly JavaScript performs the conversion, but is not as clear in terms of programmer readability as `parseInt()` and `parseFloat()`.

Converting from a number to a string is far less likely to cause problems, but you can do so by invoking the `toString()` method:

```
var message = 'Your total is $' + total.toString();
```

The `toString()` method is supported by most objects and returns a string representation of the object itself.

Earlier in the chapter, I mentioned two other meaningful values in JavaScript: `undefined` and `null`. As a gotcha, you should be aware of what happens when an `undefined` or `null` value is used as if it were a number. The `undefined` value translates to `NaN` when used as a number. When a `null` value is used as a number, the result is better, although not great: `null` values are treated as 0 as numbers (**Figure 4.14**). In the next chapter, you'll learn how to verify that a value is numeric prior to attempting to use it as such.

FIGURE 4.14 How arithmetic is handled if `undefined` or `null` is involved.

REVIEW AND PURSUE

Beginning in Part 2: JavaScript Fundamentals, each chapter of this book ends with a "Review and Pursue" section. In these sections, you'll find questions regarding the material just covered and prompts for ways to expand your knowledge and experience on your own. If you have any problems with these sections, either in answering the questions or pursuing your own endeavors, turn to the book's supporting forum (`www.LarryUllman.com/forums/`).

REVIEW

- How do you *declare* a variable?
- What is variable *scope*?
- What are the rules for a variable's name?
- What is the assignment operator?

- What simple types were introduced in this chapter?
- How can you use a single quotation mark within a string? A double quotation mark?
- What does the *= operator do? How about +=? (There are two answers to this last question.) And what about ++?
- What operator can cause bugs when used with a string and a number together?
- What does the `toFixed()` method do?
- What are some of the differences between `Number` objects and the `Math` object?
- What is an empty string?
- What does the `charAt()` method do? What does `indexOf()` do? How about `lastIndexOf()`? What are the arguments to the `indexOf()` and `lastIndexOf()` methods? What happens when you use negative numbers for the second argument to either method?
- What function should you use to pull a substring out of a string and how do you use it?
- What are the various ways you can perform concatenation with strings?
- What are escape sequences?
- What are some of the ways you can convert a string to a number?

PURSUE

- Use a development tool such as Firebug to practice creating and manipulating variables.
- Look up some of JavaScript's reserved words, if you have not already.
- If you're curious, find out what "hoisting" is.
- Create another calculator, such as one that calculates the area of a shape (rectangle, triangle, circle, etc.).

- Look online (e.g., at `https://developer.mozilla.org`) to research all the `Number` and `Math` object properties and methods.
- Look online to learn more about the `String` object and its methods.
- Create another string manipulation example.
- Update the shopping example to add a shipping cost option, and then rework the JavaScript to properly add the shipping amount to the total.
- Test all of this chapter's code in as many browsers and devices as you can to see the various results.

WRAPPING **UP**

In this chapter, you started learning the fundamental lessons of real programming in JavaScript, centered around the simple variable types. Those types include numbers, strings, and Booleans. You learned how to declare variables, how to properly name them, and how to assign them simple values.

Next, the chapter looked into the number type in detail, which starts with basic arithmetic. From there, you saw how to use the `Number` and `Math` object methods in this object-oriented language to perform such commonplace tasks as formatting numbers and rounding them.

After numbers, similar treatment was given to strings: what they are and how to create them. You also learned that there are several methods defined within the `String` object that are usable on any string you have. One of the most common manipulations of strings is *concatenation*, accomplished via the plus sign. Attention was also given to using the backslash as an escaping character.

The chapter concluded with a discussion of type conversion between numbers and strings. Implicit conversion can lead to bugs, as demonstrated, so it's best to formally convert values when needed. Along the way you also started creating practical examples, mostly as mathematical calculators.

This knowledge will be expanded in the next chapter, where you will learn about *control structures*. These are primarily conditionals and loops, but Chapter 5 will introduce more operators, too, before Chapter 6 gets into more complicated variable types.

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