Appendix

B

Java Basics

Contents

Prerequisite

Knowledge of a programming language

This book assumes that you know how to write programs in Java. If you know some other programming language, this appendix will help you to learn Java by reviewing the essential elements of the language. Appendixes C, D, and E supplement the coverage of Java that is presented here by discussing methods, classes, inheritance, and file I/O.

If you already know Java, note that this book uses applications, not applets. If you know only about applets, you should read at least the first few pages of this appendix.

Introduction

Applications and Applets

B.1 There are two kinds of Java programs, applications and applets. An **application** is simply a program that runs on your computer like any other program. It is a **stand-alone** program. In contrast, an **applet** is a program that cannot run without the support of a browser or a viewer. Typically, an applet is sent to another location on the Internet and is run there. The term "applet" is meant to suggest a little application.

Applets and applications are almost identical. Once you know how to design and write one, it is easy to learn to write the other. This book uses applications rather than applets.

Objects and Classes

B.2 An **object** is a program construct that contains data and can perform certain actions. When a Java program is run, the objects interact with one another to accomplish a particular task. The actions performed by objects are defined by **methods** in the program. When you ask an object to perform an action, you **invoke**, or **call**, a method. Java has two kinds of methods. A **valued method** uses a `return` statement to return a result, but a **void method** does not.

All objects of the same kind are said to be in the same class. So a **class** is a category or kind or type of object. All objects in the same class have the same types of data and the same methods.

You will see some objects and methods in the next section and again when we discuss the classes `Math`, `Scanner`, and `String` later in this appendix. Appendix C reviews classes, objects, and methods in more detail. If you are not familiar with these concepts, you should read at least Segment C.1 in Appendix C now and the rest of Appendix C later.

A First Java Application Program

B.3 To give you a feel for the Java language, let's take a brief, informal look at the following sample Java application program:

```
import java.util.Scanner;
public class FirstProgram
{
   public static void main(String[] args)
   {
      Scanner keyboard = new Scanner(System.in);
      System.out.println("Hello out there.");
      System.out.println("Want to talk some more?");
      System.out.println("Answer yes or no.");

      String answer = keyboard.next();
      if (answer.equals("yes"))
         System.out.println("Nice weather we are having.");
      System.out.println("Good-bye.");
   } // end main
} // end FirstProgram
```

The program is stored in the file `FirstProgram.java`.

Figure B-1 shows two screen displays that might be produced when a user runs and interacts with this program. The text typed by the user is shown in bold.

FIGURE B-1 Two possible results when running the sample program

```
Hello out there.
Want to talk some more?
Answer yes or no.
yes
Nice weather we are having.
Good-bye.
```

```
Hello out there.
Want to talk some more?
Answer yes or no.
no
Good-bye.
```

B.4 This program uses the class `Scanner`, which is a part of the **Java Class Library**. This library contains many standard classes that you can use in your Java programs. The classes in the library are organized into groups called **packages**. The `import` statement indicates that this program uses the class `Scanner` from the package `java.util`.

The program contains the definition of a class that begins with the lines

```
public class FirstProgram
{
```

and ends with

```
} // end FirstProgram
```

Within the class definition is a method called `main` that begins with the statements

```
public static void main(String[] args)
{
```

and ends with

```
} // end main
```

Statements within this pair of braces are the **body** of the method `main`. Generally, a class contains several methods, each defining a specific task and each having a name of our choosing. An application program, however, must contain a method that is called `main`.

B.5 The line

```
Scanner keyboard = new Scanner(System.in);
```

gets us ready to read data from the keyboard using Java's class `Scanner`. It defines the `Scanner` object `keyboard` and associates it with the object `System.in`. This latter object represents the computer's keyboard. `System.in` is in the class `System`, which is in the package `java.lang` of the Java Class Library.

Programming Tip: No `import` statement is necessary when you use a class from the package `java.lang` of the Java Class Library.

B.6 The next three lines display text for the user of the program:

```
System.out.println("Hello out there.");
System.out.println("Want to talk some more?");
System.out.println("Answer yes or no.");
```

Each of these lines causes the quoted characters, or **string**, given within the parentheses to be displayed on the screen. `System.out` is an object within the class `System` that can send output to the screen via its method `println`. You invoke an object's method by writing the object name followed by a period, or **dot**, followed by the method name and some parentheses that may or may not have something inside them. The text inside the parentheses is called an **argument** and provides the information the method needs to carry out its action. In each of these three lines, the method `println` writes the value of its argument—here, the characters inside the quotes—to the screen.

The method `println` is an example of a void method. It performs an action, but does not return a value.

B.7 The next line of the program reads the characters that are typed at the keyboard and stores them in the variable `answer` as a string:

```
String answer = keyboard.next();
```

You use the `Scanner` object `keyboard` to invoke its method `next`. In this way, you read the word that the user types at the keyboard. The user presses the Enter key (also called the Return key) after typing the word. Although the method `next` has no arguments, the parentheses are required. You will learn more about the class `Scanner` later in this appendix.

The method `next` is an example of a valued method. It returns the value read. Its **invocation**, `keyboard.next()`, represents this value.

B.8 The next two lines of the program make a decision to do or not do something based on the value of the variable `answer`. The first line asks whether the string stored in `answer` is the string *yes*. If it is, a message is displayed on the screen. Otherwise, the message is not displayed.

Notice that the first sample dialogue in Figure B-1 displays the string *Nice weather we are having*, and the second one does not. That is because, in the first run of the program, the string *yes* is stored in the variable `answer`, and in the second run of the program, the string *no* is stored in `answer`.

B.9 Of course, precise rules govern how you write each part of a Java program. For example, a final semicolon ends each Java statement. These rules form the **grammar** for the Java language, just as there are rules for the grammar of the English language. The grammar rules for a programming language (or any language) are called the **syntax** of the language. We now look at the elements of Java in more detail.

Elements of Java

In this section, we examine how to use Java to perform arithmetic computations.

Identifiers

B.10 You use **identifiers** to name certain parts of a program. An identifier in Java consists entirely of letters, digits, the underscore character _, and the dollar sign $. An identifier cannot start with a digit and must not contain a space or any other special character such as a period or an asterisk. There is no official limit to the length of a name, though in practice, there is always a limit. Although Java allows identifiers to contain a dollar sign, it is reserved for special purposes, and so you should not use $ in a Java identifier.

Java is **case sensitive**. This means that it treats uppercase letters and lowercase letters as different characters. For example, `mystuff`, `myStuff`, and `MyStuff` are three different identifiers. Having these identifiers in the same program could be confusing to human readers, and therefore doing so is a poor programming practice. But the Java compiler would be happy with them.

Java uses a character set, called **Unicode**, that includes characters from languages other than English. Java allows you to use these extra characters in identifiers, but you are not likely to find them on most keyboards. Segment B.68 discusses Unicode further.

B.11 Although it is not required by the Java language, the common practice, and the one followed in this book, is to start the names of classes with uppercase letters and to start the names of objects, methods, and variables (which you are about to see) with lowercase letters. These names are usually spelled using only letters and digits. We separate multiword names by using uppercase letters, since we cannot use spaces. For example, the following are all legal identifiers that follow this well-established convention:

```
inputStream   YourClass   CarWash   hotCar   theTimeOfDay
```

Some people use an underscore to separate the words in an identifier, but typically we will not.

The following are all illegal identifiers in Java, and the compiler will complain if you use any of them:

```
.MyClass   goTeam-   7eleven
```

The first two contain an illegal character, either a dot or a dash. The last name is illegal because it starts with a digit.

Reserved Words

B.12 Some words, such as the word `if`, have a special predefined meaning in the Java language. You cannot use these words, called **reserved words** or **keywords**, for anything other than their intended meaning. A full list of reserved words for Java is given on the inside cover of this book. Within a programming environment, the names of reserved words are often highlighted in some way. In this book, they will appear in boldface.

Some other words, such as `String`, name classes that are supplied with Java. They have a predefined meaning but are not reserved words. This means that you can change their meaning, but doing so could easily confuse you or somebody else reading your program.

Variables

B.13 A **variable** in a program represents a memory location that stores data such as numbers and letters. The number, letter, or other data item in a variable is called its **value**. This value can be changed, so that at one time the variable contains, say, 6, and at another time after the program has run for a while, the variable contains a different value, such as 4.

You use an identifier to name a variable. Besides following the rules and conventions for identifiers, you should choose variable names that suggest their use or the kind of data they will hold. For example, if a variable is used to count something, you might name the variable `count`. If the variable is used to hold the speed of an automobile, you might call the variable `speed`. You should almost never use single-letter variable names like `x` and `y`. Also by convention, variable names begin with a lowercase letter.

B.14 A variable's **data type**—or simply **type**—determines what kind of value the variable can hold. If the type is `int`, the variable can hold integers. If the type is `double`, the variable can hold numbers with a decimal point and a fractional part after the decimal point. If the type is `char`, the variable can hold any one character from the computer keyboard.

Java has two kinds of types, primitive types and reference types. A **primitive type** represents simple, indecomposable values, such as a single number or a single letter. The types `int`, `double`, and `char` are primitive types. A **reference type** represents a **reference**, or a memory address, instead of the actual item stored at that address. A **class type**—which is a type for objects of a class—is a reference type. For example, `String` is a class type. A variable of a reference type is called a **reference variable**. A second kind of reference type is an **array type**. We will discuss arrays in Segment B.86.

Note: Naming conventions help you to distinguish among identifiers when reading a program. By convention, variables begin with a lowercase letter, as do the names of primitive types. The names of class types begin with an uppercase letter.

B.15 A **variable declaration** indicates the type of data the variable will hold. Different types of data are stored in the computer's memory in different ways. Variable declarations are necessary so that the value of a variable can be correctly stored in or retrieved from the computer's memory. Even though the mechanisms for storing values in the variables of class types differ from the mechanisms used for primitive types, you declare variables for class types and primitive types in the same way.

You declare a variable by writing a type name followed by a list of variable names separated by commas and ending with a semicolon. All the variables named in the list will have the type given at the start of the declaration. For example:

```
int numberOfBaskets, eggsPerBasket, totalEggs;
String myName;
```

The first line declares that the three variables `numberOfBaskets`, `eggsPerBasket`, and `totalEggs` will contain values of type `int`. The second line declares that `myName` will store a `String` object.

You must declare a variable in a Java program before you use it. Normally, you declare a variable either just before it is used or at the start of a method definition.

Primitive Types

B.16 A whole number without a decimal point, such as 0, 1, or −2, is called an **integer**. A number with a decimal point, such as 3.14159, −8.63, or 5.0, is called a **floating-point number**. Notice that 5.0 is a floating-point number, not an integer. If a number has a fractional part, even if the fractional part is zero, it is a floating-point number.

All the Java primitive types appear inside the cover of this book. Notice that there are four types for integers—namely `byte`, `short`, `int`, and `long`. The only difference among the various integer types is the range of integers they can store and the amount of computer memory they use. If you cannot decide which integer type to use, use the type `int`. It has a large enough range for most purposes and does not use as much memory as the type `long`.

Java has two types for floating-point numbers, `float` and `double`. If you cannot decide between the types `float` and `double`, use `double`. It allows a wider range of values and is used as a default type for floating-point numbers.

You use the primitive type `char` for single characters, such as letters, digits, or punctuation. For example, the following declares the variable `symbol` to be of type `char`, stores the character for uppercase *A* in `symbol`, and then displays that value—the *A*—on the screen:

```
char symbol;
symbol = 'A';
System.out.println(symbol);
```

Notice that we enclose the character *A* in single quotes. Again note that uppercase letters and lowercase letters are different characters. For example, `'a'` and `'A'` represent two different characters.

Finally, the primitive type `boolean` has two values, true and false. You can use a variable of type `boolean` to store the answer to a true/false question such as "Is `myTime` less than `yourTime`?"

Constants

B.17 A variable can have its value changed; its value *varies*. A literal number like 2 cannot change. It is always 2. It is never 3. Values like 2 or 4.8 are called **constants**, or **literals**, because their values do not change.

You write constants of integer types with an optional plus sign or minus sign, but without commas or decimal points. Floating-point constants have an optional plus sign or a minus sign and no commas. You can write a floating-point constant in one of two ways. One way looks like the everyday way of writing numbers. For example, `9.8`, `-3.14`, and `5.0` are floating-point constants, because they contain a decimal point. The second way is to include a multiplier that is a power of 10. You use the letter `e` to represent both the multiplication sign and the 10. For example, the number 8.65×10^8 appears in Java as `8.65e8` (or in the less convenient form `865000000.0`). The two forms, `8.65e8` and `865000000.0`, are equivalent in a Java program. Similarly, the number 4.83×10^{-4}, which is equal to 0.000483, can be written as `4.83e-4` in Java.

The `e` stands for "exponent," since it is followed by a number that is thought of as an exponent of 10. The number before the `e` can be a number with or without a decimal point. The number after the `e` cannot contain a decimal point.

Other types of literal expressions are also called constants. You write constants of type `char` by placing the character within single quotes. For example, `'Y'` is a constant of type `char`. A string constant is a sequence of characters enclosed in double quotes, as in `"Java"`.

Assignment Statements

B.18 You can use an **assignment statement** to give a value to a variable. For example, if `answer` is a variable of type `int` and we want to give it the value 42, we could use the following assignment statement:

```
answer = 42;
```

An assignment statement always consists of a single variable on the left-hand side of an equal sign and an expression on the right-hand side followed by a semicolon. The expression can be another variable, a constant, or a more complicated expression made up by combining **operators**, such as `+` and `*`, with variables and constants. The value of the expression is assigned to the variable on the left of the equal sign.

For example, the following are all examples of assignment statements:

```
amount = 3.99;
firstInitial = 'B';
score = numberOfCards + handicap;
```

Here we assume that `amount` is a variable of type `double`, `firstInitial` is of type `char`, and the rest of the variables are of type `int`. If the variable `numberOfCards` has the value 7 and `handicap` has the value 2, the value of the variable `score` is 9.

The equal sign, `=`, which is called the **assignment operator**, does not mean equality. You can think of the assignment operator as saying, "Make the value of the variable equal to what follows." For example, in the statement

```
eggsPerBasket = eggsPerBasket - 2;
```

the variable `eggsPerBasket` occurs on both sides of the assignment operator. This statement subtracts 2 from the present value of `eggsPerBasket` and assigns the new value to `eggsPerBasket`. In effect, the statement decreases the value of `eggsPerBasket` by 2.

B.19 A variable that has been declared but that has not yet been given a value by the program is **uninitialized**. Such a variable might literally have no value, or it might have some default value. For example, an integer variable might have a default value of zero, and a reference variable might have a default value of **`null`**, which is a predefined constant in Java. However, your program will be clearer if you explicitly give the variable a value, even if you are simply reassigning it the default value. (The exact details on default values have been known to change and should not be counted on.)

One easy way to ensure that you do not have an uninitialized variable is to initialize it within the declaration. Simply combine the declaration and an assignment statement, as in the following examples:

```
int count = 0;
double taxRate = 0.075;
char grade = 'A';
int balance = 1000, newBalance;
```

Note that a single declaration, such as the last statement, can initialize some variables and not others.

Sometimes the compiler may complain that you have failed to initialize a variable. In most cases, this is indeed true. Occasionally, the compiler is mistaken about this. However, the compiler will not compile your program until you convince it that the variable in question is initialized. To make the compiler happy, initialize the variable when it is declared, even if the variable will be given a different value before you use it for anything. In such cases, you cannot argue with the compiler.

Note: A reference variable that contains `null` does not reference any object.

Assignment Compatibilities

B.20 You cannot put a square peg in a round hole, and similarly you cannot put a value of one type in a variable of another type. You cannot put an `int` value like 42 in a variable of type `char`. You cannot put a `double` value like 3.5 in a variable of type `int`. You cannot even put the `double` value 3.0 in a variable of type `int`. You cannot store a value of one type in a variable of another type unless the value is somehow converted to match the type of the variable.

When dealing with numbers, however, this conversion will sometimes—but not always—be performed for you automatically. For example, you can always assign a value of an integer type to a variable of a floating-point type, such as when you write either

```
double interestRate = 7;
```

or

```
int wholeRate = 7;
double interestRate = wholeRate;
```

More generally, you can assign a value of any type on the following list to a variable of any type that appears further down on the list:

```
byte → short → int → long → float → double
```

For example, you can assign a value of type `long` to a variable whose type is either `long`, `float`, or `double`. Notice that you can assign a value of any integer type to a variable of any floating-point type. This is not an arbitrary ordering of the types. As you move down the list from left to right, the types become more complex, or **wider**, either because they allow larger values or because they allow decimal points in the numbers. Thus, you can assign a value of one type to a variable of either the same type or a wider type.

In addition, you can assign a value of type `char` to a variable of type `int` or to any of the numeric types that follow `int` in the previous list of types. However, we do not advise doing so, because the result could be confusing.[1]

If you want to assign a value of type `double` to a variable of type `int`, you must change the type of the value explicitly by using a type cast, as we explain next.

Type Casting

B.21 A **type cast** is the changing of the type of a value to some other type, such as changing the type of 2.0 from `double` to `int`. The previous segment described when a change in type is done for you automatically. In all other cases, if you want to assign a value of one type to a variable of another type, you must perform a type cast. For example, you cannot simply assign a value of type `double` to a variable of type `int`, even if the value of type `double` happens to have all zeros after the decimal point and so is conceptually a whole number. Thus, the second of the following statements is illegal:

```
double distance = 9.0;
int points = distance; // ILLEGAL
```

To cast the type of `distance` to `int`, you enclose `int` within parentheses and place it in front of `distance`. For example, we would replace the preceding illegal assignment with

```
int points = (int)distance; // Casting from double to int
```

Note that when you type-cast from any floating-point type to any integer type, the value is not rounded. The part after the decimal point is simply discarded, or **truncated**. For example, if the variable `distance` contains 25.86, `(int)distance` has an `int` value of 25. A type cast does not really change the value of a variable; `distance` is still 25.86, but `points` is 25.

Recall that when you assign an integer value to a variable of a floating-point type, the type cast is done automatically for you.

1. Readers who have used certain other languages, such as C or C++, may be surprised to learn that we cannot assign a value of type `char` to a variable of type `byte`. This is because Java uses the Unicode character set rather than the ASCII character set, and so Java reserves two bytes of memory for each value of type `char`, but naturally reserves only one byte of memory for values of type `byte`. This is one of the few cases where we might notice that Java uses the Unicode character set. Indeed, if we convert from an `int` to a `char` or vice versa, we can expect to get the usual correspondence of ASCII numbers and characters.

Note: When casting, some programmers place a space before the variable, as in `(int) sum`. We prefer to treat casting much like a minus sign. Just as we write minus five as –5, we cast `sum` to an integer by writing `(int)sum`.

Arithmetic Operators and Expressions

B.22 In Java, you perform arithmetic by using the **arithmetic operators** `+`, `-`, `*`, `/`, and `%`. You combine variables and constants with these operators and parentheses to form an **arithmetic expression**. The variables and constants in an expression are called **operands**. Spaces around the operators, operands, and parentheses within an expression are ignored.

A **unary operator** is one that has only one operand, like the operator `-` in the assignment statement

```
bankBalance = -cost;
```

A **binary operator** has two operands, like the operators `+` and `*` in

```
total = cost + (tax * discount);
```

Note that the operators `-` and `+` can be used as both unary and binary operators.

The meaning of an expression is basically what you expect it to be, but there are some subtleties about the type of the result and occasionally even about the value of the result. The type of the value produced when an expression is evaluated depends on the types of the values being combined. Consider an expression with only two operands, such as

```
amount - adjustment
```

If both `amount` and `adjustment` are of type `int`, the result of the subtraction has type `int`. If either `amount` or `adjustment`, or both, is of type `double`, the result is of type `double`. If we replace the operator `-` with any of the operators `+`, `*`, `/`, or `%`, the type of the result is determined in the same way. However, the operator `%` is typically used with integers, as you will see soon.

Larger expressions using more than two operands are viewed as a series of steps, each of which involves only two operands. For example, to evaluate the expression

```
balance + (balance * rate)
```

we evaluate `balance * rate` and obtain a number, and then we add that number to `balance`. Thus, if `balance` is `int` and `rate` is `double`, `balance * rate` is `double` and so is the entire expression.

Note: If all the items in an arithmetic expression have the same type, the result has that type. If at least one of the items has a floating-point type, the result has a floating-point type.

Knowing whether the value produced has an integer type or a floating-point type is typically all that you need. However, if you need to know the exact type of the value produced by an arithmetic expression, you can use the following rule:

Note: The data type of an arithmetic expression's value matches the most complex, or widest, data type among the operands in the expression. In other words, the data type matches the type that appears rightmost in the following list:

```
byte → short → int → long → float → double
```

For example, if `sum` is `float` and `more` is `int`, `sum + more` is `float`.

B.23 The division operator `/` deserves special attention, because the type of its operands can affect the value produced in a dramatic way. When you combine two numbers with the division operator `/` and at least one of the numbers has a floating-point type, the result has a floating-point type. For example, `9.0 / 2` has one operand of type `double`, namely `9.0`. Hence, the result is the type `double` number 4.5. However, when both operands have an integer type, the result can be surprising. For example `9 / 2` has two operands of type `int`, and so it yields the result 4 of type `int`, not 4.5. The fraction after the decimal point is simply lost. When you divide two integers, the result is truncated, *not* rounded. The part after the decimal point is discarded no matter how large it is. So, `11 / 3` is 3, not 3.6666 . . . . If nothing but a zero is after the decimal point, that decimal point and zero are still lost. Even this seemingly trivial difference can be of some significance. For example, `8.0 / 2` has the value 4.0 of type `double`, which technically is only an approximate quantity. However, `8 / 2` has the `int` value 4, which is an exact quantity. The approximate nature of 4.0 can affect the accuracy of any further calculation that is performed with this result.

Often, the `%` operator has operands only of integer types. You use it to recover the equivalent of the fraction after the decimal point. When you divide one integer by another, you get a result (which some call a quotient) and a remainder. For example, 14 divided by 4 yields 3 with a remainder of 2 (or with 2 left over). The `%` operation gives the remainder—that is, the amount left over after doing the division. So `14 / 4` is 3 and `14 % 4` is 2, because 14 divided by 4 is 3 with 2 left over. The `%` operator is called the **remainder operator**.

The `%` operator has more applications than you might at first suspect. It allows your program to count by 2s, 3s, or any other number. For example, if you want to do something to every other integer, you need to know whether the integer is even or odd. An integer `n` is even if `n % 2` is zero, and it is odd if `n % 2` is not zero. Similarly, if you want your program to do something to every third integer, you test whether the integer `n` is divisible by 3. It will be if `n % 3` is zero.

Programming Tip: To make your arithmetic expressions more readable, place a space on both sides of each binary operator.

Parentheses and Precedence Rules

B.24 You can use parentheses to group portions of an arithmetic expression in the same way that you use parentheses in algebra and arithmetic. With the aid of parentheses, you can indicate which operations are performed first, second, and so forth. For example, consider the following two expressions that differ only in the positioning of their parentheses:

```
(cost + tax) * discount
cost + (tax * discount)
```

To evaluate the first expression, the application first adds `cost` and `tax` and then multiplies the result by `discount`. To evaluate the second expression, it multiplies `tax` by `discount` and then adds the result to `cost`. If you use some numbers for the values of the variables and carry out the two evaluations, you will see that they produce different results.

If you omit parentheses, as in the assignment statement

```
total = cost + tax * discount;
```

multiplication occurs before addition. Thus, the previous statement is equivalent to

```
total = cost + (tax * discount);
```

More generally, when the order of operations is not determined by parentheses, the operations occur in an order determined by the following **precedence rule**:

Note: Precedence of arithmetic operators
Arithmetic operators in an expression execute in the order of their precedence, as follows:

- The unary operators `+`, `-`
- The binary operators `*`, `/`, `%`
- The binary operators `+`, `-`

Parentheses can override this order.

Operators that are listed higher on the list are said to have **higher precedence**. For example, unary operators have a higher precedence than binary operators, and binary operators have a **lower precedence** than unary operators. Operators of higher precedence execute before operators of lower precedence, unless parentheses override this order. Operators at the same level have the same precedence. When two operators have equal precedence, the operations are performed using the following convention:

Note: Binary operators of equal precedence in an expression are performed in left-to-right order.

Increment and Decrement Operators

B.25 The increment and decrement operators increase or decrease the value of a variable by 1. The **increment operator** is written as two plus signs, `++`. For example, the following Java statement will increase the value of the variable `count` by 1:

```
count++;
```

If the variable `count` has the value 5 before this statement is executed, it will have the value 6 after the statement is executed. Thus, this statement is equivalent to

```
count = count + 1;
```

You can use the increment operator with variables of any numeric type, but it is used most often with variables of an integer type such as `int`.

The **decrement operator** is similar, except that it subtracts 1 rather than adds 1 to the value of the variable. The decrement operator is written as two minus signs, `--`. For example, the following will decrease the value of the variable `count` by 1:

```
count--;
```

If the variable `count` has the value 5 before this statement is executed, it will have the value 4 after the statement is executed. This statement is equivalent to

```
count = count - 1;
```

B.26 You can use the increment and decrement operators within expressions, but when you do, the increment operator or the decrement operator changes the value of the variable it is applied to and returns a value. Although we do not recommend using the increment and decrement operators in expressions, you might see them used this way in code written by other developers.

In expressions, you can place the `++` or `--` either before or after a variable, but your choice affects the result. For example, consider the code

```
int n = 3;
int m = 4;
int result = n * (++m);
```

After this code executes, the value of `n` is unchanged at 3, the value of `m` is 5, and the value of `result` is 15. Thus, `++m` changes the value of `m` and returns that changed value to the multiply operator.

In the previous example, we placed the increment operator before the variable `m`. If we place it after the variable `m`, something slightly different happens. Consider the code

```
int n = 3;
int m = 4;
int result = n * (m++);
```

Now, after the code executes, the value of `n` is 3 and the value of `m` is 5, just as in the previous example. However, the value of `result` is 12, not 15, because `m++` returns the value of `m` to the multiply operator and then changes the value of `m`.

The two expressions `n * (++m)` and `n * (m++)` both increase the value of `m` by 1, but the first expression increases the value of `m` *before* it does the multiplication, whereas the second expression increases the value of `m` *after* it does the multiplication. Both `++m` and `m++` have the same effect on the final value of `m`, but when we use them as part of an arithmetic expression, they give a different value to the expression.

Similarly, both `--m` and `m--` have the same effect on the final value of `m`, but when we use them as part of an arithmetic expression, they give a different value to the expression. If the `--` is *before* the `m`, the value of `m` is decreased *before* its value is used in the expression. If the `--` is *after* the `m`, the value of `m` is decreased after its value is used in the expression.

The increment and decrement operators can be applied only to variables. They cannot be applied to constants or to entire, more complicated arithmetic expressions.

Programming Tip: To avoid errors and confusing code, use the operator `++` or `--` only in a statement that involves one variable and no other operators.

Special Assignment Operators

B.27 You can combine the simple assignment operator (`=`) with an arithmetic operator, such as `+`, to produce a kind of special-purpose assignment operator. For example, the following will increase the value of the variable `amount` by 5:

```
amount += 5;
```

This is really just a shorthand for

```
amount = amount + 5;
```

You can do the same thing with any of the other arithmetic operators `-`, `*`, `/`, and `%`. For example, the statement

```
amount *= 25
```

is equivalent to

```
amount = amount * 25;
```

Named Constants

B.28 You probably recognize the number 3.14159 as the approximate value of *pi*, the number that is used in many circle calculations and that is often written as π. However, when you see 3.14159, you might not be sure that it is π and not some other number; somebody other than you might have no idea of where the number 3.14159 came from. To avoid such confusion, you should always give a name to constants, such as 3.14159, and use the name instead of writing out the number. For example, we might give the number 3.14159 the name `PI`. Then the assignment statement

```
area = 3.14159 * radius * radius;
```

could be written more clearly as

```
area = PI * radius * radius;
```

How do you give a number, or other constant, a name like `PI`? You could use a variable named `PI` and initialize it to the desired value 3.14159. But then you might inadvertently change the value of this variable. However, Java provides a mechanism that allows you to define and initialize a variable and moreover fix the variable's value so it cannot be changed. The syntax is

`public static final` *type name* = *constant*;

For example, the statement

```
public static final double PI = 3.14159;
```

gives the name `PI` to the constant 3.14159. The part

```
double PI = 3.14159;
```

simply declares `PI` as a variable and initializes it to 3.14159. The word `public` says that there are no restrictions on where we can use the name `PI`. The word `static` defines one copy of `PI` that every object of the class can access instead of having its own copy of `PI`. The word `final` means that the value 3.14159 is the *final* value assigned to `PI` or, to phrase it another way, it means that the program cannot change the value of `PI`. Appendix C provides more details about `static` and `final`.

It is a good practice to place named constants near the beginning of a class and outside of any method definitions. That way, your named constants are handy in case you need to modify them. You might, for example, want to change the number of digits you provide for a constant.

Note: The class `Math` in the Java Class Library defines a static constant named `PI` just like the one we defined in this segment, but with more decimal places. The following segment describes this class and shows how to access `PI`. You should use `Math`'s PI instead of defining your own.

Programming Tip: Programmers typically use all uppercase letters when naming constants to distinguish constants from ordinary variables. They use an underscore as a separator in multi-word names. For example, `FEET_PER_MILE` follows this convention.

The Class `Math`

B.29 The class `Math` in the package `java.lang` of the Java Class Library provides a number of standard mathematical methods. These methods are static methods. (Segment C.28 of Appendix C discusses static methods in more detail.) When you invoke a static method, you write the class name—`Math`, in this case—a dot, the name of the method, and a pair of parentheses. Using the name of a class to invoke a method is not typical. Ordinarily, you use the name of an object to invoke a method.

Most `Math` methods require that you specify items within the pair of parentheses. As we noted earlier in this appendix, these items are called arguments to the method. Thus, a typical invocation of a method in this class has the form `Math.`*method_name*`(`*arguments*`)`.

You can invoke the method in an assignment statement, such as

variable `= Math.`*method_name*`(`*arguments*`);`

or embed it within an arithmetic expression. That is, you can use `Math.`*method_name*`(`*arguments*`)` anyplace that you can use a variable of a primitive data type. Figure B-2 describes some of the available methods in this class.

The class `Math` also has two predefined named constants. `E` is the base of the natural logarithm system—often written *e* in mathematical formulas—and is approximately 2.72. `PI` is used in calculations involving circular geometric figures—often written π in mathematical formulas—and is approximately 3.14159. Because these constants are defined in the class `Math`, you use them by writing `Math.E` and `Math.PI`.

Simple Input and Output Using the Keyboard and Screen

The input and output of data is usually referred to as **I/O**. A Java program can perform I/O in many different ways. In this section, we present some ways to handle simple text input that we type at the keyboard and simple text output displayed on the screen.

Screen Output

B.30 Statements like

```
System.out.println("Enter a whole number from 1 to 99.");
```

and

```
System.out.println(quarters + " quarters");
```

send output to the display screen. As we mentioned earlier in this appendix, `System.out` is an object within the class `System`, which is a class in the Java Class Library. This object has `println` as one of its methods. So the preceding output statements are calls to the method `println` of the object `System.out`. You simply follow `System.out.println` with a pair of parentheses that contain what you want to display. You end the statement with a semicolon.

Within the parentheses can be strings of text in double quotes, like `"Enter a whole number from 1 to 99."`, variables like `quarters`, numbers like `5` or `7.3`, and almost any other object or value. To display more than one thing, simply place a `+` operator between them. For example,

```
System.out.println("Lucky number = " + 13 +
                   "Secret number = " + number);
```

If the value of `number` is 7, the output will be

```
Lucky number = 13Secret number = 7
```

Notice also that no spaces are added. If we want a space between the 13 and the word "Secret" in the preceding output—and we probably do—we should add a space to the beginning of the string `"Secret number = "` so that it becomes `" Secret number = "`.

Notice that you use double quotes, not single quotes, and that the opening and closing quotes are the same symbol. Finally, notice that you can place the statement on two lines if it is too long.

FIGURE B-2 Some methods in the class `Math`

In each of the following methods, the argument and the return value are `double:`

`Math.cbrt(x)`	Returns the cube root of x.
`Math.ceil(x)`	Returns the nearest whole number that is $\geq x$.
`Math.cos(x)`	Returns the trigonometric cosine of the angle x in radians.
`Math.exp(x)`	Returns e^x.
`Math.floor(x)`	Returns the nearest whole number that is $\leq x$.
`Math.hypot(x, y)`	Returns the square root of the sum $x^2 + y^2$.
`Math.log(x)`	Returns the natural (base e) logarithm of x.
`Math.log10(x)`	Returns the base 10 logarithm of x.
`Math.pow(x, y)`	Returns x^y.
`Math.random()`	Returns a random number that is ≥ 0 but < 1.
`Math.sin(x)`	Returns the trigonometric sine of the angle x in radians.
`Math.sqrt(x)`	Returns the square root of x, assuming that $x \geq 0$.
`Math.tan(x)`	Returns the trigonometric tangent of the angle x in radians.
`Math.toDegrees(x)`	Returns an angle in degrees equivalent to the angle x in radians.
`Math.toRadians(x)`	Returns an angle in radians equivalent to the angle x in degrees.

In each of the following methods, the argument and the return value have the same type–either `int`, `long`, `float`, or `double:`

`Math.abs(x)`	Returns the absolute value of x.
`Math.max(x, y)`	Returns the larger of x and y.
`Math.min(x, y)`	Returns the smaller of x and y.

`Math.round(x)`	Returns the nearest whole number to x. If x is `float`, returns an `int`; if x is `double`, returns a `long`.

However, you should break the line before or after a + operator, not in the middle of a quoted string or a variable name. You also should indent the second line to make the entire statement easier to read.

Later, in the section about the class `String`, you will see that the + operator joins, or **concatenates**, two strings. In the preceding `System.out.println` statement, Java converts the number 13 to the string `"13"`. Likewise, it converts the integer 7 in the variable `number` to the string `"7"`. Then the + operator joins the strings and the `System.out.println` statement displays the result. You do need to be a bit careful, however. If you write a + between two numeric values or variables, they will be added rather than concatenated.

You can also use the `println` method to display the value of a `String` variable, as illustrated by the following:

```
String greeting = "Hello Programmers!";
System.out.println(greeting);
```

This will cause the following to be written on the screen.

```
Hello Programmers!
```

B.31 Every invocation of `println` ends a line of output. If you want the output from two or more output statements to appear on a single line, use `print` instead of `println`. For example,

```
System.out.print("One, two,");
System.out.print(" buckle my shoe.");
System.out.println(" Three, four,");
System.out.println("shut the door.");
```

will produce the following output:

```
One, two, buckle my shoe. Three, four,
shut the door.
```

Notice that a new line is not started until you use `println`, rather than `print`. Also notice that the new line starts *after* displaying the items specified in the `println` statement. This is the only difference between `print` and `println`.

Keyboard Input Using the Class Scanner

B.32 A Java program can read data from either the keyboard or another source such as a disk, and place it into memory. The Java Class Library provides the class `Scanner` for this purpose. Here, we will use the methods in `Scanner` to read data typed at the keyboard and place it into variables that we specify.

As we noted earlier, the class `Scanner` is in the package `java.util`. To use `Scanner` in your program, you must **import** it from this package by writing the following `import` statement before the rest of your program:

```
import java.util.Scanner;
```

Before you can use any of the methods in `Scanner`, you must create a `Scanner` object by writing a statement such as

```
Scanner keyboard = new Scanner(System.in);
```

The variable `keyboard`—which could be any variable of your choosing—is assigned a `Scanner` object that is associated with the input device that `System.in` represents. This device by convention is the keyboard. The variable `keyboard` has a class type.

B.33 `Scanner` provides several methods that read input data. You can use any of these methods by writing a statement that has the following form, where `keyboard` is the `Scanner` object that we defined previously:

variable = `keyboard.`*method_name*`();`

The named method reads a value from the keyboard and returns it. That is, the expression `keyboard.`*method_name*`()` represents the value that was read. The previous statement then assigns this value to the indicated variable.

You can read integers and real numbers by using the following expressions:

`keyboard.nextInt()`— Returns the next integer encountered in the input data.

`keyboard.nextDouble()`— Returns the next real number encountered in the input data.

Each of these expressions ignores any **white space** that might precede or follow the number typed at the keyboard. White-space characters are the characters that appear as spaces when printed on paper or displayed on the screen. The blank-space character is likely the only white-space character that will concern us at first, but the start of a new line and the tab symbol are also white-space characters.

B.34 **Example.** To read an integer from the keyboard, you can write a statement such as

```
size = keyboard.nextInt();
```

where `size` has been declared previously as an `int` variable. The user of your program would type an integer and press the Enter, or Return, key. The value is read by the method `nextInt`, returned, and assigned to the variable `size`.

Typically, you should display a message, or **prompt**, for the user to enter data. For example, your program might contain the following statements:

```
System.out.println("What is your age?");
int age = keyboard.nextInt();
```

Whatever the user types appears in the same window as the prompt. Here, the prompt would appear on one line and the user would type his or her age on the next.

B.35 **Example.** To read a real number from the keyboard, you can write statements such as

```
System.out.print("Enter the area of your room in square feet: ");
double area = keyboard.nextDouble();
```

After the user types a real number at the keyboard and presses the Enter key, the value of the number is assigned to the variable `area`. Since we have used `print` instead of `println`, both the prompt and the input data appear on the same line on the display.

B.36 **Example.** You can read more than one value per line of input. For example,

```
System.out.println("Please enter your height in feet and inches:");
int feet = keyboard.nextInt();
int inches = keyboard.nextInt();
```

The user could type either

```
6 2
```

on one line or

```
6
2
```

on two lines. In either case, `feet` is 6 and `inches` is 2.

Note: Streams
The characters that a user types at the keyboard are directed into the memory assigned to your program by an object known as an **input stream**. The name of the input stream associated with the keyboard is `System.in`. Likewise, an **output stream** is an object that directs data from your program to an output device. `System.out` is such an object, directing characters to a display.

B.37 **More input methods.** The class `Scanner` includes the following method to read a string:

`nextLine()`— Returns the string that appears next in the input data.

For example, if `keyboard` is defined as shown earlier, the statement

```
String message = keyboard.nextLine();
```

reads the entire string that the user types before pressing the Enter key—including any spaces—and assigns it to the variable `message`.

The method `next` in the class `Scanner` reads the next group of contiguous characters that are not white space and returns it as a string. For example, you can use this method to read the next word that appears in the input data, as follows:

```
String word = keyboard.next();
```

We used `next` in Segment B.3 to read the user's yes or no response.

The `Scanner` methods we've looked at—`nextInt`, `nextDouble`, `nextLine`, and `next`—often are invoked in simple assignment statements, although that is not necessary. Since each method returns a value, you can call it within an arithmetic expression, for example.

The `if-else` Statement

B.38 In programs, as in everyday life, things can sometimes go in one of two different ways. If you have money in your checking account, some banks will pay you a little interest. On the other hand, if you have overdrawn your checking account, you will be charged a penalty. This might be reflected in the bank's accounting program by the following Java statement, known as an **`if-else` statement**:

```
if (balance >= 0)
   balance = balance + (INTEREST_RATE * balance) / 12;
else
   balance = balance - OVERDRAWN_PENALTY;
```

The two-symbol operator >= means "greater than or equal to" in Java. We use two symbols because the one-character symbol ≥ is not on the keyboard.

The meaning of an `if-else` statement is really just the meaning it would have if read as an English sentence. When your program executes an `if-else` statement, it first checks the expression in parentheses after the `if`. This expression must evaluate to either true or false. If it is true, the statement after the `if` is executed. If the expression is false, the statement after the `else` is executed. In the preceding example, if `balance` is positive or zero, the following action occurs:

```
balance = balance + (INTEREST_RATE * balance) / 12;
```

(We divide by 12 because the interest is for only 1 of 12 months.) On the other hand, if the value of `balance` is negative, the following is executed instead:

```
balance = balance - OVERDRAWN_PENALTY;
```

The indentation in the `if-else` statement is conventional as an aid in reading the statement; it does not affect the statement's meaning.

B.39 If you want to include more than one statement in either of the two portions of the `if-else` statement, you simply enclose the statements in braces, as in the following example:

```
if (balance >= 0)
{
   System.out.println("Good for you. You earned interest.");
   balance = balance + (INTEREST_RATE * balance) / 12;
}
else
{
   System.out.println("You will be charged a penalty.");
   balance = balance - OVERDRAWN_PENALTY;
} // end if
```

When you enclose several statements within braces, you get one larger statement called a **compound statement**. Compound statements are seldom used by themselves but often are used as substatements of a larger statement such as an `if-else` statement.

Programming Tip: Some programmers always use compound statements within other statements such as `if-else`, even when only a single statement appears between the braces. Doing so makes it easier to add another statement to the compound statement, but more importantly, it avoids the error that would occur if you forgot to add the braces. We encourage you to follow this convention, even though we do not always do so in this book to save space.

B.40 You can omit the `else` part. If you do, nothing happens when the tested expression is false. For example, if your bank does not charge an overdraft penalty, the statement would be the following, instead of the previous one:

```
if (balance >= 0)
{
   System.out.println("Good for you. You earned interest.");
   balance = balance + (INTEREST_RATE * balance) / 12;
} // end if
```

If `balance` is negative, the statement after the closing brace executes next.

Boolean Expressions

B.41 A **boolean expression** is an expression that is either true or false. The expression

```
balance >= 0
```

that we used in the previous `if-else` statement is an example of a simple boolean expression. Such expressions compare two things, like numbers, variables, or other expressions. Figure B-3 shows the various Java **comparison operators** you can use to compare two expressions.

FIGURE B-3 Java comparison operators

Math Notation	Name	Java Operator	Java Examples
≥	Greater than or equal to	`>=`	`points >= 60`
≤	Less than or equal to	`<=`	`expenses <= income`
>	Greater than	`>`	`expenses > income`
<	Less than	`<`	`pressure < max`

=	Equal to	`==`	`balance == 0`
			`answer == 'y'`

≠	Not equal to	`!=`	`income != tax`
			`answer != 'y'`

B.42 **Logical operators.** Often, when you write an `if-else` statement, you will want to use a boolean expression that is more complicated than a simple comparison. You can form more-complicated boolean expressions from simpler ones by joining expressions with either the Java version of "and," which is `&&`, or the Java version of "or," which is `||`. For example, consider the following:

```
if ((pressure > min) && (pressure < max))
   System.out.println("Pressure is OK.");
else
   System.out.println("Warning: Pressure is out of range.");
```

If the value of `pressure` is greater than `min`, *and* the value of `pressure` is less than `max`, the output will be

```
Pressure is OK.
```

Otherwise, the output is

```
Warning: Pressure is out of range.
```

Note that you *cannot* use a string of inequalities in Java, like the following:

`min < pressure < max` ⟵ **Illegal!**

Instead, you must express each inequality separately and connect them with `&&`, as follows:

```
(pressure > min) && (pressure < max)
```

The parentheses in the previous expression are not necessary, but we typically include them. The parentheses that surround the entire expression in an `if-else` statement are required, however.

The binary operators `&&` and `||` together with the unary operator ! are **logical operators**. We look at each of them next.

B.43 **The operator `&&`.** When you form a larger boolean expression by connecting two smaller expressions with `&&`, the entire larger expression is true provided that both of the smaller expressions are true. Thus, if at least one of `pressure > min` and `pressure < max` is false, the larger expression is false. Moreover, if the first part of the larger expression is false, the second part is ignored, since the larger expression must be false regardless of the value of the second part. For example, if `pressure` is less than `min`, we know that

```
(pressure > min) && (pressure < max)
```

is false without looking at `pressure < max`.

B.44 **The operator `||`.** You also can use `||` to form a larger boolean expression from smaller ones in the same way that you use `&&`, but with different results. The meaning is essentially the same as the English word "or." For example, consider

```
if ((salary > expenses) || (salary + savings > expenses))
   System.out.println("Solvent");
else
   System.out.println("Bankrupt");
```

If the value of `salary` is greater than the value of `expenses` *or* the value of `salary + savings` is greater than the value of `expenses`—or both—the output will be

```
Solvent
```

Otherwise, the output will be

```
Bankrupt
```

The entire larger expression is true if either of the smaller expressions is true. Moreover, if the first part of the larger expression is true, the second part is ignored, since the larger expression must be true regardless of the value of the second part. For example, if `salary` is greater than `expenses`, we know that

```
(salary > expenses) || (salary + savings > expenses)
```

is true without looking at `salary + savings > expenses`.

You use parentheses in expressions containing the `||` operator in the same way that you use them with `&&`.

Note: Short-circuit evaluation
When two boolean expressions are joined by either `&&` or `||`, the second expression is not evaluated if the value of the first expression implies the value of the entire expression. Such is the case if the first expression is false when the operator is `&&` or true when the operator is `||`. This behavior is known as the **short-circuit evaluation** of a boolean expression.

Besides saving execution time, short-circuit evaluation can prevent execution errors. For example, the following statement prevents a division by zero:

```
if ((count != 0) && (sum / count > minimum))
```

If `count` is zero, the expression `count != 0` is false. Thus, the expression `sum / count > minimum` is not evaluated, thereby avoiding the erroneous division.

B.45 **The operator `!`.** You can negate a boolean expression by preceding it with the operator !. For example, the expression

```
!(number >= min)
```

has the same meaning as the expression

```
number < min
```

In this case, you can and should avoid using `!`.

Sometimes, however, the use of `!` makes perfect sense. For example, if you have two strings that should be the same for normal processing to continue, you would compare them and issue a warning if they are not equal. Later, in the section about the class `String`, you will see that you use the `equals` method to compare two strings. For example,

```
stringOne.equals(stringTwo)
```

is true if the strings `stringOne` and `stringTwo` are equal. But if we want to know whether these strings are not equal, we could write

```
if (!stringOne.equals(stringTwo))
   System.out.println("Warning: The strings are not the same.");
```

The precedence of the boolean operators in relation to each other and to the arithmetic operators follows:

Note: Precedence of a selection of Java operators
Operators in the same expression execute in the order of their precedence, as follows:

- The unary operators +, -, !
- The binary arithmetic operators *, /, %
- The binary arithmetic operators +, -
- The comparison operators <, >, <=, >=
- The comparison operators ==, !=
- The logical operator &&
- The logical operator ||

Parentheses can override this order.

Nested Statements

B.46 Notice that an `if-else` statement contains smaller statements within it. These smaller statements can be any sort of Java statements. In particular, you can use one `if-else` statement within another `if-else` statement to get **nested** `if-else` statements, as illustrated by the following:

```
if (balance >= 0)
   if (INTEREST_RATE >= 0)
      balance = balance + (INTEREST_RATE * balance) / 12;
   else
      System.out.println("Cannot have a negative interest.");
else
   balance = balance - OVERDRAWN_PENALTY;
```

If the value of `balance` is greater than or equal to zero, the entire following `if-else` statement is executed:

```
if (INTEREST_RATE >= 0)
   balance = balance + (INTEREST_RATE * balance) / 12;
else
   System.out.println("Cannot have a negative interest.");
```

When writing nested `if-else` statements, you may sometimes become confused about which `if` goes with which `else`. To eliminate this confusion, you can add braces as follows:

```
if (balance >= 0)
{
   if (INTEREST_RATE >= 0)
      balance = balance + (INTEREST_RATE * balance) / 12;
   else
      System.out.println("Cannot have a negative interest.");
}
else
   balance = balance - OVERDRAWN_PENALTY;
```

Here, the braces are an aid to clarity but are not, strictly speaking, needed. In other cases, they are needed. While you should use indentation to indicate your intentions, remember that it is ignored by the compiler.

B.47 If you omit an `else`, things get a bit trickier. The following two `if-else` statements differ only in that one has a pair of braces, but they do not have the same meaning:

```
// First Version
if (balance >= 0)
{
   if (INTEREST_RATE >= 0)
      balance = balance + (INTEREST_RATE * balance) / 12;
}
else
   balance = balance - OVERDRAWN_PENALTY;
// Second Version
if (balance >= 0)
   if (INTEREST_RATE >= 0)
      balance = balance + (INTEREST_RATE * balance) / 12;
else
   balance = balance - OVERDRAWN_PENALTY;
```

In the second version, without braces, the `else` is paired with the second `if`, not the first one, as the indentation leads us to believe. Thus, the meaning is

```
// Equivalent to Second Version
if (balance >= 0)
{
   if (INTEREST_RATE >= 0)
      balance = balance + (INTEREST_RATE * balance) / 12;
   else
      balance = balance - OVERDRAWN_PENALTY;
}
```

To clarify the difference a bit more, consider what happens when `balance` is less than zero. The first version causes the following action:

```
balance = balance - OVERDRAWN_PENALTY;
```

However, the second version takes no action.

Note: In an `if-else` statement, each `else` is paired with the nearest previous unmatched `if`.

Programming Tip: Indentation within an `if-else` statement does not affect the action of the statement. For clarity, you should use indentation that matches the logic of the statement.

Multiway `if-else` Statements

B.48 Since an `if-else` statement has two outcomes, and each of these two outcomes can have an `if-else` statement with two outcomes, you can use nested `if-else` statements to produce any number of possible effects. Convention provides a standard way of doing this. Let's start with an example.

Suppose `balance` is a variable that holds your checking account balance and you want to know whether your balance is positive, negative (overdrawn), or zero. To avoid any questions about accuracy, let's assume that `balance` is of type `int`—that is, `balance` is the number of dollars in your account, with the cents ignored. To find out if your `balance` is positive, negative, or zero, you could use the following nested `if-else` statement:

```
if (balance > 0)
   System.out.println("Positive balance");
else if (balance < 0)
   System.out.println("Negative balance");
else if (balance == 0)
   System.out.println("Zero balance");
```

This is really an ordinary nested `if-else` statement, but it is indented differently than before. The indentation reflects the logic more clearly and is preferred. Although this is not a separate kind of `if-else` statement, we call this nested construction a **multiway `if-else` statement**.

When a multiway `if-else` statement is executed, the application tests the boolean expressions one after the other, starting from the top. When it finds the first true boolean expression, it executes the statement after the expression. The rest of the `if-else` statement is ignored. For example, if `balance` is greater than zero, the preceding statements will display

```
Positive balance
```

Exactly one of the three possible messages will be displayed, depending on the value of the variable `balance`.

B.49 The previous example has three possibilities, but you can have any number of possibilities by adding more `else-if` parts. In this example, the possibilities are **mutually exclusive**. That is, only one of the three possibilities can actually occur for any given value of `balance`. However, you can use any boolean expressions, even if they are not mutually exclusive. If more than one boolean expression is true, only the action associated with the first true boolean expression is executed. A multiway `if-else` statement never performs more than one action.

If none of the boolean expressions is true, nothing happens. However, it is a good practice to add an `else` clause—without any `if`—at the end, to be executed in case none of the boolean expressions is true. In fact, we can rewrite our previous example in this way. We know that if `balance` is neither positive nor negative, it must be zero. So we do not need the test

```
if (balance == 0)
```

Thus, we can and should write the previous `if-else` statement as

```
if (balance > 0)
   System.out.println("Positive balance");
else if (balance < 0)
   System.out.println("Negative balance");
else
   System.out.println("Zero balance");
```

The Conditional Operator *(Optional)*

B.50 To allow compatibility with older programming styles, Java includes an operator that is a notational variant on certain forms of the `if-else` statement. A **conditional operator expression** consists of a boolean expression followed by a question mark and two expressions separated by a colon. For example, the expression on the right side of the assignment operator in the following statement is a conditional operator expression:

```
max = (n1 > n2) ? n1 : n2;
```

The `?` and `:` together form a **ternary operator** that has three operands and is known as the **conditional operator**. If the boolean expression is true, the value of the first of the two expressions is returned; otherwise, the value of the second of the two expression is returned. Thus, the logic of this example is equivalent to

```
if (n1 > n2)
   max = n1;
else
   max = n2;
```

This book will not use conditional operator expressions, as they are less clear than equivalent `if-else` statements. If you decide to use them in your program, realize that not everyone will know their meaning.

The `switch` Statement

B.51 Multiway `if-else` statements can become unwieldy when you must choose from among many possible courses of action. If the choice is based on the value of an integer or character expression, the **`switch` statement** can make your code easier to read.

The `switch` statement begins with the word `switch` followed by an expression in parentheses. This expression is called the **controlling expression**. Its value must be of type `int`, `char`, `byte`, `short`, or `String`. The `switch` statement in the following example determines the price of a ticket according to the location of the seat in a theater. An integer code that indicates the seat location is the controlling expression:

```
int seatLocationCode;
< Code here assigns a value to seatLocationCode >
. . .
double price = -0.01;
switch (seatLocationCode)
{
   case 1:
      System.out.println("Balcony.");
      price = 15.00;
      break;
   case 2:
      System.out.println("Mezzanine.");
      price = 30.00;
      break;
   case 3:
      System.out.println("Orchestra.");
      price = 40.00;
      break;
   default:
      System.out.println("Unknown ticket code.");
      break;
} // end switch
```

The `switch` statement contains a list of cases, each consisting of the reserved word `case`, a constant, a colon, and a list of statements that are the actions for the case. The constant after the word `case` is called a **case label**. When the `switch` statement executes, the controlling expression—in this example, `seatLocationCode`—is evaluated. The list of alternative cases is searched until a case label that matches the current value of the controlling expression is found. Then the action associated with that label is executed. You are not allowed to have duplicate case labels, as that would be ambiguous.

If no match is found, the case labeled `default` is executed. The `default` case is optional. If there is no `default` case, and no match is found to any of the cases, no action takes place. Although the `default` case is optional, we encourage you to always use it. If you think your cases cover all the possibilities without a `default` case, you can insert an error message or an assertion as the `default` case. You never know when you might have missed some obscure case.

Notice that the action for each case in the previous example ends with a **break statement**. If you omit the break statement, the action just continues with the statements in the next case until it reaches either a break statement or the end of the switch statement. Sometimes this feature is desirable, but sometimes omitting the break statement causes unwanted results.

Note: The controlling expression in a switch statement provides an entry point to a case within the statement. Execution continues from this point until it reaches either a break statement or the end of the switch.

B.52 At times, you will want to take the same action in more than one case. You can list cases one after the other so that they all apply to the same action. In the following example, we have changed the seat location code to a character instead of an integer. A code of *B* or *b*, for example, indicates a balcony seat:

```
char seatLocationCode;
< Code here assigns a value to seatLocationCode >
. . .
double price = -0.01;
switch (seatLocationCode)
{
   case 'B':
   case 'b':
      System.out.println("Balcony.");
      price = 15.00;
      break;
   case 'M': case 'm':
      System.out.println("Mezzanine.");
      price = 30.00;
      break;
   case 'O': case 'o':
      System.out.println("Orchestra.");
      price = 40.00;
      break;
   default:
      System.out.println("Unknown ticket code.");
      break;
} // end switch
```

The first case, *B*, has no break statement; in fact, the case has no action statements at all. Execution continues with the case for *b*, as desired. Note that we have written the cases in two ways to show two common programming styles.

The controlling expression in a switch statement need not be a single variable. It can be a more complicated expression, but it must evaluate to a single value. The expression cannot indicate a range of values. That is, the expression cannot be a boolean expression like the ones you use in an if-else statement. Thus, if you want to take one action when the controlling expression has values from 1 to 10 and a second action for values from 11 to 20, you would need a case label for each value. In situations like this, a switch statement would be harder to write than an if-else statement.

Programming Tip: Omitting a break statement
If you test a program that contains a switch statement and it executes two cases when you expect it to execute only one case, you probably have forgotten to include a break statement where one is needed.

B.53 Our last example of a `switch` statement revises the previous ones to use strings as the case labels:

```
String seatLocationCode;
< Code here assigns a value to seatLocationCode >
. . .
double price = -0.01;
if (seatLocationCode != null)
{
   switch (seatLocationCode)
   {
      case "balcony":
         System.out.println("Balcony.");
         price = 15.00;
         break;
      case "mezzanine":
         System.out.println("Mezzanine.");
         price = 30.00;
         break;
      case "orchestra":
         System.out.println("Orchestra.");
         price = 40.00;
         break;
      default:
         System.out.println("Unknown ticket code.");
         break;
   } // end switch
} // end if
```

Because strings are objects, you must be careful that the value of the controlling expression is not `null`, as we have done here. You should also take care that the possible strings assigned to `seatLocationCode` match the case labels exactly. In this example, the labels use lowercase letters. To ensure that the value of the controlling expression uses lowercase letters, we can replace the beginning of the `switch` statement with

```
switch (seatLocationCode.toLowercase())
```

Segment B.76 later in this appendix will describe the `String` method `toLowercase` further.

Enumerations

B.54 To compute a student's quality-point average—also known as a grade-point average—a program could assign the number of quality points for a given letter grade to the `double` variable `qualityPoints`. You could use a `char` variable `grade` for the letter grade, but then it could contain any character, not just the letters *A*, *B*, *C*, *D*, and *F*. Instead, to restrict the contents of `grade` to the values you specify, you could declare it as an **enumerated data type**, or **enumeration**. An enumeration itemizes the values that a variable can have.

For example, the following statement defines `LetterGrade` as an enumeration:

```
enum LetterGrade {A, B, C, D, F}
```

`LetterGrade` behaves as a class type, so we can declare `grade` to have this type, as follows:

```
LetterGrade grade;
```

The items listed between the braces in the definition of `LetterGrade` are objects that `grade` can reference. These values behave as static constants. For example, you can write

```
grade = LetterGrade.A;
```

to assign `A` to `grade`. You qualify each of them with the name of the enumeration just as you qualify the constant `PI` with the name of its class `Math`. Assigning a value other than `A`, `B`, `C`, `D`, or `F` to `grade` will cause a syntax error.

Note: An enumeration is actually a class. Therefore, you cannot define an enumeration within a method. Instead, define enumerations outside of any method definitions, preferably near the beginning of your class. Also, note that no semicolon follows an enumeration's definition. Writing one, however, will not cause a syntax error; the semicolon will simply be ignored.

B.55 **Example.** You can use a `switch` statement with a variable whose data type is an enumeration. For example, if we define `LetterGrade` and `grade` as in the previous segment, the following `switch` statement assigns the correct number of quality points to the `double` variable `qualityPoints`:

```
switch (grade)
{
   case A:
      qualityPoints = 4.0;
      break;
   case B:
      qualityPoints = 3.0;
      break;
   case C:
      qualityPoints = 2.0;
      break;
   case D:
      qualityPoints = 1.0;
      break;
   case F:
      qualityPoints = 0.0;
      break;
   default:
      qualityPoints = -9.0;
} // end switch
```

Since the data type of the expression in the `switch` statement is an enumeration, the case labels are assumed to belong to that enumeration without qualification. In fact, writing

```
case LetterGrade.A: // Syntax error
```

for example, is a syntax error. However, if you need to reference one of the enumerated values elsewhere within the `switch` statement, you must qualify it.

Since we know that `grade` cannot have values other than those in the enumeration, a default case is unnecessary. However, if you choose to omit the default case, you must assign a value to `qualityPoints` prior to the `switch` statement to avoid a syntax error. Without this initialization, the compiler would think it possible for `qualityPoints` to remain uninitialized after the `switch` statement.

B.56 When the compiler encounters an enumeration, it creates a class that has several methods. Among them is the method `ordinal`, which you can use to access the **ordinal value** of an object within an enumeration. These values begin at zero. Thus, in `LetterGrade`, the ordinal values of `A` and `F` are 0 and 4, respectively. For example, if you have the following assignment:

```
LetterGrade yourGrade = LetterGrade.A;
```

the expression

```
yourGrade.ordinal()
```

returns 0. Likewise, the expression

```
LetterGrade.B.ordinal()
```

returns 1.

The method `equals` tests whether `yourGrade` is equal to a given object within the enumeration. For example, you might write

```
if (yourGrade.equals(LetterGrade.A))
   System.out.println("Congratulations, your grade is A!");
```

Finally, the static method `valueOf` takes a string and returns a matching object in a given enumeration. For example, the expression

```
LetterGrade.valueOf("A")
```

returns `LetterGrade.A`. The string passed to `valueOf` must match the name of the constant exactly.

Appendix C discusses enumerations further, beginning at Segment C.30.

Scope

B.57 The **scope** of a variable (or a named constant) is the portion of a program in which the variable is available. That is, a variable does not exist outside of its scope. A variable's scope begins at its declaration and ends at the closing brace of the pair of braces that enclose the variable's declaration.

For example, consider the following statements that involve two variables, `counter` and `greeting`:

```
{
   // counter and greeting are not available here
   . . .
   int counter = 1;
   // counter is available here
   . . .
   {
      String greeting = "Hello!";
      // Both greeting and counter are available here
      . . .
   } // end scope of greeting
   . . .
   // Only counter is available here
   . . .
} // end scope of counter
```

The variable `counter` is available anywhere after its declaration. The variable `greeting` is available only within the inner pair of braces.

The concept of scope applies to every pair of braces within a Java program, regardless of whether they delineate the definition of a class or a method, appear within an `if-else` statement or `switch` statement, or appear within the loops described in the next section.

Loops

B.58 Programs often need to repeat some action. For example, a grading program would contain some code that assigns a letter grade to a student based on the student's scores on assignments and exams. To assign grades to the entire class, the program would repeat this action for each student in the class. A portion of a program that repeats a statement or group of statements is called a **loop**. The statement (or group of statements) to be repeated in a loop is called the **body** of the loop. Each repetition of the loop body is called an **iteration** of the loop.

When you design a loop, you need to decide what action the body of the loop should take and when the loop should stop repeating this action. Once you have made these choices, you can pick one of three Java statements to implement the loop: the `while` statement, the `for` statement, or the `do-while` statement.

The `while` Statement

B.59 One way to construct a loop in Java is with a **`while` statement**, which is also known as a **`while` loop**. A `while` statement repeats its action again and again until a controlling boolean expression becomes false. That is, the loop is repeated *while* the controlling boolean expression is true. The general form of a `while` statement is

```
while (expression)
   statement;
```

The `while` loop starts with the reserved word `while` followed by a boolean expression in parentheses. The loop body is a statement, typically a compound statement enclosed in braces `{}`. The loop body is repeated while the boolean expression is true. The loop body normally contains some action that can change the value of the boolean expression from true to false and so end the loop.

For example, the following `while` statement displays the integers from 1 to a given integer `number`:

```
int number;
. . . // Assign a value to number here
int count = 1;
while (count <= number)
{
   System.out.println(count);
   count++;
} // end while
```

Let's suppose that `number` is 2. Since the variable `count` begins at 1, the boolean expression `count <= number` is true at this point, and so the body of the loop executes. Thus, 1 is displayed and then `count` becomes 2. The expression `count <= number` is still true, so the loop's body executes a second time, displaying 2 and incrementing `count` to 3. Now `count <= number` is false, so the `while` loop ends. Execution continues with the statement, if any, that follows the loop.

Notice that if `number` is zero or negative in the previous example, nothing is displayed. The body of the loop would not execute at all, since `count`, which is 1, would be greater than `number`.

Programming Tip: A `while` loop can perform zero iterations
The body of a `while` loop can execute zero times. When a `while` loop executes, its first action is to check the value of the boolean expression. If the boolean expression is false, the loop body is not executed even one time. Perhaps the loop adds up the sum of all your expenses for the day. If you did not go shopping on a given day, you do not want the loop body to execute at all.

B.60 **Infinite loops.** A common program bug is a loop that does not end but simply repeats its loop body again and again. A loop that iterates its body repeatedly without ever ending is called an **infinite loop**. Normally, a statement in the body of the loop will change some variables so that the controlling boolean expression becomes false. If this variable does not change in the right way, you can get an infinite loop.

For instance, let's consider a slight variation to the previous example of a `while` loop. If we forget to increment `count`, the boolean expression will never change and the loop will be infinite:

```
int count = 1;
while (count <= number)
{
   System.out.println(count);
} // end while
```

Some infinite loops will not really run forever but will instead end your program abnormally when a system resource is exhausted. However, some infinite loops will run forever if left alone. To end a program that is in an infinite loop, you should learn how to force a program to stop running. The way to do this depends on your particular operating system. For example, in a Unix operating system, you would press the key combination Control-C.

Sometimes a programmer might intentionally write an infinite loop. For example, an ATM machine would typically be controlled by a program with an infinite loop that handles deposits and withdrawals indefinitely. However, at this point in your programming, an infinite loop is likely to be an error.

The `for` Statement

B.61 When a counter controls the number of iterations in a `while` loop, you can replace the `while` statement with a **`for` statement**, or **`for` loop**. The `for` statement has the following general form:

```
for (initialize; test; update)
   statement;
```

Here *initialize* is an optional assignment of a value to a variable, *test* is a boolean expression, and *update* is an optional assignment that can change the value of *test*.

For example, the following `for` statement is exactly equivalent to the `while` statement in Segment B.59:

```
int count, number;
. . . // Assign a value to number here
for (count = 1; count <= number; count++)
   System.out.println(count);
```

The first of the three expressions in parentheses, `count = 1`, initializes the counter before the loop body is executed for the first time. The second expression, `count <= number`, is a boolean expression that determines whether the loop should continue execution. This boolean expression is tested immediately after the first expression executes and again after each execution of the third expression. The third expression, `count++`, executes after each iteration of the loop body. Thus, the loop body is executed while `count <= number` is true.

In the previous example, we declared `count` before the `for` statement. After the loop completes its execution, `count` is still available as a variable. We could instead declare `count` within the `for` statement, as follows:

```
int number;
. . . // Assign a value to number here
for (int count = 1; count <= number; count++)
   System.out.println(count);
```

In this case, `count` is defined only within the `for` loop and is not available after the loop completes its execution.

Programming Tip: Although declaring a variable within a `for` statement is convenient, realize that the variable's scope is then the `for` loop. The variable is not available after the loop completes its execution.

The counter in a `for` statement is not restricted to an integer type. It can have any primitive type. You can omit any of the expressions *initialize*, *test*, and *update* from a `for` statement, but you cannot omit their semicolons. Sometimes it is more convenient to write the *initialize* part before the `for` statement or to place the *update* part within the body of the loop. This is especially true when these parts are lengthy. Although you technically can omit the *test* from a `for` loop, you will get an infinite loop if you do.

Some Java programmers tend to favor the `for` statement over the `while` statement because in the `for` statement the initialization, testing, and incrementing of the counter all appear at the beginning of the loop. This tendency is especially true for loops that simply count. For more complex logic, a `while` loop is often more appropriate.

Note: A `for` statement is basically another notation for a kind of `while` loop. Thus, like a `while` loop, a `for` statement might not execute its loop body at all.

B.62 **The comma in `for` statements.** A `for` loop can perform more than one initialization. To use a list of initialization actions, separate the actions with commas, as in the following example:

```
int n, product;
for (n = 1, product = 1; n <= 10; n++)
   product = product * n;
```

This `for` loop initializes `n` to 1 and `product` to 1. Note that you use a comma, not a semicolon, to separate the initialization actions.

You can have multiple update actions that are separated by commas. This can sometimes lead to a situation in which the `for` statement has an empty body and still does something useful. For example, we can rewrite the previous `for` statement in the following equivalent way:

```
for (n = 1, product = 1; n <= 10; product = product * n, n++);
```

In effect, we have made the loop body part of the update action. Notice the semicolon at the end of the statement. Since a semicolon at the end of a `for` statement is often the result of a programming error, a clearer way to write this loop makes the empty body explicit:

```
for (n = 1, product = 1; n <= 10; product = product * n, n++)
{
} // end for
```

However, the most readable style uses the update action only for variables that control the loop, as in the original version of this `for` loop.

Finally, you cannot have multiple boolean expressions to test for ending a `for` loop. However, you can string together multiple tests by using the `&&` and `||` operators to form one larger boolean expression.

Programming Tip: If you have used other programming languages that have a general-purpose comma operator, be warned that the comma operator in Java can appear only in `for` statements.

B.63 **Using an enumeration with a `for` statement.** The `for` statement has another form when you want to repeat statements for each object in an enumeration. For example, if you define

```
enum Suit {CLUBS, DIAMONDS, HEARTS, SPADES}
```

the `for` loop

```
for (Suit nextSuit : Suit.values())
   System.out.println(nextSuit);
```

displays

```
CLUBS
DIAMONDS
HEARTS
SPADES
```

You declare a variable to the left of a colon in the `for` statement. To the right of the colon, you represent the values that the variable will have. For the enumeration `Suit`, the expression `Suit.values()` represents the four possible values `CLUBS`, `DIAMONDS`, `HEARTS`, and `SPADES`. As the loop executes, `nextSuit` takes on each of these values.

This kind of loop—called a **for-each loop**—can be used with other collections of data, as you will see.

The `do-while` Statement

B.64 The **`do-while` statement**, or **`do-while` loop**, is similar to the `while` statement, but the body of a `do-while` statement always executes at least once. As you saw earlier, the body of a `while` loop might not execute at all.

The general form of a `do-while` statement is

```
do
   statement;
while (expression);
```

The `do-while` loop starts with the reserved word `do`. The loop body is a statement, typically a compound statement enclosed in braces `{}`. The loop ends with the reserved word `while` followed by a boolean expression in parentheses and a semicolon.

Programming Tip: Be sure to include a semicolon at the end of a `do-while` statement.

The loop body executes and is repeated while the boolean expression is true. The loop body normally contains some action that can change the value of the boolean expression from true to false and so end the loop. The boolean expression is tested at the end of the loop, not at its beginning, as it is in a `while` statement. Thus, the loop body executes at least once even if the boolean expression starts out false.

The following `do-while` statement displays the integers from 1 to a given integer `number`:

```
int number;
. . . // Assign a value to number here
int count = 1;
do
{
   System.out.println(count);
   count++;
} while (count <= number);
```

Again, let's suppose that `number` is 2. The variable `count` begins at 1 and is displayed. Next, `count` is incremented to 2. Since the expression `count <= number` is true at this point, the body of the loop executes again. The value of `count` (2) is displayed, and then `count` becomes 3. The expression `count <= number` is now false, so the `do-while` loop ends. Execution continues with the statement that follows the loop.

If `number` is zero or negative in the previous example, 1 is displayed, since the body of the loop executes at least once. If `number` can possibly be zero or negative, we should use either a `while` loop or a `for` loop here instead of a `do-while` loop.

Notice that we placed the ending brace and the `while` on the same line. Some programmers prefer to place them on different lines. Either form is fine, but be consistent.

To better understand a `do-while` loop, let's rewrite the previous example in the following way:

```
int number;
. . . // Assign a value to number here
int count = 1;
{
   System.out.println(count);
   count++;
}
while (count <= number)
{
   System.out.println(count);
   count++;
}
```

When you compare the two versions, it is obvious that a `do-while` loop differs from a `while` loop in only one detail. With a `do-while` loop, the loop body is always executed at least once. With a `while` loop, the loop body might not execute at all.

Additional Loop Information

B.65 **Choosing a loop statement.** Suppose you decide that your program needs a loop. How do you decide whether to use a `while` statement, a `for` statement, or a `do-while` statement? You *cannot* use a `do-while` statement unless you are certain that the loop body should execute at least one time. If you are certain of this, a `do-while` statement is likely to be a good choice. However, more often than you might think, a loop requires the possibility that the body will not execute at all. In those cases, you must use either a `while` statement or a `for` statement. If it is a computation that changes some numeric quantity by some equal amount on each iteration, consider a `for` statement. If the `for` statement does not work well, use a `while` statement. The `while` statement is always a safe choice, since you can use it for any sort of loop. But sometimes one of the other alternatives is easier or clearer.

Programming Tip: A `while` loop can do anything that another loop can do.

B.66 **The `break` and `continue` statements in loops.** You can use the `break` statement in a `switch` statement or in any kind of loop statement. When the `break` statement executes in a loop, the immediately enclosing loop ends, and the remainder of the loop body is not executed. Execution continues with the statement after the loop.

Adding a `break` statement to a loop can make the loop more difficult to understand. Without a `break` statement, a loop has a simple, easy-to-understand structure. There is a test for ending the loop at the top (or bottom) of the loop, and every iteration will go to the end of the loop body. When you add a `break` statement, the loop might end because either the condition given at the top (or bottom) of the loop is false or the `break` statement has executed. Some loop iterations may go to the end of the loop body, but one loop iteration might end prematurely. Because of the complications they introduce, you should avoid `break` statements in loops. Some authorities contend that a `break` statement should never be used to end a loop, but virtually all programming authorities agree that they should be used at most sparingly.

The `continue` statement ends the current iteration of a loop. The loop continues with the next iteration. Using a `continue` statement in this way has the same problems as using a `break` statement. However, replacing an empty loop body with a `continue` statement is acceptable. For example, you can revise the loop at the end of Segment B.62, as follows:

```
for (n = 1, product = 1; n <= 10; product = product * n, n++)
   continue;
```

Programming Tip: In general, do not use `break` or `continue` statements within the body of a loop.

The Class `String`

B.67 Strings of characters, such as `"Enter the amount:"`, do not have a primitive type in Java. However, Java does provide a class, called `String`, that you use to create and process strings of characters. The string constant `"Enter the amount:"`, in fact, is a value of type `String`. The class `String` is part of the package `java.lang` in the Java Class Library.

A variable of type `String` can name one of these string values. The statement

```
String greeting;
```

declares `greeting` to be the name of a `String` variable, and the following statement sets the value of `greeting` to the `String` value `"Hello!"`:

```
greeting = "Hello!";
```

These two statements are often combined into one, as follows:

```
String greeting = "Hello!";
```

We now can display `greeting` on the screen by writing

```
System.out.println(greeting);
```

The screen will show

```
Hello!
```

Characters Within Strings

B.68 Most programming languages use the **ASCII** character set, which assigns a standard number to each of the characters normally used on an English-language keyboard. Java, however, uses the Unicode character set instead. The Unicode character set includes all the ASCII characters plus many of the characters used in languages that have an alphabet different from English. As it turns out, this is not likely to be a big issue if you are using an English-language keyboard. Normally, you can just program as if Java were using the ASCII character set, since the codes for the ASCII characters are the same in Unicode. The advantage of the Unicode character set is that it allows you to easily handle languages other than English. The disadvantage of the Unicode character set is that it requires two bytes to store each character, whereas the ASCII character set requires one.

B.69 **Escape characters.** Suppose we want to display the following line on the screen:

The word “Java” names a language and a drink!

This string contains quotes, so the statement

```
System.out.println("The word "Java" names a language and a drink!");
```

will not work: It produces a compiler error message. The problem is that the compiler sees

```
"The word "
```

as a perfectly valid quoted string. Then the compiler sees

```
Java"
```

which is not valid in the Java language. The compiler does not know that we mean to include the quote character as part of the string unless we tell it that we want to do so. We tell the compiler this by placing a backslash \ before the troublesome character, like so:

```
System.out.println("The word \"Java\" names a language and a drink!");
```

Some other special characters also need a backslash in order to be included in strings. They are listed in Figure B-4. These are often called **escape characters** because they escape from the usual meaning of a character in Java, such as the usual meaning of the double-quote character.

FIGURE B-4 Escape characters

`\"`	Double quote.
`\'`	Single quote (apostrophe).
`\\`	Backslash.
`\n`	New line. (Go to the beginning of the next line.)
`\r`	Carriage return. (Go to the beginning of the current line.)
`\t`	Tab. (Insert whitespace up to the next tab stop.)

It is important to note that each escape sequence is a single character, even though it is spelled with two symbols. So the string `"Say \"Hi\"!"` contains 9 characters, not 11.

To include a backslash in a string, you must write two backslashes. Displaying the string `"abc\\def"` on the screen would produce

abc\def

Writing the string with only one backslash, as in `"abc\def"`, is likely to produce the error message “Invalid escape character,” because `\d` is invalid.

The escape sequence `\n` indicates that the string starts a new line at the `\n`. For example, the statement

```
System.out.println("The motto is\nGo for it!");
```

will write the following to the screen

```
The motto is
Go for it!
```

You can include a single quote (apostrophe) inside a quoted string, such as `"How's this?"`, but you cannot write a single quote within single quotes. Thus, to define a single-quote character, you use the escape sequence \', as follows:

```
char singleQuote = '\'';
```

Concatenation of Strings

B.70 You can join two strings by using the + operator. Joining two strings together, end to end, to obtain a larger string is called **concatenation**. When + is used with strings, it is sometimes called the **concatenation operator**. For example, the statements

```
String greeting = "Hello";
String sentence = greeting + "my friend.";
System.out.println(sentence);
```

set the variable `sentence` to `"Hellomy friend."` and will write the following on the screen:

```
Hellomy friend.
```

No space separates the first two words, because no spaces are added when you concatenate two strings. If we want `sentence` to contain `"Hello my friend."`, we could change the assignment statement to

```
sentence = greeting + " my friend.";
```

Notice the space before the word "my."

You can concatenate any number of `String` objects by using the `+` operator. You can even concatenate a `String` object to any other type of object and get a `String` object as a result. Java can express any object as a string when you concatenate it to a string. For primitives like numbers, Java does the obvious thing. For example,

```
String solution = "The answer is " + 42;
```

will set the `String` variable `solution` to `"The answer is 42"`. This is so natural that it may seem as though nothing special is happening, but it does require a real conversion from one type to another. The Java literal `42` is an integer, whereas `"42"` is a string consisting of the two characters 4 and 2. Java converts the integer constant `42` to the string constant `"42"` and then concatenates the two strings `"The answer is "` and `"42"` to obtain the longer string

```
"The answer is 42".
```

Note: Every class has a method `toString` that Java uses to get a string representation of any object. If you do not define `toString` for a class that you write, the default `toString` will return a representation of an object's location in memory. Thus, you generally should provide your own `toString` method when you define a class. Appendixes C and D discuss this method in more detail.

You can also concatenate a single character to a string by using `+`. For example,

```
String label = "mile";
String pluralLabel = label + 's';
```

sets `pluralLabel` to the string `"miles"`.

Segment B.73 will show you another way to concatenate strings.

`String` Methods

Readers who need to review Java methods should consult Appendix C before reading this section.

B.71 A `String` object has methods as well as a value. You use these methods to manipulate string values. A few of these `String` methods are described here. You invoke, or call, a method for a `String` object by writing the object name, a dot, and the name of the method, followed by a pair of parentheses. Some methods require nothing within the parentheses, while others require that you specify arguments. Let's look at some examples.

B.72 **The method `length`.** The method `length` gets the number of characters in a string. For example, suppose we declare two `String` variables as follows:

```
String command = "Sit Fido!";  // 9 characters
String answer = "bow-wow";     // 7 characters
```

Now `command.length()` has the value 9 (it returns 9), and `answer.length()` returns 7. Notice that you must include a pair of parentheses, even though there are no arguments to the method `length`. Also notice that spaces, special symbols, and repeated characters are all counted in computing the length of a string. All characters except the double quotes that enclose the string are counted.

You can use a call to the method `length` anywhere that you can use a value of type `int`. For example, all of the following are legal Java statements:

```
int count = command.length();
System.out.println("Length is " + command.length());
count = answer.length() + 3;
```

B.73 **The method `concat`.** You can use the method `concat` instead of the `+` operator to concatenate two strings. For example, if we declare the `String` variables

```
String one = "sail";
String two = "boat";
```

the expressions

```
one + two
```

and

```
one.concat(two);
```

are the same string, *sailboat*.

B.74 **Indices.** Some of the methods in the class `String` refer to the positions of the characters in the string. Positions in a string start with 0, not with 1. Thus, in the string `"Hi Mom"`, *H* is in position 0, *i* is in position 1, the blank character is in position 2, and so forth. A position is usually referred to as an **index**. So it would be more normal to say that *H* is at index 0, *i* is at index 1, and so on. Figure B-5 illustrates how index positions are numbered in a string.

FIGURE B-5 Indices 0 through 11 for the string `"Java is fun."`

0	1	2	3	4	5	6	7	8	9	10	11
J	a	v	a		i	s		f	u	n	.

B.75 **The methods `charAt` and `indexOf`.** The method `charAt` returns the character at the index given as its one argument. For example, the statements

```
String phrase = "Time flies like an arrow.";
char sixthCharacter = phrase.charAt(5);
```

assign the character *f* to the variable `sixthCharacter`, since the *f* in *flies* is at index 5. (Remember, the first index is 0, not 1.)

The method `indexOf` tests whether a string contains a given substring and, if it does, returns the index at which the substring begins. Thus, `phrase.indexOf("flies")` will return 5 because the substring *flies* begins at index 5 within `phrase`.

Note: Out-of-bounds index
`String` methods such as `charAt` that take an index as an argument will cause an error during execution if the index is negative or too large. Such an index is said to be **out of bounds**. The error causes a `StringIndexOutOfBoundsException`. Java Interludes 2 and 4 discuss exceptions.

B.76 **Changing case.** The method `toLowerCase` returns a string obtained from its argument string by replacing any uppercase letters with their lowercase counterparts. Thus, if `greeting` is defined by

```
String greeting = "Hi Mary!";
```

the expression

```
greeting.toLowerCase()
```

returns the string `"hi mary!"`. An analogous method, `toUpperCase`, converts any lowercase letters in a string to uppercase. Note the capital *C* in `toLowerCase` and `toUpperCase`.

B.77 **The method `trim`.** The method `trim` trims off any leading and trailing white space, such as blanks. So the statements

```
String command = "   Sit Fido!    ";
String trimmedCommand = command.trim();
```

set `trimmedCommand` to the string `"Sit Fido!"`. The blanks between words are not affected.

B.78 **Comparing strings.** You use the method `compareTo` to compare two strings. Strings are ordered according to the Unicode values of their characters. This ordering—called **lexicographic ordering**—is analogous to alphabetic ordering. The expression

```
stringOne.compareTo(stringTwo)
```

returns a negative integer or a positive integer, depending on whether `stringOne` occurs before or after `stringTwo`. The expression returns zero if the two strings are equal.

The method `compareToIgnoreCase` behaves similarly to `compareTo`, except that the uppercase and lowercase versions of the same letter are considered to be equal. For example, the method `compareTo` places the string `"Hello"` before the string `"hello"`, but the method `compareToIgnoreCase` finds these strings to be equal.

Programming Tip: Do not use the operators `==`, `!=`, `<`, `<=`, `>`, or `>=` to compare the contents of two strings.

If you want only to see whether two strings are equal—that is, contain the same values—you can use the method `equals`. Thus,

```
stringOne.equals(stringTwo)
```

is true if `stringOne` equals `stringTwo` and is false if they are not equal. The method `equalsIgnoreCase` behaves similarly to `equals`, except that the uppercase and lowercase versions of the same letter are equal. For example, the method `equals` finds the strings `"Hello"` and `"hello"` unequal, but the method `equalsIgnoreCase` finds them equal.

Programming Tip: When applied to two strings (or to any two objects), the operator `==` tests whether they are stored in the same memory location. Sometimes that is sufficient, but if you want to know whether two strings that are in different memory locations contain the same sequence of characters, use the method `equals`.

The Class `StringBuilder`

B.79 Once you create a string object of the class `String`, you cannot alter it. But sometimes you would like to. For example, we might define the string

```
String name = "rover";
```

and then decide that we want to capitalize its first letter. We cannot. We could, of course, write

```
name = "Rover";
```

but this statement creates a new string *Rover* and discards *rover*.

The class `String` has no method that modifies a `String` object. However, the class `StringBuilder` in the package `java.lang` has methods such as the following:

> **`public`** `StringBuilder append(String s)`
> Concatenates the string `s` to the end of this string and returns a reference to the result.
>
> **`public`** `StringBuilder delete(`**`int`** `start,` **`int`** `after)`
> Removes the substring of this string beginning at the index `start` and ending at either the index `after - 1` or the end of the string, whichever occurs first, and returns a reference to the result. Throws `StringIndexOutOfBoundsException` if `start` is invalid.
>
> **`public`** `StringBuilder insert(`**`int`** `index, String s)`
> Inserts the string `s` into this string at the given index and returns a reference to the result. Throws `StringIndexOutOfBoundsException` if the index is invalid.
>
> **`public`** `StringBuilder replace(`**`int`** `start,` **`int`** `after, String s)`
> Replaces a substring of this string with the string `s`. The substring to be replaced begins at the index `start` and ends at either the index `after - 1` or the end of the string, whichever occurs first. Returns a reference to the result. Throws `StringIndexOutOfBoundsException` if `start` is invalid.
>
> **`public void`** `setCharAt(`**`int`** `index,` **`char`** `character)`
> Sets the character at the given index of this string to a given character. Throws `IndexOutOfBoundsException` if the index is invalid.

If you are not familiar with exceptions, think of them as error messages for now. Java Interludes 2 and 4 will explain them to you.

`StringBuilder` has other versions of the methods `append` and `insert` that take data of any type as arguments. While the classes `StringBuilder` and `String` have some methods in common, several methods in `String` are not in `StringBuilder`.

B.80 **Examples.** If we have the following instance of `StringBuilder`

```
StringBuilder message = new StringBuilder("rover");
```

we can capitalize its first letter by writing

```
message.setCharAt(0, 'R');
```

Now the statement

```
message.append(", roll over!");
```

changes `message` to the string *Rover, roll over!*, and

```
message.insert(7, "Rover, ");
```

changes it to *Rover, Rover, roll over!* Next,

```
message.delete(0, 7);
```

changes `message` to *Rover, roll over!*, and

```
message.replace(7, 16, "come here");
```

changes `message` to *Rover, come here!*

Each of the previous methods except `setCharAt` returns the result of the operation. So, for example, if we write

```
newMessage = message.append(", roll over!");
```

both `newMessage` and `message` reference the same sequence of characters.

Using Scanner to Extract Pieces of a String

B.81 Segments B.32 through B.37 show how the class `Scanner` is used to read data that a user types at the keyboard. Methods in `Scanner`—such as `nextInt`, `nextDouble`, and `next`—read a group of contiguous characters, or **token**, as an integer, a real number, or a string, respectively. When more than one token appears in the input data, they are separated by one or more characters known as **delimiters**. By default, `Scanner` uses white space as the delimiter.

In addition to reading data from the keyboard, you can use `Scanner` to process a string that you define within your program. You simply use the string instead of `System.in` when creating a `Scanner` object.

For example, the statements

```
String phrase = "one potato        two    potato three potato four";
Scanner scan = new Scanner(phrase);
System.out.println(scan.next());
System.out.println(scan.next());
System.out.println(scan.next());
System.out.println(scan.next());
```

display the words

```
one
potato
two
potato
```

We essentially have read tokens from a string instead of from the keyboard. The tokens here are separated by white space, the default delimiter.

B.82 **Specifying delimiters.** Whether you read characters from an input device such as a keyboard or from a string defined in your program, you can specify the delimiters that `Scanner` will use. The `Scanner` method `useDelimiter` sets the delimiters to those indicated in its string argument. For example, to use a comma as a delimiter, you would write

```
scan.useDelimiter(",");
```

where `scan` is a `Scanner` object. Thus, the statements

```
String data = "one,potato,two,potato";
Scanner scan = new Scanner(data);
scan.useDelimiter(",");
System.out.println(scan.next());
System.out.println(scan.next());
System.out.println(scan.next());
System.out.println(scan.next());
```

display the words

```
one
potato
two
optato
```

B.83 **Example.** To extract the words *one*, *two*, *three*, and *four* from the string `phrase` that we defined in Segment B.81, you would describe the delimiter as one or more blanks, the word *potato*, and one or more blanks. You use the notation in Figure B-6 to describe the delimiters. For example, `\s+` denotes one or more white-space characters. You must duplicate each backslash character in this notation when it appears between the quotes of a string literal to distinguish it from escape characters such as `\n`.

FIGURE B-6 Some notation used to define the delimiters that `Scanner` uses

`\d`	Any digit 0 through 9
`\D`	Any character other than a digit
`\s`	Any white-space character
`\S`	Any character other than white space
`\w`	Any letter, digit, or underscore
`\W`	Any character other than a letter, digit, or underscore
`-`	Any character
X	One occurrence of *X*
X?	Zero or one occurrence of *X*
*X**	Zero or more occurrences of *X*
X+	One or more occurrences of *X*
X{*n*}	Exactly *n* occurrences of *X*
X{*n*,}	At least *n* occurrences of *X*

The following statement sets the delimiter of the `Scanner` object `scan` to the word *potato* with leading and trailing white-space characters:

```
scan.useDelimiter("\\s+potato\\s+");
```

Thus, the statements

```
String phrase = "one potato two potato three potato four";
Scanner scan = new Scanner(phrase);
scan.useDelimiter("\\s+potato\\s+");
System.out.println(scan.next());
System.out.println(scan.next());
System.out.println(scan.next());
System.out.println(scan.next());
```

display the words

```
one
two
three
four
```

B.84 **Example.** The statements

```
String phrase = "5 potato        6potato 7 potato more";
Scanner scan = new Scanner(phrase);
scan.useDelimiter("\\s*\\d\\s*");
System.out.println(scan.next());
System.out.println(scan.next());
System.out.println(scan.next());
```

display the words

```
potato
potato
potato more
```

The delimiter is a digit with optional leading and trailing white space.

If you now write

```
scan = new Scanner(phrase);
scan.useDelimiter("\\s*potato\\s*");
System.out.println(scan.nextInt());
System.out.println(scan.nextInt());
System.out.println(scan.next());
System.out.println(scan.next());
```

you will get the following output

```
5
6
7
more
```

Here the delimiter is the word *potato* with optional leading and trailing white space.

B.85 **Example.** The statements

```
String phrase = "one - two   -    three four";
Scanner scan = new Scanner(phrase);
scan.useDelimiter("\\s+-?\\s*");
System.out.println(scan.next());
System.out.println(scan.next());
System.out.println(scan.next());
System.out.println(scan.next());
```

display the words

```
one
two
three
four
```

The delimiter is at least one white space character optionally followed by a dash and more white space.

Arrays

B.86 In Java, an array is a special kind of object that stores a finite collection of items having the same data type. For example, you can create an array of seven numbers of type `double` as follows:

```
double[] temperature = new double[7];
```

The left side of the assignment operator declares `temperature` as an array whose contents are of type `double`. The right side uses the `new` operator to request seven memory locations for the array. This is like declaring the following strangely named variables to have type `double`:

```
temperature[0], temperature[1], temperature[2], temperature[3],
temperature[4], temperature[5], temperature[6]
```

Note that the numbering starts with 0, not 1. Each of these seven variables can be used just like any other variable of type `double`. For example, we can write

```
temperature[3] = 32;
temperature[6] = temperature[3] + 5;
System.out.println(temperature[6]);
```

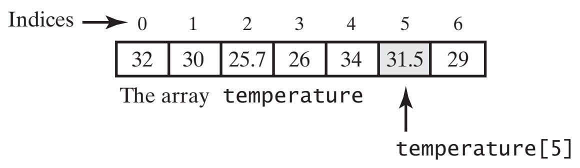
But these seven variables are more than just seven plain old variables of type `double`. The number in square brackets—called an **index**, or **subscript**—can be any arithmetic expression whose value is an integer. In this example, the index value must be between 0 and 6, because we declared the array `temperature` to have seven memory locations. A variable such as `temperature[3]` is called either an **indexed variable**, a **subscripted variable**, or simply an **element** of the array. The value in an indexed variable is called an **entry**, and its data type is the array's **entry type**.

For example, the following statements read seven temperatures into an array and compare them with their average:

```
public static final int DAYS_PER_WEEK = 7;
Scanner keyboard = new Scanner(System.in);
. . .
double[] temperature = new double[DAYS_PER_WEEK];

System.out.println("Enter " + DAYS_PER_WEEK + " temperatures:");
double sum = 0;
for (int index = 0; index < DAYS_PER_WEEK; index++)
{
   temperature[index] = keyboard.nextDouble();
   sum = sum + temperature[index];
} // end for

double average = sum / DAYS_PER_WEEK;

System.out.println("The average temperature is " + average);
System.out.println("The temperatures are");
for (int index = 0; index < DAYS_PER_WEEK; index++)
{
   if (temperature[index] < average)
      System.out.println(temperature[index] + " below average.");
   else if (temperature[index] > average)
      System.out.println(temperature[index] + " above average.");
   else // temperature[index] == average
      System.out.println(temperature[index] + " average.");
} // end for
```

Figure B-7 illustrates the array `temperature` after seven values have been read into it.

FIGURE B-7 An array of seven temperatures



Each location in the array `temperature` contains a temperature. That is, the array is full. But arrays are not always full. You need to distinguish between the number of locations in an array—its **length**—and the number of items currently stored in the array.

An array has a data field `length` that contains the declared number of elements in the array. For example, if we create an array by writing

```
int[] age = new int[50];
```

then `age.length` is 50. Notice that `length` is not a method, so no parentheses follow it. If we place only 10 values into the first 10 locations of this array, `age.length` is still 50. If we need to know how many values we place into an array, we will need to keep track of that ourselves.

Note: An array has a data type and an entry type
The data type of the previously defined array `age` is `int[]`, but its entry type is `int`.

Array Parameters and Returned Values

Readers who need to review Java methods should consult Appendix C before reading this section.

B.87 **Array parameters.** You can pass an indexed variable as an argument to a method anyplace that you can pass an ordinary variable of the array's entry type. For example, if a method has the header

```
public double compute(double value)
```

and `temperature` is the array of `double` values that we defined earlier, we can invoke the method by writing

```
double result = compute(temperature[3])
```

An entire array can also be a single argument to a method. For example, the following method

```
public static void incrementArrayBy2(double[] array)
{
   for (int index = 0; index < array.length; index++)
      array[index] = array[index] + 2;
} // end incrementArrayBy2
```

will accept any array of `double` values as its single argument. We declare the parameter `array` in the method's header just as we would declare any other array: by specifying the type of the array entries followed by square brackets. We do not specify the length of the array.

The following statement is an example of how we would invoke this method:

```
incrementArrayBy2(temperature);
```

You use no square brackets when you pass an entire array as an argument to a method. Notice that the method can take any length array as an argument. The method `incrementArrayBy2` adds 2 to each entry in the argument array `temperature`. That is, the method actually changes the values in the argument array.

Note: A method can change the values in an argument array. However, a method cannot replace an argument array with another array.

B.88 **Arrays as return values.** In Java, a method can return an array. For example, rather than modifying its array argument, the previous method `incrementArrayBy2` could return an array whose values are 2 more than the corresponding values in the array argument. You specify the method's return type in the same way that you specify a type for an array parameter. The method would then look like this:

```
public static double[] incrementArrayBy2(double[] array)
{
   double[] result = new double[array.length];
   for (int index = 0; index < array.length; index++)
      result[index] = array[index] + 2;
   return result;
} // end incrementArrayBy2
```

The following statements invoke this method:

```
double[] originalArray = new double[10];
< Statements that place values into originalArray >
. . .
```

```
double[] revisedArray = incrementArrayBy2(originalArray);
< At this point, originalArray is unchanged. >
```

Programming Tip: When a method returns an array that you want to assign to an array variable, you should declare the variable but not allocate memory for an array. For example, to invoke the method in the previous example, you do not write

```
double[] revisedArray = new double[10]; // WRONG!
revisedArray = incrementArrayBy2(originalArray);
```

The first statement allocates 10 locations for a new array, but these locations are discarded when the second statement executes.

Initializing Arrays

B.89 You can provide initial values for the elements in an array when you declare it. To do this, you enclose the values for the array in braces and place them after the assignment operator, as in the following example:

```
double[] reading = {3.3, 15.8, 9.7};
```

You do not explicitly state the array's length. Instead the length is the minimum number of locations that will hold the given values. This initializing declaration is equivalent to the following statements:

```
double[] reading = new double[3];
reading[0] = 3.3;
reading[1] = 15.8;
reading[2] = 9.7;
```

If you do not initialize the elements of an array, they are given initial default values according to their type. For example, if you do not initialize an array of integers, each element of the array will be initialized to zero. In an array of objects, each element is initialized to `null`. However, it is usually clearer to do your own explicit initialization, either when you declare the array or later by using a loop and assignment statements.

Array Index Out of Bounds

B.90 When programming with arrays, making a mistake with an index is easy. This is especially true if that index is an expression. If the array `temperature` has seven elements, but an index is some integer other than 0 through 6, the index is said to be out of bounds. An out-of-bounds index expression will compile without any error message, but will cause an error when you run your program. In particular, you will get an `IndexOutOfBoundsException`. As we mentioned in Segment B.75, a similar situation can occur when you work with strings. (Java Interludes 2 and 4 discuss exceptions.)

Use of = and == with Arrays

B.91 **The operator =.** Recall that a variable for an object really contains the memory address of the object. The same is true of arrays. All array locations are together in one section of memory so that one memory address can specify the location of the entire array. The assignment operator copies this memory address. For example, if `a` and `b` are arrays of the same size, the assignment `b = a` gives the array variable `b` the same memory address as the array variable `a`. In other words, `a` and `b` are two different names for the same array. These variables are **aliases**. Thus, when you change the value of `a[2]`, you are also changing the value of `b[2]`. Appendix C talks more about aliases and references.

If you want the array b to have the same values as the array a, but in separate memory locations, then instead of one assignment statement you must use a loop like the following one:

```
for (int index = 0; index < a.length; index++)
   b[index] = a[index];
```

B.92 **The operator ==.** The equality operator == tests two arrays to see if they are stored in the same place in the computer's memory. It does not test whether the arrays contain the same values. To do so, you must compare the two arrays entry by entry. For example, if the arrays a and b contain primitive values and have the same length, the following code could be used:

```
boolean match = true;
int index = 0;
while (match && (index < a.length))
{
   if (a[index] != b[index])
      match = false;
   else
      index++;
} // end while
if (match)
   System.out.println("Arrays have the same contents");
else
   System.out.println("Arrays have different contents");
```

If the arrays contained objects instead of primitive values, we would use the boolean expression `!a[index].equals(b[index])` instead of `a[index] != b[index]`.

Note: Are arrays really objects?
Arrays behave very much like objects. On the other hand, arrays do not belong to any class. Because arrays were used by programmers for many years before classes and objects (as we have used them) were invented, arrays use a special notation of their own. Other features of objects do not apply to arrays, such as inheritance (which we discuss in Appendix D). So whether or not arrays should be considered objects is primarily an academic debate. Whenever Java documentation says that something applies to all objects, it also applies to arrays.

Note: Array types are reference types
A variable of an array type holds only the address where the array is stored in memory. This memory address is often called a *reference* to the array object in memory. For this reason, an array type is a reference type. A reference type is any type whose variables hold references—that is, memory addresses—as opposed to the actual item named by the variable. Array types and class types are both reference types. Primitive types are not reference types.

Arrays and the For-Each Loop

B.93 Earlier in Segment B.63 we used a for-each loop to process all the values in an enumeration. We can use a similar for-each loop to process all the values in an array. For example, the following statements compute the sum of the integers in an array:

```
int[] anArray = {1, 2, 3, 4, 5};
int sum = 0;
```

```
for (int integer : anArray)
   sum = sum + integer;
System.out.println(sum);
```

Similarly, the following statements display all the strings in an array:

```
String[] friends = {"Gavin", "Gail", "Jared", "Jessie"};
for (String name : friends)
   System.out.println(name);
```

Multidimensional Arrays

B.94 You can have an array with more than one index. For example, suppose we wanted to store the dollar amounts shown in Figure B-8 in some sort of array. The bold items are just labeling. There are 60 entries. If we use an array with one index, the array will have a length of 60, and keeping track of which entry goes with which index would be almost impossible. On the other hand, if we allow ourselves two indices, we can use one index for the row and one index for the column. This arrangement is illustrated in Figure B-9.

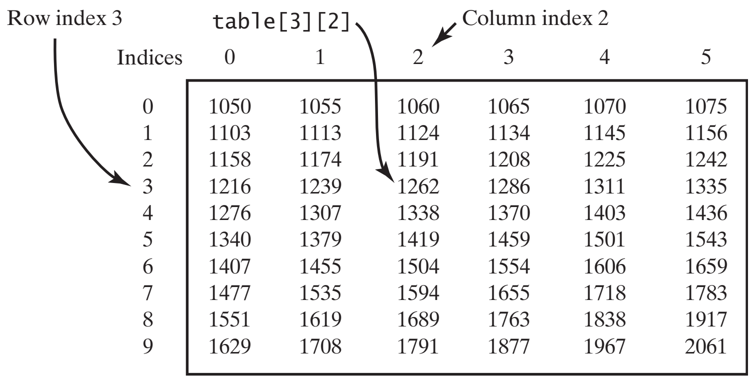
FIGURE B-8 A table of values

The effect of various interest rates on $1000 when compounded annually (rounded to whole dollars)

Year	**5.00%**	**5.50%**	**6.00%**	**6.50%**	**7.00%**	**7.50%**
1	$1050	$1055	$1060	$1065	$1070	$1075
2	$1103	$1113	$1124	$1134	$1145	$1156
3	$1158	$1174	$1191	$1208	$1225	$1242
4	$1216	$1239	$1262	$1286	$1311	$1335
5	$1276	$1307	$1338	$1370	$1403	$1436
6	$1340	$1379	$1419	$1459	$1501	$1543
7	$1407	$1455	$1504	$1554	$1606	$1659
8	$1477	$1535	$1594	$1655	$1718	$1783
9	$1551	$1619	$1689	$1763	$1838	$1917
10	$1629	$1708	$1791	$1877	$1967	$2061

Note that, as was true for the simple arrays you have already seen, you begin numbering indices with 0 rather than 1. If the array is named `table` and it has two indices, the Java notation `table[3][2]` specifies the entry in the fourth row and third column. By convention, we think of the first index as denoting the row and the second as denoting the column. Arrays that have exactly two indices can be displayed on paper as a two-dimensional table and are called **two-dimensional arrays**. More generally, an array is said to be an ***n*-dimensional array** if it has *n* indices. Thus, the ordinary one-index arrays that we have used up to now are **one-dimensional arrays**.

FIGURE B-9 Row and column indices for an array named `table`; `table[3][2]` is the element in the fourth row and third column


Row index 3
table[3][2]
Column index 2

Indices	0	1	2	3	4	5
0	1050	1055	1060	1065	1070	1075
1	1103	1113	1124	1134	1145	1156
2	1158	1174	1191	1208	1225	1242
3	1216	1239	1262	1286	1311	1335
4	1276	1307	1338	1370	1403	1436
5	1340	1379	1419	1459	1501	1543
6	1407	1455	1504	1554	1606	1659
7	1477	1535	1594	1655	1718	1783
8	1551	1619	1689	1763	1838	1917
9	1629	1708	1791	1877	1967	2061

B.95 Arrays with multiple indices are handled much like arrays with one index. To declare and create the array `table` with 10 rows and 6 columns, we write

```
int[][] table = new int[10][6];
```

You can have arrays with any number of indices. To get more indices, you just use more square brackets in the declaration.

Indexed variables for multidimensional arrays are just like indexed variables for one-dimensional arrays, except that they have multiple indices, each enclosed in a pair of square brackets. For example, the following statements set all the elements in `table` to zero:

```
for (int row = 0; row < 10; row++)
   for (int column = 0; column < 6; column++)
      table[row][column] = 0;
```

Note that we used two `for` loops, one nested within the other. This is a common way of stepping through the indexed variables in a two-dimensional array. If we had three indices, we would use three nested `for` loops, and so forth for higher numbers of indices.

As was true of the indexed variables for one-dimensional arrays, indexed variables for multidimensional arrays are variables of the array's entry type and can be used anywhere that a variable of the entry type is allowed. For example, for the two-dimensional array `table`, an indexed variable such as `table[3][2]` is a variable of type `int` and can be used anyplace that an ordinary `int` variable can be used.

A multidimensional array can be a parameter of a method. For example, the following method header has a two-dimensional array as a parameter:

```
public static void clearArray(double[][] array)
```

B.96 Java implements multidimensional arrays as one-dimensional arrays. For example, consider the array

```
int[][] table = new int[10][6];
```

The array `table` is in fact a one-dimensional array of length 10, and its entry type is `int[]`. Thus, each entry in the array `table` is a one-dimensional array of length 6. In other words, a multidimensional array is an array of arrays.

Normally, you do not need to be concerned with this fact, since this detail is handled automatically by the compiler. However, sometimes you can profit from this knowledge. For example, consider the previous nested `for` loops that filled the two-dimensional array `table` with zeros. We used the constants 6 and 10 to control the `for` loops, but it would be better style to use the data field `length` instead. To do so, we need to think in terms of an array of arrays. For example, the following is a rewrite of the nested `for` loops:

```
for (int row = 0; row < table.length; row++)
   for (int column = 0; column < table[row].length; column++)
      table[row][column] = 0;
```

Here, `table.length` is the number of rows in `table`, and `table[row].length` is the number of columns.

Wrapper Classes

B.97 Java makes a distinction between the primitive types, such as `int`, `double`, and `char`, and the class types, such as `String` and the classes that you write. Java sometimes treats primitive types and class types differently. For example, an argument to a method and the assignment operator = behave differently for primitive types and class types. To make things uniform, Java provides a **wrapper class** for each of the primitive types that enables us to convert a value of a primitive type to an object of a corresponding class type.

For example, the wrapper class for the primitive type `int` is the predefined class `Integer`. If we want to convert an `int` value, such as 10, to an object of type `Integer`, we can do so in one of three ways, as the following statements demonstrate:

```
Integer ten = new Integer(10);
Integer fiftyTwo = new Integer("52");
Integer eighty = 80;
```

In the first way, you supply an `int` value as a literal, a variable, or an expression. In the second, you provide a string that contains an `int` value. The third way allows you to simply assign an `int` value without using the `new` operator.

B.98 Once you have defined `Integer` objects, you can compare them by using the methods `compareTo` and `equals`, much as you compare strings or the other objects we have discussed in this appendix. Do not use operators such as ==. Just as for strings and other objects, operators like == compare the memory addresses of objects, not their values.

If you need the value of an `Integer` object as a primitive, you can use methods such as `intValue` or `doubleValue`. For example, if `ten` is defined as in the previous segment, the expression

```
ten.intValue()
```

returns the `int` value 10, whereas

```
ten.doubleValue()
```

returns the `double` value 10.0. You also can simply assign the `Integer` object to an `int` variable, as in

```
int primitive10 = ten;
```

No type cast is necessary; however, using one is not an error.

B.99 **Boxing and unboxing.** When performing arithmetic with `Integer` objects, for example, you can use the same operators that you use for arithmetic with primitives. You can also intermix primitive integers with `Integer` objects. Thus, you can write statements such as the following:

```
Scanner keyboard = new Scanner(System.in);
System.out.print("What is his age? ");
int hisAge = keyboard.nextInt();
System.out.print("What is her age? ");
Integer herAge = keyboard.nextInt();

Integer ageDifference = Math.abs(hisAge - herAge);
System.out.println("He is " + hisAge + ", she is " + herAge +
                   ": a difference of " + ageDifference + ".");
```

Java converts between `int` and `Integer` as necessary. The process of converting from a primitive type to a corresponding wrapper class is called **boxing**. **Unboxing** is the process used to convert in the other direction. Since these conversions happen automatically, they are often called **auto-boxing** and **auto-unboxing**. Realize that the previous statements are just a demonstration of what is possible. Using only primitive integers for this simple computation is certainly adequate.

B.100 The wrapper classes for the primitive types `double`, `float`, `long`, and `char` are `Double`, `Float`, `Long`, and `Character`, respectively. You create objects of these classes in a way analogous to how you create `Integer` objects. Except for `Character`, each wrapper class has methods that return a value in a variety of types. `Integer` has the methods `doubleValue`, `floatValue`, `intValue`, and `longValue`. `Double`, `Float`, and `Long` also have these same methods. The class `Character` has only the analogous method `charValue`.

Many of the classes that we study in this book represent collections of objects. If your data has a primitive type, an appropriate wrapper class enables you to represent the data as objects so that you can use these classes.

B.101 Wrapper classes also contain some useful static constants. For example, you can find the largest and smallest values of any of the primitive number types by using the associated wrapper class. The largest and smallest values of type `int` are

```
Integer.MAX_VALUE and Integer.MIN_VALUE
```

The largest and smallest values of type `double` are

```
Double.MAX_VALUE and Double.MIN_VALUE
```

B.102 Wrapper classes have static methods that can be used to convert a string to the corresponding number of type `int`, `double`, `long`, or `float`. For example, suppose your program needs to convert the string `"199.98"` to a `double` value (which will turn out to be 199.98, of course). The static method `parseDouble` of the wrapper class `Double` will convert a string to a value of type `double`. So if `theString` is a variable of type `String` whose value is `"199.98"`,

```
Double.parseDouble(theString)
```

returns the `double` value 199.98. The other wrapper classes `Integer`, `Long`, and `Float` have the analogous methods `parseInt`, `parseLong`, and `parseFloat`.

If there is any possibility that the string named by `theString` has extra leading or trailing blanks, you should instead use

```
Double.parseDouble(theString.trim())
```

As we discussed in Segment B.77, the method `trim`, included in the class `String`, trims off leading or trailing white space, such as blanks. If the string is not a correctly formed number, the invocation of `Double.parseDouble` will cause an exception. The use of `trim` helps some in avoiding this problem.

B.103 Each of the numeric wrapper classes also has a static method called `toString` that will convert in the other direction—that is, it will convert from a primitive numeric value to a string representation of the numeric value. For example,

```
Integer.toString(42)
```

returns the string value `"42"`, and

```
Double.toString(199.98)
```

returns the string value `"199.98"`. Additionally, each wrapper class, like all other classes, has a nonstatic version of `toString`. For example, if we define `n` as follows:

```
Integer n = new Integer(198);
```

then `n.toString()` returns the string `"198"`.

Note: Wrapper classes
Every primitive type has a wrapper class. Wrapper classes allow you to represent values of a primitive type as a class type. They also contain a number of useful predefined constants and methods.

B.104 `Character` is the wrapper class for the primitive type `char`. The following piece of code illustrates some of the basic methods for this class:

```
Character c1 = new Character('a');
Character c2 = new Character('A');
if (c1.equals(c2))
   System.out.println(c1.charValue() + " is the same as " + c2.charValue());
else
   System.out.println(c1.charValue() + " is not the same as " + c2.charValue());
```

This code displays

```
a is not the same as A
```

The `equals` method checks for equality of characters, so uppercase and lowercase letters are considered different.

Some of the static methods in the class `Character` follow:

`public static char` `toLowerCase(`**`char`** `ch)`
Returns the lowercase equivalent of `ch`, if `ch` is a letter; otherwise returns `ch`.

Examples:

`Character.toLowerCase('a')` returns `'a'`
`Character.toLowerCase('A')` returns `'a'`
`Character.toLowerCase('5')` returns `'5'`

`public static char` `toUpperCase(`**`char`** `ch)`
Returns the uppercase equivalent of `ch`, if `ch` is a letter; otherwise returns `ch`.

Examples:

`Character.toUpperCase('a')` returns `'A'`
`Character.toUpperCase('A')` returns `'A'`
`Character.toUpperCase('5')` returns `'5'`

`public static boolean` `isLowerCases(`**`char`** `ch)`
Returns true if `ch` is a lowercase letter.

Examples:

`Character.isLowerCase('a')` returns true
`Character.isLowerCase('A')` returns false
`Character.isLowerCase('5')` returns false

`public static boolean` `isUpperCase(`**`char`** `ch)`
Returns true if `ch` is an uppercase letter.

Examples:

`Character.isUpperCase('a')` returns false
`Character.isUpperCase('A')` returns true
`Character.isUpperCase('5')` returns false

public static boolean `isLetter(`**char** `ch)`
Returns true if `ch` is a letter.

Examples:

`Character.isLetter('a')` returns true
`Character.isLetter('A')` returns true
`Character.isLetter('5')` returns false

public static boolean `isDigit(`**char** `ch)`
Returns true if `ch` is a digit.

Examples:

`Character.isDigit('a')` returns false
`Character.isDigit('A')` returns false
`Character.isDigit('5')` returns true

public static boolean `isLetterOrDigit(`**char** `ch)`
Returns true if `ch` is either a letter or a digit.

Examples:

`Character.isLetterOrDigit('a')` returns true
`Character.isLetterOrDigit('A')` returns true
`Character.isLetterOrDigit('5')` returns true
`Character.isLetterOrDigit('%')` returns false

public static boolean `isWhitespace(`**char** `ch)`
Returns true if `ch` is a white-space character.

Examples:

`Character.isWhitespace('a')` returns false
`Character.isWhitespace(' ')` returns true

B.105 Java also has a wrapper class `Boolean`. This class has the two constants `Boolean.TRUE` and `Boolean.FALSE`. However, the Java reserved words `true` and `false` are much easier to use for these constants. So the constants in the class `Boolean` will not be of much help to us. The methods of the class `Boolean` are also not used very often. Although the class `Boolean` is not useless, it will be of little use to us in this text and we will discuss it no further.