Java Is a Strongly Typed Language:

It is important to state at the outset that Java is a strongly typed language. Indeed, part of Java's safety and robustness comes from this fact. Let's see what this means. First, every variable has a type, every expression has a type, and every type is strictly defined.

Second, all assignments, whether explicit or via parameter passing in method calls, are checked for type compatibility. There are no automatic coercions or conversions of conflicting types as in some languages.

The Java compiler checks all expressions and parameters to ensure that the types are compatible. Any type mismatches are errors that must be corrected before the compiler will finish compiling the class.

The Primitive Types:

Java defines eight *primitive* types of data: **byte**, **short**, **int**, **long**, **char**, **float**, **double**, and **boolean**. The primitive types are also commonly referred to as *simple* types, and both terms will be used in this book. These can be put in four groups:

- **Integers** This group includes **byte**, **short**, **int**, and **long**, which are for whole-value designed numbers.
- **Floating-point numbers** This group includes **float** and **double**, which represent numbers with fractional precision.
- **Characters** This group includes **char**, which represents symbols in a character set, like letters and numbers.
- **Boolean** This group includes **boolean**, which is a special type for representing true/false values.

You can use these types as-is, or to construct arrays or your own class types. Thus, they form the basis for all other types of data that you can create. The primitive types represent single values—not complex objects.

Although Java is otherwise completely object-oriented, the primitive types are not. They are analogous to the simple types found in most other non–object-oriented languages. The reason for this is efficiency. Making the primitive types into objects would have degraded performance too much.

The primitive types are defined to have an explicit range and mathematical behavior. Languages such as C and C++ allow the size of an integer to vary based upon the dictates of the execution environment.

However, Java is different. Because of Java's portability requirement, all data types have a strictly defined range. For example, an int is always 32 bits, regardless of the particular platform.

This allows programs to be written that are guaranteed to run without porting on any machine architecture. While strictly specifying the size of an integer may cause a small loss of performance in some environments, it is necessary in order to achieve portability.

Data Types:

1. Integers:

Java defines four integer types: **byte**, **short**, **int**, and **long**. All of these are signed, positive and negative values. Java does not support unsigned, positive-only integers. Many other computer languages support both signed and unsigned integers.

However, Java's designers felt that unsigned integers were unnecessary. Specifically, they felt that the concept of *unsigned* was used mostly to specify the behavior of the *high-order bit*, which defines the *sign* of an integer value.

Java manages the meaning of the high order bit differently, by adding a special "unsigned right shift" operator. Thus, the need for an unsigned integer type was eliminated. The *width* of an integer type should not be thought of as the amount of storage it consumes, but rather as the *behavior* it defines for variables and expressions of that type.

The Java run-time environment is free to use whatever size it wants, as long as the types behave as you declared them. The width and ranges of these integer types vary widely, as shown in this table:

Name	Width	Range
long	**64**	–9,223,372,036,854,775,808 to 9,223,372,036,854,775,807
int	**32**	–2,147,483,648 to 2,147,483,647
short	**16**	–32,768 to 32,767
byte	**8**	–128 to 127

Let's look at each type of integer:

byte:

The smallest integer type is **byte**. This is a signed 8-bit type that has a range from –128 to127. Variables of type **byte** are especially useful when you're working with a stream of data from a network or file. They are also useful when you're working with raw binary data that may not be directly compatible with Java's other built-in types.

Byte variables are declared by use of the **byte** keyword. For example, the following declares two **byte** variables called **b** and **c**:

```
byte b, c;
```

short:

short is a signed 16-bit type. It has a range from –32,768 to 32,767. It is probably the least used Java type. Here are some examples of **short** variable declarations:

```
short s;
short t;
```

int:

The most commonly used integer type is **int**. It is a signed 32-bit type that has a range from –2,147,483,648 to 2,147,483,647. In addition to other uses, variables of type **int** are commonly employed to control loops and to index arrays.

Although you might think that using a **byte** or **short** would be more efficient than using an **int** in situations in which the larger range of an **int** is not needed, this may not be the case. The reason is that when **byte** and **short** values are used in an expression, they are *promoted* to **int** when the expression is evaluated. Therefore, **int** is often the best choice when an integer is needed.

long:

long is a signed 64-bit type and is useful for those occasions where an **int** type is not large enough to hold the desired value. The range of a **long** is quite large. This makes it useful when big, whole numbers are needed.

```
// Compute distance light travels using long variables.
class Light {
public static void main(String args[]) {
int lightspeed;
long days;
long seconds;
long distance;
// approximate speed of light in miles per second
lightspeed = 186000;
days = 1000; // specify number of days here
seconds = days * 24 * 60 * 60; // convert to seconds
distance = lightspeed * seconds; // compute distance
System.out.print("In " + days);
System.out.print(" days light will travel about ");
System.out.println(distance + " miles.");
}
}
```

This program generates the following output:

```
In 1000 days light will travel about 16070400000000 miles.
```

Note: Clearly, the result could not have been held in an **int** variable.

Floating-Point Types:

Floating-point numbers, also known as *real* numbers, are used when evaluating expressions that require fractional precision. For example, calculations such as square root, or transcendentals such as sine and cosine, result in a value whose precision requires a floating-point type. Java implements the standard (IEEE–754) set of floating-point types and operators.

There are two kinds of floating-point types, **float** and **double**, which represent single- and double-precision numbers, respectively. Their width and ranges are shown here:

Name	Width in Bits	Approximate Range
double	64	4.9e–324 to 1.8e+308
float	32	1.4e–045 to 3.4e+038

float:

The type **float** specifies a *single-precision* value that uses 32 bits of storage. Single precision is faster on some processors and takes half as much space as double precision, but will become imprecise when the values are either very large or very small. Variables of type **float** are useful when you need a fractional component, but don't require a large degree of precision.

For example, **float** can be useful when representing dollars and cents. Here are some example **float** variable declarations:

float hightemp, lowtemp;

double:

Double precision, as denoted by the **double** keyword, uses 64 bits to store a value. Double precision is actually faster than single precision on some modern processors that have been optimized for high-speed mathematical calculations. All transcendental math functions, such as **sin( )**, **cos( )**, and **sqrt( )**, return **double** values. When you need to maintain accuracy over many iterative calculations, or are manipulating large-valued numbers, **double** is the best choice.

```
// Compute the area of a circle.
class Area {
public static void main(String args[]) {
double pi, r, a;
r = 10.8; // radius of circle
pi = 3.1416; // pi, approximately
a = pi * r * r; // compute area
System.out.println("Area of circle is " + a);
}
}
```

Characters:

In Java, the data type used to store characters is **char**. However, C/C++ programmers beware: **char** in Java is not the same as **char** in C or C++. In C/C++, **char** is 8 bits wide. This is *not* the case in Java.

Instead, Java uses *Unicode* to represent characters. Unicode defines a fully international character set that can represent all of the characters found in all human languages.

It is a unification of dozens of character sets, such as Latin, Greek, Arabic, Cyrillic, Hebrew, Katakana, Hangul, and many more. At the time of Java's creation, Unicode required16 bits. Thus, in Java **char** is a 16-bit type. The range of a **char** is 0 to 65,536.

There are nonegative **char**s. The standard set of characters known as ASCII still ranges from 0 to 127 as always, and the extended 8-bit character set, ISO-Latin-1, ranges from 0 to 255.Here is a program that demonstrates **char** variables:

```
// Demonstrate char data type.
class CharDemo {
public static void main(String args[]) {
char ch1, ch2;
ch1 = 88; // code for X
ch2 = 'Y';
System.out.print("ch1 and ch2: ");
System.out.println(ch1 + " " + ch2);
}
}
```

This program displays the following output:

```
ch1 and ch2: X Y
```

Notice that **ch1** is assigned the value 88, which is the ASCII (and Unicode) value that corresponds to the letter *X*. As mentioned, the ASCII character set occupies the first 127values in the Unicode character set. For this reason, all the "old tricks" that you may have used with characters in other languages will work in Java, too.

Although **char** is designed to hold Unicode characters, it can also be used as an integer type on which you can perform arithmetic operations. For example, you can add two

characters together, or increment the value of a character variable. Consider the following program:

```
// char variables behave like integers.
class CharDemo2 {
public static void main(String args[]) {
char ch1;
ch1 = 'X';
System.out.println("ch1 contains " + ch1);
ch1++; // increment ch1
System.out.println("ch1 is now " + ch1);
}
}
```

The output generated by this program is shown here:

```
ch1 contains X
ch1 is now Y
```

In the program, **ch1** is first given the value *X*. Next, **ch1** is incremented. This results in **ch1**containing *Y*, the next character in the ASCII (and Unicode) sequence.

NOTE *In the formal specification for Java, char is referred to as an integral type, which means that it is in the same general category as int, short, long, and byte. However, because its principal use is for representing Unicode characters, char is commonly considered to be in a category of its own.*

Booleans:

Java has a primitive type, called **boolean**, for logical values. It can have only one of two possible values, **true** or **false**. This is the type returned by all relational operators, as in the case of **a < b**. **boolean** is also the type *required* by the conditional expressions that govern the control statements such as **if** and **for**. Here is a program that demonstrates the **boolean** type:

```
// Demonstrate boolean values.
class BoolTest {
public static void main(String args[]) {
boolean b;
b = false;
System.out.println("b is " + b);
b = true;
System.out.println("b is " + b);
// a boolean value can control the if statement
if(b) System.out.println("This is executed.");
b = false;
if(b) System.out.println("This is not executed.");
// outcome of a relational operator is a boolean value
System.out.println("10 > 9 is " + (10 > 9));
}
}
```

The output generated by this program is shown here:

```
b is false
b is true
This is executed.
10 > 9 is true
```

There are three interesting things to notice about this program. First, as you can see, when a **boolean** value is output by **println( )**, "true" or "false" is displayed. Second, the value of a **boolean** variable is sufficient, by itself, to control the **if** statement. There is no need to write an **if** statement like this:

```
if(b == true) …
```

Third, the outcome of a relational operator, such as **<**, is a **boolean** value. This is why the expression **10>9** displays the value "true." Further, the extra set of parentheses around **10>9**is necessary because the **+** operator has a higher precedence than the **>**.

Variables:

The variable is the basic unit of storage in a Java program. A variable is defined by the combination of an identifier, a type, and an optional initializer. In addition, all variables have a scope, which defines their visibility, and a lifetime.

Declaring a Variable:

In Java, all variables must be declared before they can be used. The basic form of a variable declaration is shown here:

type identifier [= *value*][, *identifier* [= *value*] …];

Here, *type* is one of Java's atomic types, or the name of a class or interface. The *identifier* is the name of the variable. You can initialize the variable by specifying an equal sign and a value. Keep in mind that the initialization expression must result in a value of the same (or compatible)type as that specified for the variable.

To declare more than one variable of the specified type, use a comma-separated list. Here are several examples of variable declarations of various types. Note that some include an initialization.

int a, b, c; // declares three ints, a, b, and c.

int d = 3, e, f = 5; // declares three more ints, initializingd and f.

byte z = 22; // initializes z.

double pi = 3.14159; // declares an approximation of pi.

char x = 'x'; // the variable x has the value 'x'.

The identifiers that you choose have nothing intrinsic in their names that indicate their type. Java allows any properly formed identifier to have any declared type.

Dynamic Initialization:

Although the preceding examples have used only constants as initializers, Java allows

variables to be initialized dynamically, using any expression valid at the time the variable is declared. For example, here is a short program that computes the length of the hypotenuse of aright triangle given the lengths of its two opposing sides:

```
// Demonstrate dynamic initialization.
class DynInit {
public static void main(String args[]) {
double a = 3.0, b = 4.0;
// c is dynamically initialized
double c = Math.sqrt(a * a + b * b);
System.out.println("Hypotenuse is " + c);
}
}
```

Here, three local variables—**a**, **b**, and **c**—are declared. The first two, **a** and **b**, are initialized by constants. However, **c** is initialized dynamically to the length of the hypotenuse (using the Pythagorean theorem).

The program uses another of Java's built-in methods, **sqrt( )**,which is a member of the **Math** class, to compute the square root of its argument. The key point here is that the initialization expression may use any element valid at the time of the initialization, including calls to methods, other variables, or literals.

The Scope and Lifetime of Variables:

So far, all of the variables used have been declared at the start of the **main( )** method. However, Java allows variables to be declared within any block. A block is begun with an opening curly brace and ended by a closing curly brace. A block defines a *scope*. Thus, each time you start a new block, you are creating a new scope. A scope determines what objects are visible to other parts of your program. It also determines the lifetime of those objects.

Many other computer languages define two general categories of scopes: *global and local*. *However, these traditional scopes do not fit well with Java's* strict, object-oriented model. While it is possible to create what amounts to being a global scope, it is by far the exception, not the rule.

In Java, the two major scopes are those defined by a class and those defined by a method. Even this distinction is somewhat artificial. However, since the class scope has several unique properties and attributes that do not apply to the scope defined by a method, this distinction makes some sense.

Because of the differences, a discussion of class scope (and variables declared within it) is deferred, when classes are described. For now, we will only examine the scopes defined by or within a method. The scope defined by a method begins with its opening curly brace. However, if that method has parameters, they too are included within the method's scope.

As a general rule, variables declared inside a scope are not visible (that is, accessible)to code that is defined outside that scope. Thus, when you declare a variable within a scope, you are localizing that variable and protecting it from unauthorized access and/or modification.

Indeed, the scope rules provide the foundation for encapsulation. Scopes can be nested. For example, each time you create a block of code, you are creating a new, nested scope. When this occurs, the outer scope encloses the inner scope. This means that objects declared in the outer scope will be visible to code within the inner scope.

However, the reverse is not true. Objects declared within the inner scope will not be visible outside it. To understand the effect of nested scopes, consider the following program:

```
// Demonstrate block scope.
class Scope {
public static void main(String args[]) {
int x; // known to all code within main
```

```
x = 10;
if(x == 10) { // start new scope
int y = 20; // known only to this block
// x and y both known here.
System.out.println("x and y: " + x + " " + y);
x = y * 2;
}
// y = 100; // Error! y not known here
// x is still known here.
System.out.println("x is " + x);
}
}
```

As the comments indicate, the variable **x** is declared at the start of **main( )**'s scope and inaccessible to all subsequent code within **main( )**. Within the **if** block, **y** is declared. Since a block defines a scope, **y** is only visible to other code within its block. This is why outside of its block, the line **y = 100**; is commented out.

If you remove the leading comment symbol, a compile-time error will occur, because **y** is not visible outside of its block. Within the **if** block, **x** can be used because code within a block (that is, a nested scope) has access to variables declared by an enclosing scope.

Within a block, variables can be declared at any point, but are valid only after they are declared. Thus, if you define a variable at the start of a method, it is available to all of the code within that method. Conversely, if you declare a variable at the end of a block, it is effectively useless, because no code will have access to it. For example, this fragment is invalid because **count** cannot be used prior to its declaration:

```
// This fragment is wrong!
count = 100; // oops! cannot use count before it is declared!
int count;
```

Here is another important point to remember: variables are created when their scope is entered, and destroyed when their scope is left. This means that a variable will not hold its value once it has gone out of scope. Therefore, variables declared within a method will not hold their values between calls to that method.

Also, a variable declared within a block will lose its value when the block is left. Thus, the lifetime of a variable is confined to its scope. If a variable declaration includes an initializer, then that variable will be reinitialized each time the block in which it is declared is entered. For example, consider the next program:

```
// Demonstrate lifetime of a variable.
class LifeTime {
public static void main(String args[]) {
int x;
for(x = 0; x < 3; x++) {
int y = -1; // y is initialized each time block is entered
System.out.println("y is: " + y); // this always prints -1
y = 100;
```

```
System.out.println("y is now: " + y);
}
}
}
```

The output generated by this program is shown here:

```
y is: -1
y is now: 100
y is: -1
y is now: 100
y is: -1
y is now: 100
```

As you can see, **y** is reinitialized to –1 each time the inner **for** loop is entered. Even thought is subsequently assigned the value 100, this value is lost. One last point: Although blocks can be nested, you cannot declare a variable to have the same name as one in an outer scope. For example, the following program is illegal:

```
// This program will not compile
class ScopeErr {
public static void main(String args[]) {
int bar = 1;
{ // creates a new scope
int bar = 2; // Compile-time error – bar already defined!
}
}       }
```

Type Conversion (Boxing and Unboxing/Wrapping and Unwrapping)and Casting:

If you have previous programming experience, then you already know that it is fairly common to assign a value of one type to a variable of another type. If the two types are compatible, then Java will perform the conversion automatically. For example, it is always possible to assign an **int** value to a **long** variable.

However, not all types are compatible, and thus, not all type conversions are implicitly allowed. For instance, there is no automatic conversion defined from **double** to **byte**. Fortunately, it is still possible to obtain a conversion between incompatible types. To do so, you must use a *cast*, which performs an explicit conversion between incompatible types.

Java's Automatic Conversions

When one type of data is assigned to another type of variable, an *automatic type conversion* will take place if the following two conditions are met:

- The two types are compatible.
- The destination type is larger than the source type.

When these two conditions are met, a *widening conversion* takes place. For example, the **int** type is always large enough to hold all valid **byte** values, so no explicit cast statement is required.

For widening conversions, the numeric types, including integer and floating-point types, are compatible with each other. However, there are no automatic conversions from the numeric types to **char** or **boolean**. Also, **char** and **boolean** are not compatible with each other. Java also performs an automatic type conversion when storing a literal integer constant into variables of type **byte**, **short**, **long**, or **char**.

Casting Incompatible Types

Although the automatic type conversions are helpful, they will not fulfill all needs. For example, what if you want to assign an **int** value to a **byte** variable? This conversion will not be performed automatically, because a **byte** is smaller than an **int**. This kind of conversion is sometimes called a *narrowing conversion*, since you are explicitly making the value narrower so that it will fit into the target type.

To create a conversion between two incompatible types, you must use a cast. A *cast* is simply an explicit type conversion. It has this general form:

(*target-type*) *value*

Here, *target-type* specifies the desired type to convert the specified value to. For example, the following fragment casts an **int** to a **byte**. If the integer's value is larger than the range of a **byte**, it will be reduced modulo (the remainder of an integer division by the) **byte**'s range.

```
int a;
byte b;
// …
b = (byte) a;
```

A different type of conversion will occur when a floating-point value is assigned to an integer type: *truncation*. As you know, integers do not have fractional components. Thus, when a floating-point value is assigned to an integer type, the fractional component is lost.

For example, if the value 1.23 is assigned to an integer, the resulting value will simply be 1.The 0.23 will have been truncated. Of course, if the size of the whole number component is too large to fit into the target integer type, then that value will be reduced modulo the target type's range.

The following program demonstrates some type conversions that require casts:

```
// Demonstrate casts.
class Conversion {
public static void main(String args[]) {
byte b;
int i = 257;
double d = 323.142;
System.out.println("\nConversion of int to byte.");
```

```
b = (byte) i;
System.out.println("i and b " + i + " " + b);
System.out.println("\n Conversion of double to int.");
i = (int) d;
System.out.println("d and i " + d + " " + i);
System.out.println("\n Conversion of double to byte.");
b = (byte) d;
System.out.println("d and b " + d + " " + b);
}
}
```

This program generates the following output:

```
Conversion of int to byte.
i and b 257 1
Conversion of double to int.
d and i 323.142 323
Conversion of double to byte.
d and b 323.142 67
```

Let's look at each conversion. When the value 257 is cast into a **byte** variable, the result is the remainder of the division of 257 by 256 (the range of a **byte**), which is 1 in this case. When the **d** is converted to an **int**, its fractional component is lost. When **d** is converted to a **byte**, its fractional component is lost, *and* the value is reduced modulo 256, which in this case is 67.

Boxing (or Autoboxing) and Unboxing:

Autoboxing is the automatic conversion that the Java compiler makes between the primitive types and their corresponding object wrapper classes. For example, converting an int to an Integer, a double to a Double, and so on; if the conversion goes the other way, this is called *unboxing*.

Here is the simplest example of autoboxing:

```
Character ch = 'a';
```

Boxing Example:

```
class BoxingExample1{
  public static void main(String args[]){
        int a=50; char b='h';
      Integer a2=new Integer(a);//Boxing
      Character a3=new Character(b);//Boxing
      System.out.println(a2+" "+a3);
 }
}
```

Output:

```
50 h
```

Unboxing Example:

```
class UnboxingExample1{
  public static void main(String args[]){
        Integer i=new Integer(50);
       int a=i;
         Character c = new Character('A');
          char s=c;
       System.out.println(a);
       System.out.println(s);
 }
}
```

Output:

```
50
A
```

Advantage of Autoboxing and Unboxing:

No need of conversion between primitives and Wrappers manually so less coding is required.

Wrapping and Unwrapping:

A Wrapper class is a class whose object wraps or contains a primitive data types.

Need of Wrapper Classes:

1. They convert primitive data types into objects. Objects are needed if we wish to modify the arguments passed into a method (because primitive types are passed by value).
2. The classes in java.util package handles only objects and hence wrapper classes help in this case also.
3. Data structures in the Collection framework, such as ArrayList and Vector, store only objects (reference types) and not primitive types.
4. An object is needed to support synchronization in multithreading.

Primitive Data types and their Corresponding Wrapper class

Primitive Data Type	Wrapper Class
char	Character
byte	Byte
short	Short
long	Integer
float	Float
double	Double
boolean	Boolean

Wrapper class Example: Primitive to Wrapper

```
//Java program to convert primitive into objects
//Autoboxing example of int to Integer
public class WrapperExample1{
public static void main(String args[]){
//Converting int into Integer
int a=20;
Integer i=Integer.valueOf(a);//converting int into Integer explicitly
Integer j=a;//autoboxing, now compiler will write Integer.valueOf(a) internally
System.out.println(a+" "+i+" "+j);
}}
```

Output:

20 20 20

Wrapper class Example: Wrapper to Primitive

```
//Java program to convert object into primitives
//Unboxing example of Integer to int
public class WrapperExample2{
public static void main(String args[]){
//Converting Integer to int
Integer a=new Integer(3);
int i=a.intValue();//converting Integer to int explicitly
int j=a;//unboxing, now compiler will write a.intValue() internally
System.out.println(a+" "+i+" "+j);
}}
```

Output:

3 3 3

Arrays:

An *array* is a group of like-typed variables that are referred to by a common name. Arrays of any type can be created and may have one or more dimensions. A specific element in an array is accessed by its index. Arrays offer a convenient means of grouping related information.

NOTE If you are familiar with C/C++, be careful. Arrays in Java work differently than they do in those languages.

One-Dimensional Arrays:

A *one-dimensional array* is, essentially, a list of like-typed variables. To create an array, you first must create an array variable of the desired type. The general form of a one-dimensional array declaration is

type var-name[ ];

Here, *type* declares the element type (also called the base type) of the array. The element type determines the data type of each element that comprises the array. Thus, the element type for the array determines what type of data the array will hold. For example, the following declares an array named **month_days** with the type "array of int":

int month_days[];

Although this declaration establishes the fact that **month_days** is an array variable, no array actually exists. To link **month_days** with an actual, physical array of integers, you must allocate one using **new** and assign it to **month_days**. **new** is a special operator that allocates memory.

The general form of **new** as it applies to one-dimensional arrays appears as follows:

array-var = new *type* [*size*];

Here, *type* specifies the type of data being allocated, *size* specifies the number of elements in the array, and *array-var* is the array variable that is linked to the array. That is, to use **new** to allocate an array, you must specify the type and number of elements to allocate. The elements in the array allocated by **new** will automatically be initialized to zero (for numeric types), **false**(for **boolean**), or **null** (for reference types).

This example allocates a 12-element array of integers and links them to **month_days**:

month_days = new int[12];

After this statement executes, **month_days** will refer to an array of 12 integers. Further, all elements in the array will be initialized to zero. Thus, in Java all arrays are dynamically allocated.

Once you have allocated an array, you can access a specific element in the array by

specifying its index within square brackets. All array indexes start at zero. For example,

this statement assigns the value 28 to the second element of **month_days**:

month_days[1] = 28;

The next line displays the value stored at index 3:

System.out.println(month_days[3]);

Putting together all the pieces, here is a program that creates an array of the number of days in each month:

```
// Demonstrate a one-dimensional array.
class Array {
public static void main(String args[]) {
```

```
int month_days[];
month_days = new int[12];
month_days[0] = 31;
month_days[1] = 28;
month_days[2] = 31;
month_days[3] = 30;
month_days[4] = 31;
month_days[5] = 30;
month_days[6] = 31;
month_days[7] = 31;
month_days[8] = 30;
month_days[9] = 31;
month_days[10] = 30;
month_days[11] = 31;
System.out.println("April has " + month_days[3] + " days.");
}
}
```

When you run this program, it prints the number of days in April. As mentioned, Java array indexes start with zero, so the number of days in April is **month_days[3]** or 30.It is possible to combine the declaration of the array variable with the allocation of the array itself, as shown here:

```
int month_days[] = new int[12];
```

This is the way that you will normally see it done in professionally written Java programs. Arrays can be initialized when they are declared. The process is much the same as that used to initialize the simple types.

An *array initializer* is a list of comma-separated expressions surrounded by curly braces. The commas separate the values of the array elements. The array will automatically be created large enough to hold the number of elements you specify in the array initializer. There is no need to use **new**.

For example, to store the number of days in each month, the following code creates an initialized array of integers:

```
// An improved version of the previous program.
class AutoArray {
public static void main(String args[]) {
int month_days[] = { 31, 28, 31, 30, 31, 30, 31, 31, 30, 31,30, 31 };
System.out.println("April has " + month_days[3] + " days.");
}
}
```

When you run this program, you see the same output as that generated by the previous version.

Java strictly checks to make sure you do not accidentally try to store or reference values outside of the range of the array. The Java run-time system will check to be sure that all array indexes are in the correct range.

For example, the run-time system will check the value of each index into **month_days** to make sure that it is between 0 and 11 inclusive.

If you try to access elements outside the range of the array (negative numbers or numbers greater than the length of the array), you will cause a run-time error. Here is one more example that uses a one-dimensional array. It finds the average of a set of numbers.

```
// Average an array of values.
class Average {
public static void main(String args[]) {
double nums[] = {10.1, 11.2, 12.3, 13.4, 14.5};
double result = 0;
int i;
for(i=0; i<5; i++)
result = result + nums[i];
System.out.println("Average is " + result / 5);
}
}
```

Multidimensional Arrays

In Java, *multidimensional arrays* are actually arrays of arrays. These, as you might expect, look and act like regular multidimensional arrays. However, as you will see, there are a couple of subtle differences. To declare a multidimensional array variable, specify each additional index using another set of square brackets. For example, the following declares a two-dimensional array variable called **twoD**:

```
int twoD[][] = new int[4][5];
```

This allocates a 4 by 5 array and assigns it to **twoD**. Internally, this matrix is implemented as an *array* of *arrays* of **int**. conceptually; this array will look like the one shown in Figure below:

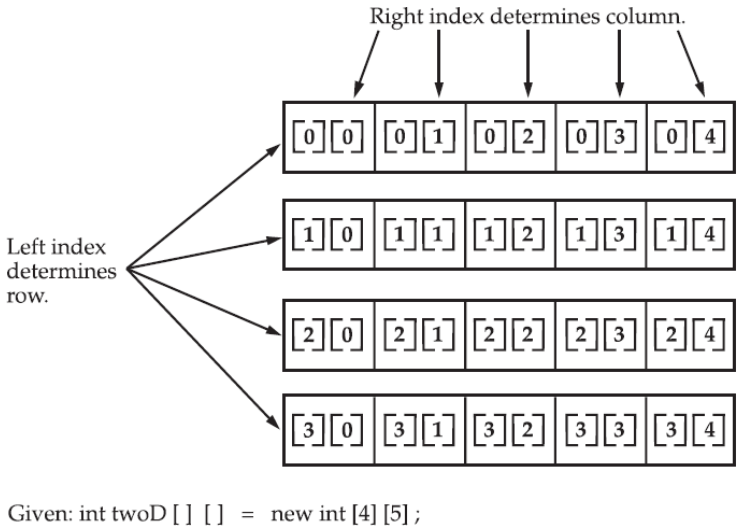


Figure:A conceptual view of a 4 by 5, two-dimensional array

The following program numbers each element in the array from left to right, top to bottom, and then displays these values:

```
// Demonstrate a two-dimensional array.
class TwoDArray {
public static void main(String args[]) {
int twoD[][]= new int[4][5];
int i, j, k = 0;
for(i=0; i<4; i++)
for(j=0; j<5; j++) {
twoD[i][j] = k;
k++;
}
for(i=0; i<4; i++) {
for(j=0; j<5; j++)
System.out.print(twoD[i][j] + " ");
System.out.println();
}
}
}
```

This program generates the following output:

```
0 1 2 3 4
5 6 7 8 9
10 11 12 13 14
15 16 17 18 19
```

When you allocate memory for a multidimensional array, you need only specify the memory for the first (leftmost) dimension. You can allocate the remaining dimensions separately. For example, this following code allocates memory for the first dimension of **twoD** when it is declared. It allocates the second dimension manually.

```
int twoD[][] = new int[4][];
twoD[0] = new int[5];
twoD[1] = new int[5];
twoD[2] = new int[5];
twoD[3] = new int[5];
```

While there is no advantage to individually allocating the second dimension arrays in this situation, there may be in others. For example, when you allocate dimensions manually, you do not need to allocate the same number of elements for each dimension.

As stated earlier, since multidimensional arrays are actually arrays of arrays, the length of each array is under your control. For example, the following program creates a two-dimensional array in which the sizes of the second dimension are unequal:

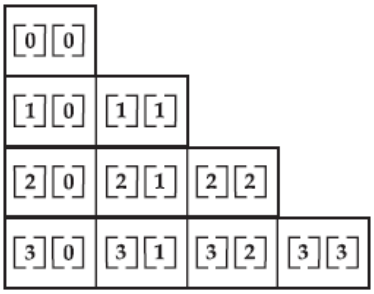
```
// Manually allocate differing size second dimensions.
class TwoDAgain {
public static void main(String args[]) {
int twoD[][] = new int[4][];
```

```
twoD[0] = new int[1];
twoD[1] = new int[2];
twoD[2] = new int[3];
twoD[3] = new int[4];
int i, j, k = 0;
for(i=0; i<4; i++)
for(j=0; j<i+1; j++) {
twoD[i][j] = k;
k++;
}
for(i=0; i<4; i++) {
for(j=0; j<i+1; j++)
System.out.print(twoD[i][j] + " ");
System.out.println();
}
}
}
```

This program generates the following output:

```
0
1 2
3 4 5
6 7 8 9
```

The array created by this program looks like this:



The use of uneven (or irregular) multidimensional arrays may not be appropriate for many applications, because it runs contrary to what people expect to find when a multidimensional array is encountered. However, irregular arrays can be used effectively in some situations.

For example, if you need a very large two-dimensional array that is sparsely populated (that is, one in which not all of the elements will be used), then an irregular array might be a perfect solution.

It is possible to initialize multidimensional arrays. To do so, simply enclose each dimension's initializer within its own set of curly braces. The following program creates a matrix where each element contains the product of the row and column indexes. Also notice that you can use expressions as well as literal values inside of array initializers.

```
// Initialize a two-dimensional array.
class Matrix {
```

```
public static void main(String args[]) {
double m[][] = {
{ 0*0, 1*0, 2*0, 3*0 },
{ 0*1, 1*1, 2*1, 3*1 },
{ 0*2, 1*2, 2*2, 3*2 },
{ 0*3, 1*3, 2*3, 3*3 }
};
int i, j;
for(i=0; i<4; i++) {
for(j=0; j<4; j++)
System.out.print(m[i][j] + " ");
System.out.println();
}
}
}
```

When you run this program, you will get the following output:

```
0.0 0.0 0.0 0.0
0.0 1.0 2.0 3.0
0.0 2.0 4.0 6.0
0.0 3.0 6.0 9.0
```

As you can see, each row in the array is initialized as specified in the initialization lists.

Alternative Array Declaration Syntax

There is a second form that may be used to declare an array:

type[ ] *var-name*;

Here, the square brackets follow the type specifier, and not the name of the array variable.

For example, the following two declarations are equivalent:

```
int al[] = new int[3];
int[] a2 = new int[3];
```

The following declarations are also equivalent:

```
char twod1[][] = new char[3][4];
char[][] twod2 = new char[3][4];
```

This alternative declaration form offers convenience when declaring several arrays at the same time. For example,

```
int[] nums, nums2, nums3; // create three arrays
```

creates three array variables of type **int**. It is the same as writing

```
int nums[], nums2[], nums3[]; // create three arrays
```

The alternative declaration form is also useful when specifying an array as a return type for a method.

Operators:

Java provides a rich operator environment. Most of its operators can be divided into the following four groups: arithmetic, bitwise, relational, and logical. Java also defines some additional operators that handle certain special situations.

Arithmetic Operators

Arithmetic operators are used in mathematical expressions in the same way that they are used in algebra. The following table lists the arithmetic operators:

Operator	Result
+	Addition (also unary plus)
–	Subtraction (also unary minus)
*	Multiplication
/	Division
%	Modulus
++	Increment
+=	Addition assignment
–=	Subtraction assignment
*=	Multiplication assignment
/=	Division assignment
%=	Modulus assignment
––	Decrement

The operands of the arithmetic operators must be of a numeric type. You cannot use them on **boolean** types, but you can use them on **char** types, since the **char** type in Java is, essentially, a subset of **int**.

The Basic Arithmetic Operators

The basic arithmetic operations—addition, subtraction, multiplication, and division—all behave as you would expect for all numeric types. The unary minus operator negates its single operand.

The unary plus operator simply returns the value of its operand. Remember that when the division operator is applied to an integer type, there will be no fractional component attached to the result.

The following simple example program demonstrates the arithmetic operators. It also illustrates the difference between floating-point division and integer division.

```
// Demonstrate the basic arithmetic operators.
class BasicMath {
public static void main(String args[]) {
// arithmetic using integers
System.out.println("Integer Arithmetic");
int a = 1 + 1;
int b = a * 3;
```

```
int c = b / 4;
int d = c - a;
int e = -d;
System.out.println("a = " + a);
System.out.println("b = " + b);
System.out.println("c = " + c);
System.out.println("d = " + d);
System.out.println("e = " + e);
// arithmetic using doubles
System.out.println("\nFloating Point Arithmetic");
double da = 1 + 1;
double db = da * 3;
double dc = db / 4;
double dd = dc - a;
double de = -dd;
System.out.println("da = " + da);
System.out.println("db = " + db);
System.out.println("dc = " + dc);
System.out.println("dd = " + dd);
System.out.println("de = " + de);
}
}
```

When you run this program, you will see the following output:

```
Integer Arithmetic
a = 2
b = 6
c = 1
d = -1
e = 1

Floating Point Arithmetic
da = 2.0
db = 6.0
dc = 1.5
dd = -0.5
de = 0.5
```

The Modulus Operator

The modulus operator, **%**, returns the remainder of a division operation. It can be applied to floating-point types as well as integer types. The following example program demonstrates the **%**:

```
// Demonstrate the % operator.
class Modulus {
public static void main(String args[]) {
int x = 42;
double y = 42.25;
System.out.println("x mod 10 = " + x % 10);
```

```
System.out.println("y mod 10 = " + y % 10);
}
}
```

When you run this program, you will get the following output:

```
x mod 10 = 2
y mod 10 = 2.25
```

Arithmetic Compound Assignment Operators

Java provides special operators that can be used to combine an arithmetic operation with an assignment. As you probably know, statements like the following are quite common in programming:

```
a = a + 4;
```

In Java, you can rewrite this statement as shown here:

```
a += 4;
```

This version uses the += *compound assignment operator*. Both statements perform the same action: they increase the value of **a** by 4.Here is another example,

```
a = a % 2;
```

which can be expressed as

```
a %= 2;
```

In this case, the **%=** obtains the remainder of **a** /2 and puts that result back into **a**. There are compound assignment operators for all of the arithmetic, binary operators. Thus, any statement of the form

var = *var op expression*;

can be rewritten as *var op= expression*;

The compound assignment operators provide two benefits. First, they save you a bit of typing, because they are "shorthand" for their equivalent long forms. Second, in some cases they are more efficient than are their equivalent long forms.

For these reasons, you will often see the compound assignment operators used in professionally written Java programs. Here is a sample program that shows several *op*= assignments in action:

```
// Demonstrate several assignment operators.
class OpEquals {
public static void main(String args[]) {
int a = 1;
int b = 2;
int c = 3;
a += 5;
b *= 4;
```

```
c += a * b;
c %= 6;
System.out.println("a = " + a);
System.out.println("b = " + b);
System.out.println("c = " + c);
}
}
```

The output of this program is shown here:

```
a = 6
b = 8
c = 3
```

Increment and Decrement

The ++ and the – – are Java's increment and decrement operators. The increment operator increases its operand by one. The decrement operator decreases its operand by one. For example, this statement: ***x = x + 1;*** can be rewritten like this by use of the increment operator: ***x++;***

Similarly, this statement: ***x = x - 1;*** is equivalent to ***x--;***

These operators are unique in that they can appear both in *postfix* form, where they follow the operand as just shown, and *prefix* form, where they precede the operand. In the foregoing examples, there is no difference between the prefix and postfix forms.

However, when the increment and/or decrement operators are part of a larger expression, then a subtle, yet powerful, difference between these two forms appears. In the prefix form, the operand is incremented or decremented before the value is obtained for use in the expression. In postfix form, the previous value is obtained for use in the expression, and then the operand is modified. For example:

```
x = 42;
y = ++x;
```

In this case, **y** is set to 43 as you would expect, because the increment occurs *before* **x** is assigned to **y**. Thus, the line **y = ++x**; is the equivalent of these two statements:

```
x = x + 1;
y = x;
```

However, when written like this,

```
x = 42;
y = x++;
```

the value of **x** is obtained before the increment operator is executed, so the value of **y** is 42.Of course, in both cases **x** is set to 43. Here, the line **y = x++**; is the equivalent of these two statements: ***y = x; x = x + 1;***

The following program demonstrates the increment operator.

```
// Demonstrate ++.
class IncDec {
public static void main(String args[]) {
int a = 1;
int b = 2;
int c;
int d;
c = ++b;
d = a++;
c++;
System.out.println("a = " + a);
System.out.println("b = " + b);
System.out.println("c = " + c);
System.out.println("d = " + d);
}
}
```

The output of this program follows:

```
a = 2
b = 3
c = 4
d = 1
```

The Bitwise Operators

Java defines several *bitwise operators* that can be applied to the integer types: **long**, **int**, **short**, **char**, and **byte**. These operators act upon the individual bits of their operands. They are summarized in the following table:

Operator	Result
~	Bitwise unary NOT
&	Bitwise AND
|	Bitwise OR
^	Bitwise exclusive OR
>>	Shift right
>>>	Shift right zero fill
<<	Shift left
&=	Bitwise AND assignment
|=	Bitwise OR assignment
^=	Bitwise exclusive OR assignment
>>=	Shift right assignment
>>>=	Shift right zero fill assignment
<<=	Shift left assignment

Since the bitwise operators manipulate the bits within an integer: it is important to understand what effects such manipulations may have on a value.

Specifically, it is useful to know how Java stores integer values and how it represents negative numbers. So, before continuing, let's briefly review these two topics.

All of the integer types are represented by binary numbers of varying bit widths. For example, the **byte** value for 42 in binary is 00101010, where each position represents a power of two, starting with 2^0 at the rightmost bit. The next bit position to the left would be2^1, or 2, continuing toward the left with 2^2, or 4, then 8, 16, 32, and so on.

So 42 has 1 bits set at positions 1, 3, and 5 (counting from 0 at the right); thus, 42 is the sum of $2^1 + 2^3 + 2^5$,which is 2 + 8 + 32.All of the integer types (except **char**) are signed integers. This means that they can represent negative values as well as positive ones.

Java uses an encoding known as *two's complement*, which means that negative numbers are represented by inverting (changing 1'sto 0's and vice versa) all of the bits in a value, then adding 1 to the result. For example, –42is represented by inverting all of the bits in 42, or 00101010, which yields 11010101, then adding 1, which results in 11010110, or –42.

To decode a negative number, first invert all of the bits, then add 1. For example, –42, or 11010110 inverted, yields 00101001, or 41, so when you add 1 you get 42.

The reason Java (and most other computer languages) uses two's complement is easy to see when you consider the issue of *zero crossing*. Assuming a **byte** value, zero is represented by 00000000.

In one's complement, simply inverting all of the bits creates 11111111, which creates negative zero. The trouble is that negative zero is invalid in integer math. This problem is solved by using two's complement to represent negative values. When using two's complement, 1 is added to the complement, producing 100000000.

This produces a 1bit too far to the left to fit back into the **byte** value, resulting in the desired behavior, where–0 is the same as 0, and 11111111 is the encoding for –1. Although we used a **byte** value in the preceding example, the same basic principle applies to Java's entire integer types.

Because Java uses two's complement to store negative numbers—and because all integers are signed values in Java—applying the bitwise operators can easily produce unexpected results.

For example, turning on the high-order bit will cause the resulting value to be interpreted as a negative number, whether this is what you intended or not. To avoid unpleasant surprises, just remember that the high-order bit determines the sign of an integer no matter how that high-order bit gets set.

The Bitwise Logical Operators

The bitwise logical operators are **&**, **|**, **^**, and **~**. The following table shows the outcome of each operation. In the discussion that follows, keep in mind that the bitwise operators are applied to each individual bit within each operand.

A	B	A | B	A & B	A ^ B	~A
0	0	0	0	0	1
1	0	1	0	1	0
0	1	1	0	1	1
1	1	1	1	0	0

The Bitwise NOT

Also called the *bitwise complement*, the unary NOT operator, ~, inverts all of the bits of its operand. For example, the number 42, this has the following bit pattern:

00101010

Becomes

11010101

After the NOT operator is applied.

The Bitwise AND

The AND operator, **&**, produces a 1 bit if both operands are also 1. A zero is produced in all other cases. Here is an example:

00101010 42
&00001111 15
_____
00001010 10

The Bitwise OR

The OR operator, **|**, combines bits such that if either of the bits in the operands is a 1, then the resultant bit is a 1, as shown here:

00101010 42
| 00001111 15
_____
00101111 47

The Bitwise XOR

The XOR operator, **^**, combines bits such that if exactly one operand is 1, then the result is 1. Otherwise, the result is zero. The following example shows the effect of the **^**. This example also demonstrates a useful attribute of the XOR operation. Notice how the bit pattern of 42 is inverted wherever the second operand has a 1 bit. Wherever the second operand has a 0 bit, the first operand is unchanged. You will find this property useful when performing some types of bit manipulations.

00101010 42
^ 00001111 15
_____
00100101 37

Using the Bitwise Logical Operators

The following program demonstrates the bitwise logical operators:

```
// Demonstrate the bitwise logical operators.
class BitLogic {
public static void main(String args[]) {
String binary[] = {
"0000", "0001", "0010", "0011", "0100", "0101", "0110", "0111",
"1000", "1001", "1010", "1011", "1100", "1101", "1110", "1111"
};
int a = 3; // 0 + 2 + 1 or 0011 in binary
int b = 6; // 4 + 2 + 0 or 0110 in binary
int c = a | b;
int d = a & b;
int e = a ^ b;
int f = (~a & b)|(a & ~b);
int g = ~a & 0x0f;
System.out.println(" a = " + binary[a]);
System.out.println(" b = " + binary[b]);
System.out.println(" a|b = " + binary[c]);
System.out.println(" a&b = " + binary[d]);
System.out.println(" a^b = " + binary[e]);
System.out.println("~a&b|a&~b = " + binary[f]);
System.out.println(" ~a = " + binary[g]);
}
}
```

In this example, **a** and **b** have bit patterns that present all four possibilities for two binary digits: 0-0, 0-1, 1-0, and 1-1. You can see how the **|** and **&**operate on each bit by the results in **c** and **d**. The values assigned to **e** and **f** are the same and illustrate how the **^** works.

The string array named **binary** holds the human-readable, binary representation of the numbers 0 through 15. In this example, the array is indexed to show the binary representation of each result.

The array is constructed such that the correct string representation of a binary value **n** is stored in **binary[n]**. The value of **~a** is ANDed with **0x0f** (0000 1111 in binary) in order to reduce its value to less than 16, so it can be printed by use of the **binary** array. Here is the output from this program:

```
a = 0011
b = 0110
a|b = 0111
a&b = 0010
a^b = 0101
~a&b|a&~b = 0101
~a = 1100
```

The Left Shift

The left shift operator, **<<,** shifts all of the bits in a value to the left a specified number of times. It has this general form:

value << *num*

Here, *num* specifies the number of positions to left-shift the value in *value*. That is, the**<<**moves all of the bits in the specified value to the left by the number of bit positions specified by *num*.

For each shift left, the high-order bit is shifted out (and lost), and a zero is brought in on the right. This means that when a left shift is applied to an **int** operand, bits are lost once they are shifted past bit position 31. If the operand is a **long**, then bits are lost after bit position 63.

The Right Shift

The right shift operator, **>>**, shifts all of the bits in a value to the right a specified number of times. Its general form is shown here:

value >> *num*

Here, *num* specifies the number of positions to right-shift the value in *value*. That is, the >>moves all of the bits in the specified value to the right the number of bit positions specified by *num*.

The following code fragment shifts the value 32 to the right by two positions, resulting in **a** being set to **8**:

```
int a = 32;
a = a >> 2; // a now contains 8
```

When a value has bits that are "shifted off," those bits are lost.

The Unsigned Right Shift

As you have just seen, the **>>**operator automatically fills the high-order bit with its previous contents each time a shift occurs. This preserves the sign of the value. However, some times this is undesirable.

For example, if you are shifting something that does not represent a numeric value, you may not want sign extension to take place. This situation is common when you are working with pixel-based values and graphics.

In these cases, you will generally want to shift a zero into the high-order bit no matter what its initial value was. This is known as an *unsigned shift*. To accomplish this, you will use Java's unsigned, shift right operator, **>>>,** which always shifts zeros into the high-order bit.

The following code fragment demonstrates the **>>>.** Here, **a** is set to –1, which sets all32 bits to 1 in binary. This value is then shifted right 24 bits, filling the top 24 bits with zeros, ignoring normal sign extension. This sets **a** to 255.

```
int a = -1;
a = a >>> 24;
```

Here is the same operation in binary form to further illustrate what is happening:

```
11111111 11111111 11111111 11111111 –1 in binary as an int
>>>24
00000000 00000000 00000000 11111111 255 in binary as an int
```

The **>>>**operator is often not as useful as you might like, since it is only meaningful for 32- and 64-bit values. Remember, smaller values are automatically promoted to **int** in expressions.

This means that sign-extension occurs and that the shift will take place on a32-bit rather than on an 8- or 16-bit value. That is, one might expect an unsigned right shifton a **byte** value to zero-fill beginning at bit 7. But this is not the case, since it is a 32-bit value that is actually being shifted.

Bitwise Operator Compound Assignments

All of the binary bitwise operators have a compound form similar to that of the algebraic operators, which combines the assignment with the bitwise operation. For example, the following two statements, which shift the value in **a** right by four bits, are equivalent:

```
a = a >> 4;
a >>= 4;
```

Likewise, the following two statements, which result in **a** being assigned the bitwise expression **a** OR **b**, are equivalent:

```
a = a | b;
a |= b;
```

The following program creates a few integer variables and then uses compound bitwise operator assignments to manipulate the variables:

```
class OpBitEquals {
public static void main(String args[]) {
int a = 1;
int b = 2;
int c = 3;
a |= 4;
b >>= 1;
c <<= 1;
a ^= c;
System.out.println("a = " + a);
System.out.println("b = " + b);
System.out.println("c = " + c);
}
}
```

The output of this program is shown here:

```
a = 3
b = 1
c = 6
```

Relational Operators

The *relational operators* determine the relationship that one operand has to the other. Specifically, they determine equality and ordering. The relational operators are shown here:

Operator	Result
==	Equal to
!=	Not equal to
>	Greater than
<	Less than
>=	Greater than or equal to
<=	Less than or equal to

The outcome of these operations is a **boolean** value. The relational operators are most frequently used in the expressions that control the **if** statement and the various loop statements.

Any type in Java, including integers, floating-point numbers, characters, and Booleans can be compared using the equality test, **==**, and the inequality test, **!=**. Notice that in Java equality is denoted with two equal signs, not one. (Remember: a single equal sign is the assignment operator.) Only numeric types can be compared using the ordering operators.

That is, only integer, floating-point, and character operands may be compared to see which is greater or less than the other. As stated, the result produced by a relational operator is a **boolean** value. For example, the following code fragment is perfectly valid:

```
int a = 4;
int b = 1;
boolean c = a < b;
```

In this case, the result of **a<b** (which is **false**) is stored in **c**.If you are coming from a C/C++ background, please note the following. In C/C++,these types of statements are very common:

```
int done;
//...
if(!done)... // Valid in C/C++
if(done)... // but not in Java.
```

In Java, these statements must be written like this:

```
if(done == 0)... // This is Java-style.
if(done != 0)...
```

The reason is that Java does not define true and false in the same way as C/C++. In C/C++, true is any nonzero value and false is zero. In Java, **true** and **false** are nonnumeric values that do not relate to zero or non zero. Therefore, to test for zero or nonzero, you must explicitly employ one or more of the relational operators.

Boolean Logical Operators

The Boolean logical operators shown here operate only on **boolean** operands. All of the binary logical operators combine two **boolean** values to form a resultant **boolean** value.

Operator	Result
&	Logical AND
|	Logical OR
^	Logical XOR (exclusive OR)
||	Short-circuit OR
&&	Short-circuit AND
!	Logical unary NOT
&=	AND assignment
|=	OR assignment
^=	XOR assignment
==	Equal to
!=	Not equal to
?:	Ternary if-then-else

The logical Boolean operators, **&**, |, and ^, operate on **boolean** values in the same way that they operate on the bits of an integer. The logical **!** operator inverts the Boolean state:**!true == false** and **!false == true**. The following table shows the effect of each logical operation:

A	B	A | B	A & B	A ^ B	!A
False	False	False	False	False	True
True	False	True	False	True	False
False	True	True	False	True	True
True	True	True	True	False	False

Here is an example:

```
// Demonstrate the boolean logical operators.
class BoolLogic {
public static void main(String args[]) {
boolean a = true;
boolean b = false;
boolean c = a | b;
boolean d = a & b;
boolean e = a ^ b;
boolean f = (!a & b) | (a & !b);
```

```
boolean g = !a;
System.out.println(" a = " + a);
System.out.println(" b = " + b);
System.out.println(" a|b = " + c);
System.out.println(" a&b = " + d);
System.out.println(" a^b = " + e);
System.out.println("!a&b|a&!b = " + f);
System.out.println(" !a = " + g);
}
}
```

Output:

```
a = true
b = false
a|b = true
a&b = false
a^b = true
!a&b|a&!b = true
!a = false
```

Short-Circuit Logical Operators

Java provides two interesting Boolean operators not found in some other computer languages. These are secondary versions of the Boolean AND and OR operators, and are commonly known as *short-circuit* logical operators. As you can see from the preceding table, the OR operator results in **true** when **A** is **true**, no matter what **B** is. Similarly, the AND operator results in **false** when **A** is **false**, no matter what **B** is.

If you use the **||** and **&&**forms, rather than the **|** and **&**forms of these operators, Java will not bother to evaluate the righthand operand when the outcome of the expression can be determined by the left operand alone. This is very useful when the right-hand operand depends on the value of the left one in order to function properly.

For example, the following code fragment shows how you can take advantage of short-circuit logical evaluation to be sure that a division operation will be valid before evaluating it:

```
if (denom != 0 && num / denom > 10)
```

Since the short-circuit form of AND (**&&**) is used, there is no risk of causing a run-time exception when **denom** is zero. If this line of code were written using the single **&**version of AND, both sides would be evaluated, causing a run-time exception when **denom** is zero.

It is standard practice to use the short-circuit forms of AND and OR in cases involving Boolean logic, leaving the single-character versions exclusively for bitwise operations. However, there are exceptions to this rule. For example, consider the following statement:

```
if(c==1 & e++ < 100) d = 100;
```

Here, using a single **&**ensures that the increment operation will be applied to **e** whether **c** is equal to 1 or not.

NOTE The formal specification for Java refers to the short-circuit operators as the *conditional-and* and the *conditional-or*.

The Assignment Operator

The *assignment operator* is the single equal sign, =. The assignment operator works in Java much as it does in any other computer language. It has this general form:

var = *expression*;

Here, the type of *var* must be compatible with the type of *expression*. The assignment operator does have one interesting attribute that you may not be familiar with: it allows you to create a chain of assignments. For example, consider this fragment:

```
int x, y, z;
x = y = z = 100; // set x, y, and z to 100
```

This fragment sets the variables **x**, **y**, and **z** to 100 using a single statement. This works because the = is an operator that yields the value of the right-hand expression. Thus, the value of **z = 100** is 100, which is then assigned to **y**, which in turn is assigned to **x**. Using a "chain of assignment" is an easy way to set a group of variables to a common value.

The ? Operator

Java includes a special *ternary* (three-way) *operator* that can replace certain types of *if-then-else* statements. This operator is the **?**. It can seem somewhat confusing at first, but the **?**can be used very effectively once mastered. The **?** has this general form: ***expression1* ? *expression2* : *expression3***

Here, *expression1* can be any expression that evaluates to a **boolean** value. If *expression1* is **true**, then *expression2* is evaluated; otherwise, *expression3* is evaluated. The result of the **?**operation is that of the expression evaluated. Both *expression2* and *expression3* are required to return the same (or compatible) type, which can't be **void**.

Here is an example of the way that the **?** is employed:

```
ratio = denom == 0 ? 0 : num / denom;
```

When Java evaluates this assignment expression, it first looks at the expression to the *left* of the question mark. If **denom** equals zero, then the expression *between* the question mark and the colon is evaluated and used as the value of the entire **?** expression.

If **denom** does not equal zero, then the expression *after* the colon is evaluated and used for the value of the entire **?** expression. The result produced by the **?** operator is then assigned to **ratio**. Here is a program that demonstrates the **?** operator. It uses it to obtain the absolute value of a variable.

```
// Demonstrate ?.
class Ternary {
public static void main(String args[]) {
int i, k;
i = 10;
k = i < 0 ? -i : i; // get absolute value of i
System.out.print("Absolute value of ");
System.out.println(i + " is " + k);
i = -10;
k = i < 0 ? -i : i; // get absolute value of i
System.out.print("Absolute value of ");
System.out.println(i + " is " + k);
}
}
```

The output generated by the program is shown here:

```
Absolute value of 10 is 10
Absolute value of -10 is 10
```

Operator Precedence

Table below shows the order of precedence for Java operators, from highest to lowest. Operators in the same row are equal in precedence. In binary operations, the order of evaluation is left to right (except for assignment, which evaluates right to left).

Although they are technically separators, the **[ ]**, **( )**, and **.** can also act like operators. In that capacity, they would have the highest precedence. Also, notice the arrow operator (->). It was added by JDK 8 and is used in lambda expressions.

Highest						
++ (postfix)	-- (postfix)					
++ (prefix)	-- (prefix)	~	!	+ (unary)	- (unary)	(*type-cast*)
*	/	%				
+	-					
>>	>>>	<<				
>	>=	<	<=	instanceof		
==	!=					
&						
^						
|						
&&						
||						
?:						
->						
=	op=					
Lowest						

Table: The Precedence of the Java Operators

Using Parentheses:

Parentheses raise the precedence of the operations that are inside them. This is often necessary to obtain the result you desire. For example, consider the following expression: a >> b + 3

This expression first adds 3 to **b** and then shifts **a** right by that result. That is, this expression can be rewritten using redundant parentheses like this: a >> (b + 3)

However, if you want to first shift **a** right by **b** positions and then add 3 to that result, you will need to parenthesize the expression like this: (a >> b) + 3

In addition to altering the normal precedence of an operator, parentheses can sometimes be used to help clarify the meaning of an expression. For anyone reading your code, a complicated expression can be difficult to understand. Adding redundant but clarifying parentheses to complex expressions can help prevent confusion later. For example, which of the following expressions is easier to read?

```
a | 4 + c >> b & 7
(a | (((4 + c) >> b) & 7))
```

One other point: parentheses (redundant or not) do not degrade the performance of your program. Therefore, adding parentheses to reduce ambiguity does not negatively affect your program.

Decision Making Statements / Control Statements:

A programming language uses *control* statements to cause the flow of execution to advance and branch based on changes to the state of a program. Java's program control statements can be put into the following categories: selection, iteration, and jump.

Selection statements allow your program to choose different paths of execution based upon the outcome of an expression or the state of a variable. *Iteration* statements enable program execution to repeat one or more statements (that is, iteration statements form loops). *Jump* statements allow your program to execute in a nonlinear fashion.

Java's Selection Statements

Java supports two selection statements: **if** and **switch**. These statements allow you to control the flow of your program's execution based upon conditions known only during run time. You will be pleasantly surprised by the power and flexibility contained in these two statements.

If:

The **if** statement was introduced in Chapter 2. It is examined in detail here. The **if** statement is Java's conditional branch statement. It can be used to route program execution through two different paths. Here is the general form of the **if** statement:

```
if (condition) statement1;
else statement2;
```

Here, each *statement* may be a single statement or a compound statement enclosed in curly braces (that is, a *block*). The *condition* is any expression that returns a **boolean** value. The **else** clause is optional.

The **if** works like this: If the *condition* is true, then *statement1* is executed. Otherwise,*statement2* (if it exists) is executed. In no case will both statements be executed. For example, consider the following:

```
int a, b;
//...
if(a < b) a = 0;
else b = 0;
```

Here, if **a** is less than **b**, then **a** is set to zero. Otherwise, **b** is set to zero. In no case are they both set to zero. Most often, the expression used to control the **if** will involve the relational operators. However, this is not technically necessary. It is possible to control the **if** using a single **boolean** variable, as shown in this code fragment:

```
boolean dataAvailable;
//...
if (dataAvailable)
ProcessData();
else
waitForMoreData();
```

Remember, only one statement can appear directly after the **if** or the **else**. If you want to include more statements, you'll need to create a block, as in this fragment:

```
int bytesAvailable;
// ...
if (bytesAvailable > 0) {
ProcessData();
bytesAvailable -= n;
} else
waitForMoreData();
```

Here, both statements within the **if** block will execute if **bytesAvailable** is greater than zero. Some programmers find it convenient to include the curly braces when using the **if**, even when there is only one statement in each clause. This makes it easy to add another statement at a later date, and you don't have to worry about forgetting the braces.

Nested ifs

A *nested* **if** is an **if** statement that is the target of another **if** or **else**. Nested **if**s are very common in programming. When you nest **if**s, the main thing to remember is that an **else** statement always refers to the nearest **if** statement that is within the same block as the **else** and that is not already associated with an **else**. Here is an example:

```
if(i == 10) {
if(j < 20) a = b;
if(k > 100) c = d; // this if is
```

```
else a = c; // associated with this else
}
else a = d; // this else refers to if(i == 10)
```

As the comments indicate, the final **else** is not associated with **if(j<20)** because it is not in the same block (even though it is the nearest **if** without an **else**). Rather, the final **else** is associated with **if(i==10)**. The inner **else** refers to **if(k>100)** because it is the closest **if** within the same block.

The if-else-if Ladder:

A common programming construct that is based upon a sequence of nested **if**s is the *if-else if* ladder. It looks like this:

```
if(condition)
statement;
else if(condition)
statement;
else if(condition)
statement;
.
.
.
else
statement;
```

The **if** statements are executed from the top down. As soon as one of the conditions controlling the **if** is **true**, the statement associated with that **if** is executed, and the rest of the ladder is bypassed. If none of the conditions is true, then the final **else** statement will be executed.

The final **else** acts as a default condition; that is, if all other conditional tests fail, then the last **else** statement is performed. If there is no final **else** and all other conditions are **false**, then no action will take place.

Here is a program that uses an **if-else-if** ladder to determine which season a particular month is in.

```
// Demonstrate if-else-if statements.
class IfElse {
public static void main(String args[]) {
int month = 4; // April
String season;
if(month == 12 || month == 1 || month == 2)
season = "Winter";
else if(month == 3 || month == 4 || month == 5)
season = "Spring";
else if(month == 6 || month == 7 || month == 8)
season = "Summer";
else if(month == 9 || month == 10 || month == 11)
season = "Autumn";
```

```
else
season = "Bogus Month";
System.out.println("April is in the " + season + ".");
}
}
```

Here is the output produced by the program:

April is in the Spring.

You might want to experiment with this program before moving on. As you will find, no matter what value you give **month**, one and only one assignment statement within the ladder will be executed.

Switch:

The **switch** statement is Java's multiway branch statement. It provides an easy way to dispatch execution to different parts of your code based on the value of an expression. As such, it often provides a better alternative than a large series of **if-else-if** statements. Here is the general form of a **switch** statement:

```
switch (expression) {
case value1:
// statement sequence
break;
case value2:
// statement sequence
break;
.
.
.
case valueN :
// statement sequence
break;
default:
// default statement sequence
}
```

For versions of Java prior to JDK 7, *expression* must be of type **byte**, **short**, **int**, **char**, or an enumeration. Beginning with JDK 7, *expression* can also be of type **String**. Each value specified in the **case** statements must be a unique constant expression (such as a literal value).

Duplicate **case** values are not allowed. The type of each value must be compatible with the type of *expression*. The **switch** statement works like this: The value of the expression is compared with each of the values in the **case** statements.

If a match is found, the code sequence following that **case** statement is executed. If none of the constants matches the value of the expression, then the **default** statement is executed.

However, the **default** statement is optional. If no **case** matches and no **default** is present, then no further action is taken. The **break** statement is used inside the **switch** to terminate a statement sequence.

When a **break** statement is encountered, execution branches to the first line of code that follows the entire **switch** statement. This has the effect of "jumping out" of the **switch**. Here is a simple example that uses a **switch** statement:

```
// A simple example of the switch.
class SampleSwitch {
public static void main(String args[]) {
for(int i=0; i<6; i++)
switch(i) {
case 0:
System.out.println("i is zero.");
break;
case 1:
System.out.println("i is one.");
break;
case 2:
System.out.println("i is two.");
break;
case 3:
System.out.println("i is three.");
break;
default:
System.out.println("i is greater than 3.");
}
}
}
```

The output produced by this program is shown here:

```
i is zero.
i is one.
i is two.
i is three.
i is greater than 3.
i is greater than 3.
```

As you can see, each time through the loop, the statements associated with the **case** constant that matches **i** are executed. All others are bypassed. After **i** is greater than 3,no **case** statements match, so the **default** statement is executed.

The **break** statement is optional. If you omit the **break**, execution will continue on into the next **case**. It is sometimes desirable to have multiple **case**s without **break** statements between them. For example, consider the following program:

```
// In a switch, break statements are optional.
class MissingBreak {
public static void main(String args[]) {
```

```
for(int i=0; i<12; i++)
switch(i) {
case 0:
case 1:
case 2:
case 3:
case 4:
System.out.println("i is less than 5");
break;
case 5:
case 6:
case 7:
case 8:
case 9:
System.out.println("i is less than 10");
break;
default:
System.out.println("i is 10 or more");
}
}
}
```

This program generates the following output:

```
i is less than 5
i is less than 5
i is less than 5
i is less than 5
i is less than 5
i is less than 10
i is less than 10
i is less than 10
i is less than 10
i is less than 10
i is 10 or more
i is 10 or more
```

As you can see, execution falls through each **case** until a **break** statement (or the end of the **switch**) is reached.

While the preceding example is, of course, contrived for the sake of illustration, omitting the **break** statement has many practical applications in real programs. To sample its more realistic usage, consider the following rewrite of the season example shown earlier. This version uses a **switch** to provide a more efficient implementation.

```
// An improved version of the season program.
class Switch {
public static void main(String args[]) {
int month = 4;
String season;
```

```
switch (month) {
case 12:
case 1:
case 2:
season = "Winter";
break;
case 3:
case 4:
case 5:
season = "Spring";
break;
case 6:
case 7:
case 8:
season = "Summer";
break;
case 9:
case 10:
case 11:
season = "Autumn";
break;
default:
season = "Bogus Month";
}
System.out.println("April is in the " + season + ".");
}
}
```

As mentioned, beginning with JDK 7, you can use a string to control a **switch** statement. For example,

```
// Use a string to control a switch statement.
class StringSwitch {
public static void main(String args[]) {
String str = "two";
switch(str) {
case "one":
System.out.println("one");
break;
case "two":
System.out.println("two");
break;
case "three":
System.out.println("three");
break;
default:
System.out.println("no match");
break;
}
```

```
}
}
```

As you would expect, the output from the program is

two

The string contained in **str** (which is "two" in this program) is tested against the **case** constants. When a match is found (as it is in the second **case**), the code sequence associated with that sequence is executed.

Being able to use strings in a **switch** statement streamlines many situations. For example, using a string-based **switch** is an improvement over using the equivalent sequence of **if/else** statements. However, switching on strings can be more expensive than switching on integers.

Therefore, it is best to switch on strings only in cases in which the controlling data is already in string form. In other words, don't use strings in a **switch** unnecessarily.

Nested switch Statements:

You can use a **switch** as part of the statement sequence of an outer **switch**. This is called a *nested* **switch**. Since a **switch** statement defines its own block, no conflicts arise between the **case** constants in the inner **switch** and those in the outer **switch**. For example, the following fragment is perfectly valid:

```
switch(count) {
case 1:
switch(target) { // nested switch
case 0:
System.out.println("target is zero");
break;
case 1: // no conflicts with outer switch
System.out.println("target is one");
break;
}
break;
case 2: // ...
```

Here, the **case 1:** statement in the inner switch does not conflict with the **case 1:** statement in the outer switch. The **count** variable is compared only with the list of cases at the outer level. If **count** is 1, then **target** is compared with the inner list cases.

In summary, there are three important features of the **switch** statement to note:

- The **switch** differs from the **if** in that **switch** can only test for equality, whereas **if** can evaluate any type of Boolean expression. That is, the **switch** looks only for a match between the value of the expression and one of its **case** constants.

- No two **case** constants in the same **switch** can have identical values. Of course, a **switch** statement and an enclosing outer **switch** can have **case** constants in common.

- A **switch** statement is usually more efficient than a set of nested **if**s.

The last point is particularly interesting because it gives insight into how the Java compiler works. When it compiles a **switch** statement, the Java compiler will inspect each of the **case** constants and create a "jump table" that it will use for selecting the path of execution depending on the value of the expression.

Therefore, if you need to select among a large group of values, a **switch** statement will run much faster than the equivalent logic coded using a sequence of **if-else**s. The compiler can do this because it knows that the **case** constants are all the same type and simply must be compared for equality with the **switch** expression. The compiler has no such knowledge of a long list of **if** expressions.

Iteration Statements/Looping Statements:

Java's iteration statements are **for**, **while**, and **do-while**. These statements create what we commonly call *loops*. As you probably know, a loop repeatedly executes the same set of instructions until a termination condition is met. As you will see, Java has a loop to fit any programming need.

While:

The **while** loop is Java's most fundamental loop statement. It repeats a statement or block while its controlling expression is true. Here is its general form:

```
while(condition) {
// body of loop
}
```

The *condition* can be any Boolean expression. The body of the loop will be executed as long as the conditional expression is true. When *condition* becomes false, control passes to the next line of code immediately following the loop. The curly braces are unnecessary if only a single statement is being repeated.

Here is a **while** loop that counts down from 10, printing exactly ten lines of "tick":

```
// Demonstrate the while loop.
class While {
public static void main(String args[]) {
int n = 10;
while(n > 0) {
System.out.println("tick " + n);
n--;
}
}
}
```

When you run this program, it will "tick" ten times:

```
tick 10
tick 9
tick 8
tick 7
tick 6
tick 5
tick 4
tick 3
tick 2
tick 1
```

Since the **while** loop evaluates its conditional expression at the top of the loop, the body of the loop will not execute even once if the condition is false to begin with. For example, in the following fragment, the call to **println()** is never executed:

```
int a = 10, b = 20;

while(a > b)

System.out.println("This will not be displayed");
```

The body of the **while** (or any other of Java's loops) can be empty. This is because a *null statement* (one that consists only of a semicolon) is syntactically valid in Java. For example,

consider the following program:

```
// The target of a loop can be empty.
class NoBody {
public static void main(String args[]) {
int i, j;
i = 100;
j = 200;
// find midpoint between i and j
while(++i < --j); // no body in this loop
System.out.println("Midpoint is " + i);
}
}
```

This program finds the midpoint between **i** and **j**. It generates the following output:

```
Midpoint is 150
```

Here is how this **while** loop works. The value of **i** is incremented, and the value of **j** is decremented. These values are then compared with one another. If the new value of **i** is still less than the new value of **j**, then the loop repeats. If **i** is equal to or greater than **j**, the loop stops.

Upon exit from the loop, **i** will hold a value that is midway between the original values of **i** and **j**. (Of course, this procedure only works when **i** is less than **j** to begin with.)

As you can see, there is no need for a loop body; all of the action occurs within the conditional expression, itself. In professionally written Java code, short loops are frequently coded without bodies when the controlling expression can handle all of the details itself.

do-while:

As you just saw, if the conditional expression controlling a **while** loop is initially false, then the body of the loop will not be executed at all. However, sometimes it is desirable to execute the body of a loop at least once, even if the conditional expression is false to begin with.

In other words, there are times when you would like to test the termination expression at the end of the loop rather than at the beginning. Fortunately, Java supplies a loop that does just that: the **do-while**. The **do-while** loop always executes its body at least once, because its conditional expression is at the bottom of the loop. Its general form is

```
do {
// body of loop
} while (condition);
```

Each iteration of the **do-while** loop – first executes the body of the loop and then evaluates the conditional expression. If this expression is true, the loop will repeat. Otherwise, the loop terminates. As with all of Java's loops, *condition* must be a Boolean expression.

Here is a reworked version of the "tick" program that demonstrates the **do-while** loop. It generates the same output as before.

```
// Demonstrate the do-while loop.
class DoWhile {
public static void main(String args[]) {
int n = 10;
do {
System.out.println("tick " + n);
n--;
} while(n > 0);
}
}
```

The loop in the preceding program, while technically correct, can be written more efficiently as follows:

```
do {
System.out.println("tick " + n);
} while(--n > 0);
```

In this example, the expression **(– –n > 0)** combines the decrement of **n** and the test for zero into one expression. Here is how it works. First, the **– –n** statement executes, decrementing **n** and returning the new value of **n**. This value is then compared with zero. If it is greater than zero, the loop continues; otherwise, it terminates.

The **do-while** loop is especially useful when you process a menu selection, because you will usually want the body of a menu loop to execute at least once.

for:

Beginning with JDK 5, there are two forms of the **for** loop. The first is the traditional form that has been in use since the original version of Java. The second is the newer "for-each" form.

Both types of **for** loops are discussed here, beginning with the traditional form. Here is the general form of the traditional **for** statement:

```
for(initialization; condition; iteration) {
// body
}
```

If only one statement is being repeated, there is no need for the curly braces. The **for** loop operates as follows. When the loop first starts, the *initialization* portion of the loop is executed. Generally, this is an expression that sets the value of the *loop control variable*, which acts as a counter that controls the loop. It is important to understand that the initialization expression is executed only once. Next, *condition* is evaluated. This must be a Boolean expression.

It usually tests the loop control variable against a target value. If this expression is true, then the body of the loop is executed. If it is false, the loop terminates. Next, the *iteration* portion of the loop is executed.

This is usually an expression that increments or decrements the loop control variable. The loop then iterates, first evaluating the conditional expression, then executing the body of the loop, and then executing the iteration expression with each pass. This process repeats until the controlling expression is false. Here is a version of the "tick" program that uses a **for** loop:

```
// Demonstrate the for loop.
class ForTick {
public static void main(String args[]) {
int n;
for(n=10; n>0; n--)
System.out.println("tick " + n);
}
}
```

Declaring Loop Control Variables Inside the for Loop:

Often the variable that controls a **for** loop is needed only for the purposes of the loop and is not used elsewhere. When this is the case, it is possible to declare the variable inside the initialization portion of the **for**.

For example, here is the preceding program recoded so that the loop control variable **n** is declared as an **int** inside the **for**:

```
// Declare a loop control variable inside the for.
class ForTick {
public static void main(String args[]) {
// here, n is declared inside of the for loop
for(int n=10; n>0; n--)
System.out.println("tick " + n);
}
}
```

When you declare a variable inside a **for** loop, there is one important point to remember: the scope of that variable ends when the **for** statement does. (That is, the scope of the variable is limited to the **for** loop.) Outside the **for** loop, the variable will cease to exist.

If you need to use the loop control variable elsewhere in your program, you will not be able to declare it inside the **for** loop. When the loop control variable will not be needed elsewhere, most Java programmers declare it inside the **for**. For example, here is a simple program that tests for prime numbers.

Notice that the loop control variable, **i**, is declared inside the **for** since it is not needed elsewhere.

```
// Test for primes.
class FindPrime {
public static void main(String args[]) {
int num;
boolean isPrime;
num = 14;
if(num < 2) isPrime = false;
else isPrime = true;
for(int i=2; i <= num/i; i++) {
if((num % i) == 0) {
isPrime = false;
break;
}
}
if(isPrime) System.out.println("Prime");
else System.out.println("Not Prime");
}
}
```

Using the Comma:

There will be times when you will want to include more than one statement in the initialization and iteration portions of the **for** loop. For example, consider the loop in the following program:

```
class Sample {
public static void main(String args[]) {
int a, b;
b = 4;
for(a=1; a<b; a++) {
System.out.println("a = " + a);
System.out.println("b = " + b);
b--;
}
}
}
```

As you can see, the loop is controlled by the interaction of two variables. Since the loop is governed by two variables, it would be useful if both could be included in the **for** statement, itself, instead of **b** being handled manually. Fortunately, Java provides a way to accomplish this.

To allow two or more variables to control a **for** loop, Java permits you to include multiple statements in both the initialization and iteration portions of the **for**. Each statement is separated from the next by a comma. Using the comma, the preceding **for** loop can be more efficiently coded, as shown here:

```
// Using the comma.
class Comma {
public static void main(String args[]) {
int a, b;
for(a=1, b=4; a<b; a++, b--) {
System.out.println("a = " + a);
System.out.println("b = " + b);
}
}
}
```

In this example, the initialization portion sets the values of both **a** and **b**. The two comma separated statements in the iteration portion are executed each time the loop repeats. The program generates the following output:

```
a = 1
b = 4
a = 2
b = 3
```

NOTE If you are familiar with C/C++, then you know that in those languages the comma is an operator that can be used in any valid expression. However, this is not the case with Java. In Java, the comma is a separator.

Some for Loop Variations:

The **for** loop supports a number of variations that increase its power and applicability. The reason it is so flexible is that its three parts—the initialization, the conditional test, and the iteration—do not need to be used for only those purposes.

In fact, the three sections of the **for** can be used for any purpose you desire. One of the most common variations involves the conditional expression. Specifically, this expression does not need to test the loop control variable against some target value. In fact, the condition controlling the **for** can be any Boolean expression. For example, consider the following fragment:

```
boolean done = false;
for(int i=1; !done; i++) {
// ...
if(interrupted()) done = true;
}
```

In this example, the **for** loop continues to run until the **boolean** variable **done** is set to **true**. It does not test the value of **i**. Here is another interesting **for** loop variation. Either the initialization or the iteration expression or both may be absent, as in this next program:

```
// Parts of the for loop can be empty.
class ForVar {
public static void main(String args[]) {
int i;
boolean done = false;
i = 0;
for( ; !done; ) {
System.out.println("i is " + i);
if(i == 10) done = true;
i++;
}
}
}
```

Here, the initialization and iteration expressions have been moved out of the **for**. Thus, parts of the **for** are empty. While this is of no value in this simple example—indeed, it would be considered quite poor style—there can be times when this type of approach makes sense.

For example, if the initial condition is set through a complex expression elsewhere in the program or if the loop control variable changes in a non sequential manner determined by actions that occur within the body of the loop, it may be appropriate to leave these parts of the **for** empty.

Here is one more **for** loop variation. You can intentionally create an infinite loop (a loop that never terminates) if you leave all three parts of the **for** empty. For example:

```
for( ; ; ) {
// ...
}
```

This loop will run forever because there is no condition under which it will terminate.

Although there are some programs, such as operating system command processors, that require an infinite loop, most "infinite loops" are really just loops with special termination requirements.

The For-Each Version of the for Loop

Beginning with JDK 5, a second form of **for** was defined that implements a "for-each" style loop. As you may know, contemporary language theory has embraced the for-each concept, and it has become a standard feature that programmers have come to expect.

A for-each style loop is designed to cycle through a collection of objects, such as an array, in strictly sequential fashion, from start to finish. Unlike some languages, such as C#, that implement a for-each loop by using the keyword **foreach**, Java adds the for-each capability by enhancing the **for** statement.

The advantage of this approach is that no new keyword is required, and no preexisting code is broken. The for-each style of **for** is also referred to as the *enhanced* **for** loop. The general form of the for-each version of the **for** is shown here:

for(*type itr-var* : *collection*) *statement-block*

Here, *type* specifies the type and *itr-var* specifies the name of an *iteration variable* that will receive the elements from a collection, one at a time, from beginning to end. The collection being cycled through is specified by *collection*. There are various types of collections that can be used with the **for**, but the only type used in this chapter is the array.

With each iteration of the loop, the next element in the collection is retrieved and stored in *itr-var*. The loop repeats until all elements in the collection have been obtained. Because the iteration variable receives values from the collection, *type* must be the same as(or compatible with) the elements stored in the collection.

Thus, when iterating over arrays, *type* must be compatible with the element type of the array. To understand the motivation behind a for-each style loop, consider the type of **for** loop that it is designed to replace. The following fragment uses a traditional **for** loop to compute the sum of the values in an array:

```
int nums[] = { 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 };
int sum = 0;
for(int i=0; i < 10; i++) sum += nums[i];
```

To compute the sum, each element in **nums** is read, in order, from start to finish. Thus, the entire array is read in strictly sequential order. This is accomplished by manually indexing the **nums** array by **i**, the loop control variable.

The for-each style **for** automates the preceding loop. Specifically, it eliminates the need to establish a loop counter, specify a starting and ending value, and manually index the array. Instead, it automatically cycles through the entire array, obtaining one element at a time, in sequence, from beginning to end. For example, here is the preceding fragment rewritten using a for-each version of the **for**:

```
int nums[] = { 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 };
int sum = 0;
for(int x: nums) sum += x;
```

With each pass through the loop, **x** is automatically given a value equal to the next element in **nums**. Thus, on the first iteration, **x** contains 1; on the second iteration, **x** contains 2; and soon. Not only is the syntax streamlined, but it also prevents boundary errors.

Here is an entire program that demonstrates the for-each version of the **for** just described:

```
// Use a for-each style for loop.
class ForEach {
public static void main(String args[]) {
int nums[] = { 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 };
int sum = 0;
// use for-each style for to display and sum the values
for(int x : nums) {
System.out.println("Value is: " + x);
sum += x;
}
System.out.println("Summation: " + sum);
}
}
```

The output from the program is shown here:

```
Value is: 1
Value is: 2
Value is: 3
Value is: 4
Value is: 5
Value is: 6
Value is: 7
Value is: 8
Value is: 9
Value is: 10
Summation: 55
```

As this output shows, the for-each style **for** automatically cycles through an array in sequence from the lowest index to the highest. Although the for-each **for** loop iterates until all elements in an array have been examined, it is possible to terminate the loop early by using a **break** statement. For example, this program sums only the first five elements of **nums**:

```
// Use break with a for-each style for.
class ForEach2 {
public static void main(String args[]) {
int sum = 0;
int nums[] = { 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 };
```

```
// use for to display and sum the values
for(int x : nums) {
System.out.println("Value is: " + x);
sum += x;
if(x == 5) break; // stop the loop when 5 is obtained
}
System.out.println("Summation of first 5 elements: " + sum);
}
}
```

This is the output produced:

```
Value is: 1
Value is: 2
Value is: 3
Value is: 4
Value is: 5
Summation of first 5 elements: 15
```

As is evident, the **for** loop stops after the fifth element has been obtained. The **break** statement can also be used with Java's other loops. There is one important point to understand about the for-each style loop. Its iteration variable is "read-only" as it relates to the underlying array. An assignment to the iteration variable has no effect on the underlying array.

In other words, you can't change the contents of the array by assigning the iteration variable a new value. For example, consider this program:

```
// The for-each loop is essentially read-only.
class NoChange {
public static void main(String args[]) {
int nums[] = { 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 };
for(int x: nums) {
System.out.print(x + " ");
x = x * 10; // no effect on nums
}
System.out.println();
for(int x : nums)
System.out.print(x + " ");
System.out.println();
}
}
```

The first **for** loop increases the value of the iteration variable by a factor of 10. However, this assignment has no effect on the underlying array **nums**, as the second **for** loop illustrates. The output, shown here, proves this point:

```
1 2 3 4 5 6 7 8 9 10
1 2 3 4 5 6 7 8 9 10
```

Iterating Over Multidimensional Arrays:

The enhanced version of the **for** also works on multidimensional arrays. Remember, however, that in Java, multidimensional arrays consist of *arrays of arrays*. (For example, a two-dimensional array is an array of one-dimensional arrays.)

This is important when iterating over a multidimensional array, because each iteration obtains the *next array*, not an individual element. Furthermore, the iteration variable in the **for** loop must be compatible with the type of array being obtained.

For example, in the case of a two-dimensional array, the iteration variable must be a reference to a one-dimensional array. In general, when using the for-each **for** to iterate over an array of *N* dimensions, the objects obtained will be arrays of *N*–1 dimensions.

To understand the implications of this, consider the following program. It uses nested **for** loops to obtain the elements of a two-dimensional array in row order, from first to last.

```
// Use for-each style for on a two-dimensional array.
class ForEach3 {
public static void main(String args[]) {
int sum = 0;
int nums[][] = new int[3][5];
// give nums some values
for(int i = 0; i < 3; i++)
for(int j = 0; j < 5; j++)
nums[i][j] = (i+1)*(j+1);
// use for-each for to display and sum the values
for(int x[] : nums) {
for(int y : x) {
System.out.println("Value is: " + y);
sum += y;
}
}
System.out.println("Summation: " + sum);
}
}
```

The output from this program is shown here:

```
Value is: 1
Value is: 2
Value is: 3
Value is: 4
Value is: 5
Value is: 2
Value is: 4
Value is: 6
Value is: 8
Value is: 10
```

```
Value is: 3
Value is: 6
Value is: 9
Value is: 12
Value is: 15
Summation: 90
```

In the program, pay special attention to this line:

```
for(int x[]: nums) {
```

Notice how **x** is declared. It is a reference to a one-dimensional array of integers. This is necessary because each iteration of the **for** obtains the next *array* in **nums**, beginning with the array specified by **nums[0]**. The inner **for** loop then cycles through each of these arrays, displaying the values of each element.

Applying the Enhanced for:

Since the for-each style **for** can only cycle through an array sequentially, from start to finish, you might think that its use is limited, but this is not true. A large number of algorithms require exactly this mechanism. One of the most common is searching. For example, the following program uses a **for** loop to search an unsorted array for a value. It stops if the value is found.

```
// Search an array using for-each style for.
class Search {
public static void main(String args[]) {
int nums[] = { 6, 8, 3, 7, 5, 6, 1, 4 };
int val = 5;
boolean found = false;
// use for-each style for to search nums for val
for(int x : nums) {
if(x == val) {
found = true;
break;
}
}
if(found)
System.out.println("Value found!");
}
}
```

The for-each style **for** is an excellent choice in this application because searching an unsorted array involves examining each element in sequence. (Of course, if the array we resorted, a binary search could be used, which would require a different style loop.)

Other types of applications that benefit from for-each style loops include computing an average, finding the minimum or maximum of a set, looking for duplicates, and so on.

Nested Loops:

Like all other programming languages, Java allows loops to be nested. That is, one loop may be inside another. For example, here is a program that nests **for** loops:

```
// Loops may be nested.
class Nested {
public static void main(String args[]) {
int i, j;
for(i=0; i<10; i++) {
for(j=i; j<10; j++)
System.out.print(".");
System.out.println();
}
}
}
```

The output produced by this program is shown here:

```
.........
........
.......
......
.....
....
...
..
.
```

Jump Statements:

Java supports three jump statements: **break**, **continue**, and **return**. These statements transfer control to another part of your program. Each is examined here.

Using break:

In Java, the **break** statement has three uses. First, as you have seen, it terminates a statement sequence in a **switch** statement. Second, it can be used to exit a loop. Third, it can be used as a "civilized" form of goto. The last two uses are explained here.

Using break to Exit a Loop:

By using **break**, you can force immediate termination of a loop, bypassing the conditional expression and any remaining code in the body of the loop. When a **break** statement is encountered inside a loop, the loop is terminated and program control resumes at the next statement following the loop. Here is a simple example:

```
// Using break to exit a loop.
class BreakLoop {
public static void main(String args[]) {
```

```
for(int i=0; i<100; i++) {
if(i == 10) break; // terminate loop if i is 10
System.out.println("i: " + i);
}
System.out.println("Loop complete.");
}
}
```

This program generates the following output:

```
i: 0
i: 1
i: 2
i: 3
i: 4
i: 5
i: 6
i: 7
i: 8
i: 9
Loop complete.
```

As you can see, although the **for** loop is designed to run from 0 to 99, the **break** statement causes it to terminate early, when **i** equals 10.

The **break** statement can be used with any of Java's loops, including intentionally infinite loops. For example, here is the preceding program coded by use of a **while** loop. The output from this program is the same as just shown.

```
// Using break to exit a while loop.
class BreakLoop2 {
public static void main(String args[]) {
int i = 0;
while(i < 100) {
if(i == 10) break; // terminate loop if i is 10
System.out.println("i: " + i);
i++;
}
System.out.println("Loop complete.");
}
}
```

When used inside a set of nested loops, the **break** statement will only break out of the innermost loop. For example:

```
// Using break with nested loops.
class BreakLoop3 {
public static void main(String args[]) {
for(int i=0; i<3; i++) {
System.out.print("Pass " + i + ": ");
for(int j=0; j<100; j++) {
```

```
if(j == 10) break; // terminate loop if j is 10
System.out.print(j + " ");
}
System.out.println();
}
System.out.println("Loops complete.");
}       }
```

This program generates the following output:

```
Pass 0: 0 1 2 3 4 5 6 7 8 9
Pass 1: 0 1 2 3 4 5 6 7 8 9
Pass 2: 0 1 2 3 4 5 6 7 8 9
Loops complete.
```

As you can see, the **break** statement in the inner loop only causes termination of that loop. The outer loop is unaffected.

Here are two other points to remember about **break**. First, more than one **break** statement may appear in a loop. However, be careful. Too many **break** statements have the tendency to destructure your code. Second, the **break** that terminates a **switch** statement affects only that **switch** statement and not any enclosing loops.

Using break as a Form of Goto:

In addition to its uses with the **switch** statement and loops, the **break** statement can also be employed by itself to provide a "civilized" form of the goto statement. Java does not have a goto statement because it provides a way to branch in an arbitrary and unstructured manner.

This usually makes goto-ridden code hard to understand and hard to maintain. It also prohibits certain compiler optimizations. There are, however, a few places where the goto is a valuable and legitimate construct for flow control. For example, the goto can be useful when you are exiting from a deeply nested set of loops. To handle such situations, Java defines an expanded form of the **break** statement.

By using this form of **break**, you can, for example, break out of one or more blocks of code. These blocks need not be part of a loop or a **switch**. They can be any block. Further, you can specify precisely where execution will resume, because this form of **break** works with a label. As you will see, **break** gives you the benefits of a goto without its problems. The general form of the labeled **break** statement is shown here:

break *label*;

Most often, *label* is the name of a label that identifies a block of code. This can be a standalone block of code but it can also be a block that is the target of another statement. When this form of **break** executes, control is transferred out of the named block.

The labelled block must enclose the **break** statement, but it does not need to be the immediately enclosing block. This means, for example, that you can use a labeled **break** statement to exit from a set of nested blocks. But you cannot use **break** to transfer control out of a block that does not enclose the **break** statement.

To name a block, put a label at the start of it. A *label* is any valid Java identifier followed by a colon. Once you have labeled a block, you can then use this label as the target of a **break** statement. Doing so causes execution to resume at the *end* of the labeled block.

For example, the following program shows three nested blocks, each with its own label. The **break** statement causes execution to jump forward, past the end of the block labeled **second**, skipping the two **println( )** statements.

```
// Using break as a civilized form of goto.
class Break {
public static void main(String args[]) {
boolean t = true;
first: {
second: {
third: {
System.out.println("Before the break.");
if(t) break second; // break out of second block
System.out.println("This won't execute");
}
System.out.println("This won't execute");
}
System.out.println("This is after second block.");
}
}
}
```

Running this program generates the following output:

```
Before the break.
This is after second block.
```

One of the most common uses for a labeled **break** statement is to exit from nested loops. For example, in the following program, the outer loop executes only once:

```
// Using break to exit from nested loops
class BreakLoop4 {
public static void main(String args[]) {
outer: for(int i=0; i<3; i++) {
System.out.print("Pass " + i + ": ");
for(int j=0; j<100; j++) {
if(j == 10) break outer; // exit both loops
System.out.print(j + " ");
}
System.out.println("This will not print");
}
System.out.println("Loops complete.");
}
}
```

This program generates the following output:

Pass 0: 0 1 2 3 4 5 6 7 8 9 Loops complete.

As you can see, when the inner loop breaks to the outer loop, both loops have been terminated. Notice that this example labels the **for** statement, which has a block of code as its target.

Keep in mind that you cannot break to any label which is not defined for an enclosing block. For example, the following program is invalid and will not compile:

```
// This program contains an error.
class BreakErr {
public static void main(String args[]) {
one: for(int i=0; i<3; i++) {
System.out.print("Pass " + i + ": ");
}
for(int j=0; j<100; j++) {
if(j == 10) break one; // WRONG
System.out.print(j + " ");
}
}
}
```

Since the loop labeled **one** does not enclose the **break** statement, it is not possible to transfer control out of that block.

Using continue:

Sometimes it is useful to force an early iteration of a loop. That is, you might want to continue running the loop but stop processing the remainder of the code in its body for this particular iteration. This is, in effect, a goto just past the body of the loop, to the loop's end.

The **continue** statement performs such an action. In **while** and **do-while** loops, a **continue** statement causes control to be transferred directly to the conditional expression that controls the loop. In a **for** loop, control goes first to the iteration portion of the **for** statement and then to the conditional expression. For all three loops, any intermediate code is bypassed.

Here is an example program that uses **continue** to cause two numbers to be printed on each line:

```
// Demonstrate continue.
class Continue {
public static void main(String args[]) {
for(int i=0; i<10; i++) {
System.out.print(i + " ");
if (i%2 == 0) continue;
System.out.println("");
}
}
}
```

This code uses the **%** operator to check if **i** is even. If it is, the loop continues without printing a newline. Here is the output from this program:

```
0 1
2 3
4 5
6 7
8 9
```

As with the **break** statement, **continue** may specify a label to describe which enclosing loop to continue. Here is an example program that uses **continue** to print a triangular multiplication table for 0 through 9:

```
// Using continue with a label.
class ContinueLabel {
public static void main(String args[]) {
outer: for (int i=0; i<10; i++) {
for(int j=0; j<10; j++) {
if(j > i) {
System.out.println();
continue outer;
}
System.out.print(" " + (i * j));
}
}
System.out.println();
}
}
```

The **continue** statement in this example terminates the loop counting **j** and continues with the next iteration of the loop counting **i**. Here is the output of this program:

```
0
0 1
0 2 4
0 3 6 9
0 4 8 12 16
0 5 10 15 20 25
0 6 12 18 24 30 36
0 7 14 21 28 35 42 49
0 8 16 24 32 40 48 56 64
0 9 18 27 36 45 54 63 72 81
```

Good uses of **continue** are rare. One reason is that Java provides a rich set of loop statements which fit most applications. However, for those special circumstances in which early iteration is needed, the **continue** statement provides a structured way to accomplish it.

return:

The last control statement is **return**. The **return** statement is used to explicitly return from a method. That is, it causes program control to transfer back to the caller of the method. As such, it is categorized as a jump statement. Although a full discussion of **return** must wait until methods are discussed in Chapter 6, a brief look at **return** is presented here.

At any time in a method, the **return** statement can be used to cause execution to branch back to the caller of the method. Thus, the **return** statement immediately terminates the method in which it is executed. The following example illustrates this point. Here, **return** causes execution to return to the Java run-time system, since it is the run-time system that calls **main( )**:

```
// Demonstrate return.
class Return {
public static void main(String args[]) {
boolean t = true;
System.out.println("Before the return.");
if(t) return; // return to caller
System.out.println("This won't execute.");
}
}
```

The output from this program is shown here:

```
Before the return.
```

Methods:

Classes usually consist of two things: instance variables and methods. The general form of a method is:

```
type name(parameter-list) {
// body of method
}
```

Here, *type* specifies the type of data returned by the method. This can be any valid type, including class types that you create. If the method does not return a value, its return type must be **void**. The name of the method is specified by *name*. This can be any legal identifier other than those already used by other items within the current scope.

The *parameter-list* is a sequence of type and identifier pairs separated by commas. Parameters are essentially variables that receive the value of the arguments passed to the method when it is called.

If the method has no parameters, then the parameter list will be empty. Methods that have a return type other than **void** return a value to the calling routine using the following form of the **return** statement: return *value*;

Here, *value* is the value returned.

In the next few sections, you will see how to create various types of methods, including those that take parameters and those that return values.

Adding a Method to the Box Class:

Although it is perfectly fine to create a class that contains only data, it rarely happens. Most of the time, you will use methods to access the instance variables defined by the class. In fact, methods define the interface to most classes. This allows the class implement or to hide the specific layout of internal data structures behind cleaner method abstractions. In addition to defining methods that provide access to data, you can also define methods that are used internally by the class itself.

Let's begin by adding a method to the **Box** class. It may have occurred to you while looking at the preceding programs that the computation of a box's volume was something that was best handled by the **Box** class rather than the **BoxDemo** class. After all, since the volume of a box is dependent upon the size of the box, it makes sense to have the **Box** class compute it. To do this, you must add a method to **Box**, as shown here:

```
// This program includes a method inside the box class.

class Box {
double width;
double height;
double depth;
// display volume of a box
void volume() {
System.out.print("Volume is ");
System.out.println(width * height * depth);
}
}
class BoxDemo3 {
public static void main(String args[]) {
Box mybox1 = new Box();
Box mybox2 = new Box();
// assign values to mybox1's instance variables
mybox1.width = 10;
mybox1.height = 20;
mybox1.depth = 15;
/* assign different values to mybox2's
instance variables */
mybox2.width = 3;
mybox2.height = 6;
mybox2.depth = 9;
// display volume of first box
mybox1.volume();
// display volume of second box
mybox2.volume();
}
}
```

This program generates the following output, which is the same as the previous version.

```
Volume is 3000.0
Volume is 162.0
```

Look closely at the following two lines of code:

```
mybox1.volume();
mybox2.volume();
```

The first line here invokes the **volume( )** method on **mybox1**. That is, it calls **volume( )**relative to the **mybox1** object, using the object's name followed by the dot operator. Thus, the call to **mybox1.volume( )** displays the volume of the box defined by **mybox1**, and the call to **mybox2.volume( )** displays the volume of the box defined by **mybox2**. Each time **volume( )** is invoked, it displays the volume for the specified box.

If you are unfamiliar with the concept of calling a method, the following discussion will help clear things up. When **mybox1.volume( )** is executed, the Java run-time system transfers control to the code defined inside **volume( )**.

After the statements inside **volume( )** have executed, control is returned to the calling routine, and execution resumes with the line of code following the call. In the most general sense, a method is Java's way of implementing subroutines.

There is something very important to notice inside the **volume( )** method: the instance variables **width**, **height**, and **depth** are referred to directly, without preceding them with an object name or the dot operator.

When a method uses an instance variable that is defined by its class, it does so directly, without explicit reference to an object and without use of the dot operator. This is easy to understand if you think about it. A method is always invoked relative to some object of its class. Once this invocation has occurred, the object is known.

Thus, within a method, there is no need to specify the object a second time. This means that **width**, **height**, and **depth** inside **volume( )** implicitly refer to the copies of those variables found in the object that invokes **volume( )**.

Let's review: *When an instance variable is accessed by code that is not part of the class in which that instance variable is defined, it must be done through an object, by use of the dot operator. However, when an instance variable is accessed by code that is part of the same class as the instance variable, that variable can be referred to directly. The same thing applies to methods.*

Returning a Value

While the implementation of **volume( )** does move the computation of a box's volume inside the **Box** class where it belongs, it is not the best way to do it. For example, what if another part of your program wanted to know the volume of a box, but not display its value? A better way to implement **volume( )** is to have it compute the volume of the box and return the result to the caller.

The following example, an improved version of the preceding program, does just that:

```
// Now, volume() returns the volume of a box.
class Box {
double width;
double height;
double depth;
// compute and return volume
double volume() {
return width * height * depth;
}
}
class BoxDemo4 {
public static void main(String args[]) {
Box mybox1 = new Box();
Box mybox2 = new Box();
double vol;
// assign values to mybox1's instance variables
mybox1.width = 10;
mybox1.height = 20;
mybox1.depth = 15;
/* assign different values to mybox2's
instance variables */
mybox2.width = 3;
mybox2.height = 6;
mybox2.depth = 9;
// get volume of first box
vol = mybox1.volume();
System.out.println("Volume is " + vol);
// get volume of second box
vol = mybox2.volume();
System.out.println("Volume is " + vol);
}
}
```

As you can see, when **volume( )** is called, it is put on the right side of an assignment statement. On the left is a variable, in this case **vol**, that will receive the value returned by **volume( )**. Thus, after

```
vol = mybox1.volume();
```

executes, the value of **mybox1.volume( )** is 3,000 and this value then is stored in **vol**. There are two important things to understand about returning values:

- The type of data returned by a method must be compatible with the return type specified by the method. For example, if the return type of some method is **boolean**, you could not return an integer.
- The variable receiving the value returned by a method (such as **vol**, in this case) must also be compatible with the return type specified for the method.

One more point: The preceding program can be written a bit more efficiently because there is actually no need for the **vol** variable. The call to **volume( )** could have been used in the **println( )** statement directly, as shown here:

```
System.out.println("Volume is" + mybox1.volume());
```

In this case, when **println( )** is executed, **mybox1.volume( )** will be called automatically and its value will be passed to **println( )**.

Adding a Method That Takes Parameters

While some methods don't need parameters, most do. Parameters allow a method to be generalized. That is, a parameterized method can operate on a variety of data and/or be used in a number of slightly different situations. To illustrate this point, let's use a very simple example. Here is a method that returns the square of the number 10:

```
int square()
{
return 10 * 10;
}
```

While this method does, indeed, return the value of 10 squared, its use is very limited. However, if you modify the method so that it takes a parameter, as shown next, then you can make **square( )** much more useful.

```
int square(int i)
{
return i * i;
}
```

Now, **square( )** will return the square of whatever value it is called with. That is, **square( )** is now a general-purpose method that can compute the square of any integer value, rather than just 10.

Here is an example:

```
int x, y;
x = square(5); // x equals 25
x = square(9); // x equals 81

y = 2;

x = square(y); // x equals 4
```

In the first call to **square( )**, the value 5 will be passed into parameter **i**. In the second call, **I** will receive the value 9. The third invocation passes the value of **y**, which is 2 in this example.

As these examples show, **square( )** is able to return the square of whatever data it is passed. It is important to keep the two terms *parameter* and *argument* straight. A *parameter* is a variable defined by a method that receives a value when the method is called.

For example, in **square( )**, **i** is a parameter. An *argument* is a value that is passed to a method when it is invoked. For example, **square(100)** passes 100 as an argument. Inside **square( )**, the parameter **i** receives that value.

You can use a parameterized method to improve the **Box** class. In the preceding examples, the dimensions of each box had to be set separately by use of a sequence of statements, such as:

```
mybox1.width = 10;
mybox1.height = 20;
mybox1.depth = 15;
```

While this code works, it is troubling for two reasons. First, it is clumsy and error prone. For example, it would be easy to forget to set a dimension. Second, in well-designed Java programs, instance variables should be accessed only through methods defined by their class. In the future, you can change the behavior of a method, but you can't change the behavior of an exposed instance variable.

Thus, a better approach to setting the dimensions of a box is to create a method that takes the dimensions of a box in its parameters and sets each instance variable appropriately. This concept is implemented by the following program:

```
// This program uses a parameterized method.
class Box {
double width;
double height;
double depth;
// compute and return volume
double volume() {
return width * height * depth;
}
// sets dimensions of box
void setDim(double w, double h, double d) {
width = w;
height = h;
depth = d;
}
}

class BoxDemo5 {
public static void main(String args[]) {
Box mybox1 = new Box();
Box mybox2 = new Box();
double vol;
// initialize each box
mybox1.setDim(10, 20, 15);
mybox2.setDim(3, 6, 9);
// get volume of first box
vol = mybox1.volume();
System.out.println("Volume is " + vol);
// get volume of second box
```

```
vol = mybox2.volume();
System.out.println("Volume is " + vol);
}
}
```

As you can see, the **setDim( )** method is used to set the dimensions of each box. For example, when

```
mybox1.setDim(10, 20, 15);
```

is executed, 10 is copied into parameter **w**, 20 is copied into **h**, and 15 is copied into **d**. Inside **setDim( )** the values of **w**, **h**, and **d** are then assigned to **width**, **height**, and **depth**, respectively.

Recursion:

Java supports *recursion*. Recursion is the process of defining something in terms of itself.

As it relates to Java programming, recursion is the attribute that allows a method to call itself. A method that calls itself is said to be *recursive*.

The classic example of recursion is the computation of the factorial of a number. The factorial of a number *N* is the product of all the whole numbers between 1 and *N*. For example, 3 factorial is 1 × 2 × 3 ×, or 6. Here is how a factorial can be computed by use of a recursive method:

```
// A simple example of recursion.
class Factorial {
// this is a recursive method
int fact(int n) {
int result;
if(n==1) return 1;
result = fact(n-1) * n;
return result;
}
}
class Recursion {
public static void main(String args[]) {
Factorial f = new Factorial();
System.out.println("Factorial of 3 is " + f.fact(3));
System.out.println("Factorial of 4 is " + f.fact(4));
System.out.println("Factorial of 5 is " + f.fact(5));
}
}
```

The output from this program is shown here:

```
Factorial of 3 is 6
Factorial of 4 is 24
Factorial of 5 is 120
```

If you are unfamiliar with recursive methods, then the operation of **fact( )** may seem a bit confusing. Here is how it works. When **fact( )** is called with an argument of 1, the function returns 1; otherwise, it returns the product of **fact(n–1)*n**. To evaluate this expression, **fact( )** is called with **n–1**. This process repeats until **n** equals 1 and the calls to the method begin returning.

Method Overloading:

In Java, it is possible to define two or more methods within the same class that share the same name, as long as their parameter declarations are different.

When this is the case, the methods are said to be overloaded, and the process is referred to as *method overloading*. Method overloading is one of the ways that Java supports polymorphism.

When an overloaded method is invoked, Java uses the type and/or number of arguments as its guide to determine which version of the overloaded method to actually call. Thus, overloaded methods must differ in the type and/or number of their parameters.

While overloaded methods may have different return types, the return type alone is insufficient to distinguish two versions of a method. When Java encounters a call to an overloaded method, it simply executes the version of the method whose parameters match the arguments used in the call. Here is a simple example that illustrates method overloading:

```
// Demonstrate method overloading.
class OverloadDemo {
void test() {
System.out.println("No parameters");
}
// Overload test for one integer parameter.
void test(int a) {
System.out.println("a: " + a);
}
// Overload test for two integer parameters.
void test(int a, int b) {
System.out.println("a and b: " + a + " " + b);
}
// Overload test for a double parameter
double test(double a) {
System.out.println("double a: " + a);
return a*a;
}
}
class Overload {
public static void main(String args[]) {
OverloadDemo ob = new OverloadDemo();
double result;
// call all versions of test()
```

```
ob.test();
ob.test(10);
ob.test(10, 20);
result = ob.test(123.25);
System.out.println("Result of ob.test(123.25): " + result);
}
}
```

This program generates the following output:

```
No parameters
a: 10
a and b: 10 20
double a: 123.25
Result of ob.test(123.25): 15190.5625
```

As you can see, **test( )** is overloaded four times. The first version takes no parameters, the second takes one integer parameter, the third takes two integer parameters, and the fourth takes one **double** parameter. The fact that the fourth version of **test( )** also returns a value is of no consequence relative to overloading, since return types do not play a role in overload resolution.

When an overloaded method is called, Java looks for a match between the arguments used to call the method and the method's parameters. However, this match need not always be exact. In some cases, Java's automatic type conversions can play a role in overload resolution. For example, consider the following program:

```
// Automatic type conversions apply to overloading.
class OverloadDemo {
void test() {
System.out.println("No parameters");
}
// Overload test for two integer parameters.
void test(int a, int b) {
System.out.println("a and b: " + a + " " + b);
}
// Overload test for a double parameter
void test(double a) {
System.out.println("Inside test(double) a: " + a);
}
}
class Overload {
public static void main(String args[]) {
OverloadDemo ob = new OverloadDemo();
int i = 88;
ob.test();
ob.test(10, 20);
ob.test(i); // this will invoke test(double)
ob.test(123.2); // this will invoke test(double)
}
```

```
}
```

This program generates the following output:

```
No parameters
a and b: 10 20
Inside test(double) a: 88
Inside test(double) a: 123.2
```

As you can see, this version of **OverloadDemo** does not define **test(int)**. Therefore, when **test( )** is called with an integer argument inside **Overload**, no matching method is found. However, Java can automatically convert an integer into a **double**, and this conversion can be used to resolve the call. Therefore, after **test(int)** is not found, Java elevates **i** to **double** and then calls **test(double)**.

Of course, if **test(int)** had been defined, it would have been called instead. Java will employ its automatic type conversions only if no exact match is found. Method overloading supports polymorphism because it is one way that Java implements the "one interface, multiple methods" paradigm. To understand how, consider the following:

In languages that do not support method overloading, each method must be given a unique name. However, frequently you will want to implement essentially the same method for different types of data. Consider the absolute value function. In languages that do not support overloading, there are usually three or more versions of this function, each with a slightly different name.

For instance, in C, the function **abs( )** returns the absolute value of an integer, **labs( )** returns the absolute value of a long integer, and **fabs( )** returns the absolute value of a floating-point value. Since C does not support overloading, each function has its own name, even though all three functions do essentially the same thing.

This situation does not occur in Java, because each absolute value method can use the same name. Indeed, Java's standard class library includes an absolute value method, called **abs( )**.This method is overloaded by Java's **Math** class to handle all numeric types. Java determines which version of **abs( )** to call based upon the type of argument.

The value of overloading is that it allows related methods to be accessed by use of a common name. Thus, the name **abs** represents the *general action* that is being performed. It is left to the compiler to choose the right *specific* version for a particular circumstance. You, the programmer, need only remember the general operation being performed. Through the application of polymorphism, several names have been reduced to one.

Constructor Overloading:

In addition to overloading normal methods, you can also overload constructor methods. In fact, for most real-world classes that you create, overloaded constructors will be the norm, not the exception. To understand why, let's return to the **Box** class as follows:

```
class Box {
double width;
double height;
double depth;
// This is the constructor for Box.
Box(double w, double h, double d) {
width = w;
height = h;
depth = d;
}
// compute and return volume
double volume() {
return width * height * depth;
}
}
```

As you can see, the **Box( )** constructor requires three parameters. This means that all declarations of **Box** objects must pass three arguments to the **Box( )** constructor. For example, the following statement is currently invalid:

```
Box ob = new Box();
```

Since **Box( )** requires three arguments, it's an error to call it without them. This raises some important questions. What if you simply wanted a box and did not care (or know) what its initial dimensions were? Or, what if you want to be able to initialize a cube by specifying only one value that would be used for all three dimensions? As the **Box** class is currently written, these other options are not available to you.

Fortunately, the solution to these problems is quite easy: simply overload the **Box** constructor so that it handles the situations just described. Here is a program that contains an improved version of **Box** that does just that:

```
/* Here, Box defines three constructors to initialize the dimensions of a box
various ways.*/
class Box {
double width;
double height;
double depth;
// constructor used when all dimensions specified
Box(double w, double h, double d) {
width = w;
height = h;
depth = d;
}
// constructor used when no dimensions specified
Box() {
width = -1; // use -1 to indicate
height = -1; // an uninitialized
depth = -1; // box
}
```

```
// constructor used when cube is created
Box(double len) {
width = height = depth = len;
}
// compute and return volume
double volume() {
return width * height * depth;
}
}
class OverloadCons {
public static void main(String args[]) {
// create boxes using the various constructors
Box mybox1 = new Box(10, 20, 15);
Box mybox2 = new Box();
Box mycube = new Box(7);
double vol;
// get volume of first box
vol = mybox1.volume();
System.out.println("Volume of mybox1 is " + vol);
// get volume of second box
vol = mybox2.volume();
System.out.println("Volume of mybox2 is " + vol);
// get volume of cube
vol = mycube.volume();
System.out.println("Volume of mycube is " + vol);
}
}
```

The output produced by this program is shown here:

```
Volume of mybox1 is 3000.0
Volume of mybox2 is -1.0
Volume of mycube is 343.0
```

Parameter Passing:

Using Objects as Parameters:

So far, we have only been using simple types as parameters to methods. However, it is both correct and common to pass objects to methods. For example, consider the following short program:

```
// Objects may be passed to methods.
class Test {
int a, b;
Test(int i, int j) {
a = i;
b = j;
}
// return true if o is equal to the invoking object
```

```
boolean equalTo(Test o) {
if(o.a == a && o.b == b) return true;
else return false;
}
}
class PassOb {
public static void main(String args[]) {
Test ob1 = new Test(100, 22);
Test ob2 = new Test(100, 22);
Test ob3 = new Test(-1, -1);
System.out.println("ob1 == ob2: " + ob1.equalTo(ob2));
System.out.println("ob1 == ob3: " + ob1.equalTo(ob3));
}
}
```

This program generates the following output:

```
ob1 == ob2: true
ob1 == ob3: false
```

As you can see, the **equalTo( )** method inside **Test** compares two objects for equality and returns the result. That is, it compares the invoking object with the one that it is passed. If they contain the same values, then the method returns **true**. Otherwise, it returns **false**.

Notice that the parameter **o** in **equalTo( )** specifies **Test** as its type. Although **Test** is a class type created by the program, it is used in just the same way as Java's built-in types. One of the most common uses of object parameters involves constructors.

Frequently, you will want to construct a new object so that it is initially the same as some existing object. To do this, you must define a constructor that takes an object of its class as a parameter. For example, the following version of **Box** allows one object to initialize another:

```
// Here, Box allows one object to initialize another.
class Box {
double width;
double height;
double depth;
// Notice this constructor. It takes an object of type Box.
Box(Box ob) { // pass object to constructor
width = ob.width;
height = ob.height;
depth = ob.depth;
}
// constructor used when all dimensions specified
Box(double w, double h, double d) {
width = w;
height = h;
depth = d;
}
```

```
// constructor used when no dimensions specified
Box() {
width = -1; // use -1 to indicate
height = -1; // an uninitialized
depth = -1; // box
}
// constructor used when cube is created
Box(double len) {
width = height = depth = len;
}
// compute and return volume
double volume() {
return width * height * depth;
}
}

class OverloadCons2 {
public static void main(String args[]) {
// create boxes using the various constructors
Box mybox1 = new Box(10, 20, 15);
Box mybox2 = new Box();
Box mycube = new Box(7);
Box myclone = new Box(mybox1); // create copy of mybox1
double vol;
// get volume of first box
vol = mybox1.volume();
System.out.println("Volume of mybox1 is " + vol);
// get volume of second box
vol = mybox2.volume();
System.out.println("Volume of mybox2 is " + vol);
// get volume of cube
vol = mycube.volume();
System.out.println("Volume of cube is " + vol);
// get volume of clone
vol = myclone.volume();
System.out.println("Volume of clone is " + vol);
}
}
```

As you will see when you begin to create your own classes, providing many forms of constructors is usually required to allow objects to be constructed in a convenient and efficient manner.

A Closer Look at Argument Passing:

In general, there are two ways that a computer language can pass an argument to a subroutine. The first way is *call-by-value*. This approach copies the *value* of an argument into the formal parameter of the subroutine. Therefore, changes made to the parameter of the subroutine have no effect on the argument.

The second way an argument can be passed is *call-by-reference*. In this approach, a reference to an argument (not the value of the argument) is passed to the parameter. Inside the subroutine, this reference is used to access the actual argument specified in the call.

This means that changes made to the parameter will affect the argument used to call the subroutine. As you will see, although Java uses call-by-value to pass all arguments, the precise effect differs between whether a primitive type or a reference type is passed.

When you pass a primitive type to a method, it is passed by value. Thus, a copy of the argument is made, and what occurs to the parameter that receives the argument has no effect outside the method. For example, consider the following program:

```
// Primitive types are passed by value.
class Test {
void meth(int i, int j) {
i *= 2;
j /= 2;
}
}
class CallByValue {
public static void main(String args[]) {
Test ob = new Test();
int a = 15, b = 20;
System.out.println("a and b before call: " +
a + " " + b);
ob.meth(a, b);
System.out.println("a and b after call: " +
a + " " + b);
}
}
```

The output from this program is shown here:

```
a and b before call: 15 20
a and b after call: 15 20
```

As you can see, the operations that occur inside **meth( )** have no effect on the values of **a** and **b** used in the call; their values here did not change to 30 and 10.

When you pass an object to a method, the situation changes dramatically, because objects are passed by what is effectively call-by-reference. Keep in mind that when you create a variable of a class type, you are only creating a reference to an object.

Thus, when you pass this reference to a method, the parameter that receives it will refer to the same object as that referred to by the argument. This effectively means that objects act as if they are passed to methods by use of call-by-reference. Changes to the object inside the method *do* affect the object used as an argument. For example, consider the following program:

```
// Objects are passed through their references.
class Test {
int a, b;
Test(int i, int j) {
a = i;
b = j;
}
// pass an object
void meth(Test o) {
o.a *= 2;
o.b /= 2;
}
}
class PassObjRef {
public static void main(String args[]) {
Test ob = new Test(15, 20);
System.out.println("ob.a and ob.b before call: " +
ob.a + " " + ob.b);
ob.meth(ob);
System.out.println("ob.a and ob.b after call: " +
ob.a + " " + ob.b);
}
}
```

This program generates the following output:

```
ob.a and ob.b before call: 15 20
ob.a and ob.b after call: 30 10
```

As you can see, in this case, the actions inside **meth( )** have affected the object used as an argument.

Returning Objects:

A method can return any type of data, including class types that you create. For example, in the following program, the **incrByTen( )** method returns an object in which the value of **a** is ten greater than it is in the invoking object.

```
// Returning an object.
class Test {
int a;
Test(int i) {
a = i;
}
Test incrByTen() {
Test temp = new Test(a+10);
return temp;
}
}
class RetOb {
public static void main(String args[]) {
```

```
Test ob1 = new Test(2);
Test ob2;
ob2 = ob1.incrByTen();
System.out.println("ob1.a: " + ob1.a);
System.out.println("ob2.a: " + ob2.a);
ob2 = ob2.incrByTen();
System.out.println("ob2.a after second increase: "
+ ob2.a);
}
}
```

The output generated by this program is shown here:

```
ob1.a: 2
ob2.a: 12
ob2.a after second increase: 22
```

As you can see, each time **incrByTen( )** is invoked, a new object is created, and a reference to it is returned to the calling routine. The preceding program makes another important point: Since all objects are dynamically allocated using **new**, you don't need to worry about an object going out-of scope because the method in which it was created terminates.

The object will continue to exist as long as there is a reference to it somewhere in your program. When there are no references to it, the object will be reclaimed the next time garbage collection takes place.

String Class:

String is probably the most commonly used class in Java's class library. The obvious reason for this is that strings are a very important part of programming. The first thing to understand about strings is that every string you create is actually an object of type **String**. Even string constants are actually **String** objects.

For example, in the statement

```
System.out.println("This is a String, too");
```

the string "This is a String, too" is a **String** object. The second thing to understand about strings is that objects of type **String** are immutable; once a **String** object is created, its contents cannot be altered. While this may seem like a serious restriction, it is not, for two reasons:

- If you need to change a string, you can always create a new one that contains the modifications.

- Java defines peer classes of **String**, called **StringBuffer** and **StringBuilder**, which allow strings to be altered, so all of the normal string manipulations are still available in Java.

Strings can be constructed in a variety of ways. The easiest is to use a statement like this:

String myString = "this is a test";

Once you have created a **String** object, you can use it anywhere that a string is allowed. For example, this statement displays **myString**:

System.out.println(myString);

Java defines one operator for **String** objects: **+**. It is used to concatenate two strings. For example, this statement

String myString = "I" + " like " + "Java.";

results in **myString** containing "I like Java."The following program demonstrates the preceding concepts:

```
// Demonstrating Strings.
class StringDemo {
public static void main(String args[]) {
String strOb1 = "First String";
String strOb2 = "Second String";
String strOb3 = strOb1 + " and " + strOb2;
System.out.println(strOb1);
System.out.println(strOb2);
System.out.println(strOb3);
}
}
```

The output produced by this program is shown here:

```
First String
Second String
First String and Second String
```

The **String** class contains several methods that you can use. Here are a few. You can test two strings for equality by using **equals( )**. You can obtain the length of a string by calling the **length( )** method. You can obtain the character at a specified index within a string by calling **charAt( )**. The general forms of these three methods are shown here:

boolean equals(*secondStr*)

int length( )

char charAt(*index*)

Here is a program that demonstrates these methods:

```
// Demonstrating some String methods.
class StringDemo2 {
public static void main(String args[]) {
String strOb1 = "First String";
String strOb2 = "Second String";
String strOb3 = strOb1;
```

```
System.out.println("Length of strOb1: " +
strOb1.length());
System.out.println("Char at index 3 in strOb1: " +
strOb1.charAt(3));
if(strOb1.equals(strOb2))
System.out.println("strOb1 == strOb2");
else
System.out.println("strOb1 != strOb2");
if(strOb1.equals(strOb3))
System.out.println("strOb1 == strOb3");
else
System.out.println("strOb1 != strOb3");
}
}
```

This program generates the following output:

```
Length of strOb1: 12
Char at index 3 in strOb1: s
strOb1 != strOb2
strOb1 == strOb3
```

Of course, you can have arrays of strings, just like you can have arrays of any other type of object. For example:

```
// Demonstrate String arrays.
class StringDemo3 {
public static void main(String args[]) {
String str[] = { "one", "two", "three" };
for(int i=0; i<str.length; i++)
System.out.println("str[" + i + "]: " +
str[i]);
}
}
```

Here is the output from this program:

```
str[0]: one
str[1]: two
str[2]: three
```

final Keyword:

A field can be declared as **final**. Doing so prevents its contents from being modified, making it, essentially, a constant. This means that you must initialize a **final** field when it is declared. You can do this in one of two ways: First, you can give it a value when it is declared. Second, you can assign it a value within a constructor. The first approach is the most common. Here is an example:

```
final int FILE_NEW = 1;
final int FILE_OPEN = 2;
```

```
final int FILE_SAVE = 3;
final int FILE_SAVEAS = 4;
final int FILE_QUIT = 5;
```

Subsequent parts of your program can now use **FILE_OPEN**, etc., as if they were constants, without fear that a value has been changed. It is a common coding convention to choose all uppercase identifiers for **final** fields, as this example shows.

In addition to fields, both method parameters and local variables can be declared **final**. Declaring a parameter **final** prevents it from being changed within the method. Declaring a local variable **final** prevents it from being assigned a value more than once.

The keyword **final** can also be applied to methods, but its meaning is substantially different than when it is applied to variables.

Utility Classes:

In **java.util** there are classes and interfaces that are not part of the Collections Framework. These include classes that tokenize strings, work with dates, compute random numbers, bundle resources, and observe events.

Also covered are the **Formatter** and **Scanner** classes which make it easy to write and read formatted data, and the new **Optional** class, which makes it easier to handle situations in which a value may be absent.

StringTokenizer:

The processing of text often consists of parsing a formatted input string. *Parsing* is the division of text into a set of discrete parts, or *tokens*, which in a certain sequence can convey a semantic meaning.

The **StringTokenizer** class provides the first step in this parsing process, often called the *lexer* (lexical analyzer) or *scanner*. **StringTokenizer** implements the **Enumeration** interface. Therefore, given an input string, you can enumerate the individual tokens contained in it using **StringTokenizer**.

To use **StringTokenizer**, you specify an input string and a string that contains delimiters. *Delimiters* are characters that separate tokens. Each character in the delimiters string is considered a valid delimiter—for example, **",;:"** sets the delimiters to a comma, semicolon, and colon. The default set of delimiters consists of the whitespace characters: space, tab, form feed, newline, and carriage return.

The **StringTokenizer** constructors are shown here:

```
StringTokenizer(String str)
StringTokenizer(String str, String delimiters)
StringTokenizer(String str, String delimiters, boolean delimAsToken)
```

In all versions, *str* is the string that will be tokenized. In the first version, the default delimiters are used. In the second and third versions, *delimiters* is a string that specifies the delimiters.

In the third version, if *delimAsToken* is **true**, then the delimiters are also returned as tokens when the string is parsed. Otherwise, the delimiters are not returned. Delimiters are not returned as tokens by the first two forms.

Once you have created a **StringTokenizer** object, the **nextToken( )** method is used to extract consecutive tokens. The **hasMoreTokens( )** method returns **true** while there are more tokens to be extracted.

Since **StringTokenizer** implements **Enumeration**, the **hasMoreElements( )** and **nextElement( )** methods are also implemented, and they act the same as **hasMoreTokens( )**and **nextToken( )**, respectively.

The **StringTokenizer** methods are shown below:

Method	Description
int countTokens( )	Using the current set of delimiters, the method determines the number of tokens left to be parsed and returns the result.
boolean hasMoreElements( )	Returns **true** if one or more tokens remain in the string and returns **false** if there are none.
boolean hasMoreTokens( )	Returns **true** if one or more tokens remain in the string and returns **false** if there are none.
Object nextElement( )	Returns the next token as an **Object**.
String nextToken( )	Returns the next token as a **String**.
String nextToken(String *delimiters*)	Returns the next token as a **String** and sets the delimiters string to that specified by *delimiters*.

Here is an example that creates a **StringTokenizer** to parse "key=value" pairs. Consecutive sets of "key=value" pairs are separated by a semicolon.

```
// Demonstrate StringTokenizer.
import java.util.StringTokenizer;
class STDemo {
static String in = "title=Java: The Complete Reference;" +
"author=Schildt;" +
"publisher=McGraw-Hill;" +
"copyright=2014";
public static void main(String args[]) {
StringTokenizer st = new StringTokenizer(in, "=;");
while(st.hasMoreTokens()) {
String key = st.nextToken();
String val = st.nextToken();
System.out.println(key + "\t" + val);
}
}
}
```

Output:

```
C:\Users\Administrator\Desktop>javac STDemo.java
C:\Users\Administrator\Desktop>java STDemo
title   Java: The Complete Reference
```

author Schildt
publisher McGraw-Hill
copyright 2014

BitSet:

A **BitSet** class creates a special type of array that holds bit values in the form of **boolean** values. This array can increase in size as needed. This makes it similar to a vector of bits. The **BitSet** constructors are shown here:

BitSet( )
BitSet(int *size*)

The first version creates a default object. The second version allows you to specify its initial size (that is, the number of bits that it can hold). All bits are initialized to **false**. **BitSet** defines the methods listed as shown below:

Method	Description
void and(BitSet *bitSet*)	ANDs the contents of the invoking **BitSet** object with those specified by *bitSet*. The result is placed into the invoking object.
void andNot(BitSet *bitSet*)	For each set bit in *bitSet*, the corresponding bit in the invoking **BitSet** is cleared.
int cardinality( )	Returns the number of set bits in the invoking object.
void clear( )	Zeros all bits.
void clear(int *index*)	Zeros the bit specified by *index*.
void clear(int *startIndex*, int *endIndex*)	Zeros the bits from *startIndex* to *endIndex*–1.
Object clone( )	Duplicates the invoking **BitSet** object.
boolean equals(Object *bitSet*)	Returns **true** if the invoking bit set is equivalent to the one passed in *bitSet*. Otherwise, the method returns **false**.
void flip(int *index*)	Reverses the bit specified by *index*.
void flip(int *startIndex*, int *endIndex*)	Reverses the bits from *startIndex* to *endIndex*–1.
boolean get(int *index*)	Returns the current state of the bit at the specified index.
BitSet get(int *startIndex*, int *endIndex*)	Returns a **BitSet** that consists of the bits from *startIndex* to *endIndex*–1. The invoking object is not changed.
int hashCode( )	Returns the hash code for the invoking object.
boolean intersects(BitSet *bitSet*)	Returns **true** if at least one pair of corresponding bits within the invoking object and *bitSet* are set.
boolean isEmpty( )	Returns **true** if all bits in the invoking object are cleared.
int length( )	Returns the number of bits required to hold the contents of the invoking **BitSet**. This value is determined by the location of the last set bit.
int nextClearBit(int *startIndex*)	Returns the index of the next cleared bit (that is, the next **false** bit), starting from the index specified by *startIndex*.

int nextSetBit(int *startIndex*)	Returns the index of the next set bit (that is, the next **true** bit), starting from the index specified by *startIndex*. If no bit is set, –1 is returned.
void or(BitSet *bitSet*)	ORs the contents of the invoking **BitSet** object with that specified by *bitSet*. The result is placed into the invoking object.
int previousClearBit(int *startIndex*)	Returns the index of the next cleared bit (that is, the next **false** bit) at or prior to the index specified by *startIndex*. If no cleared bit is found, –1 is returned.
int previousSetBit(int *startIndex*)	Returns the index of the next set bit (that is, the next **true** bit) at or prior to the index specified by *startIndex*. If no set bit is found, –1 is returned.
void set(int *index*)	Sets the bit specified by *index*.
void set(int *index*, boolean *v*)	Sets the bit specified by *index* to the value passed in *v*. **true** sets the bit; **false** clears the bit.
void set(int *startIndex*, int *endIndex*)	Sets the bits from *startIndex* to *endIndex*–1.
void set(int *startIndex*, int *endIndex*, boolean *v*)	Sets the bits from *startIndex* to *endIndex*–1 to the value passed in *v*. **true** sets the bits; **false** clears the bits.
int size( )	Returns the number of bits in the invoking **BitSet** object.
IntStream stream( )	Returns a stream that contains the bit positions, from low to high, that have set bits. (Added by JDK 8.)
byte[ ] toByteArray( )	Returns a **byte** array that contains the invoking **BitSet** object.
long[ ] toLongArray( )	Returns a **long** array that contains the invoking **BitSet** object.
String toString( )	Returns the string equivalent of the invoking **BitSet** object.
static BitSet valueOf(byte[ ] *v*)	Returns a **BitSet** that contains the bits in *v*.
static BitSet valueOf(ByteBuffer *v*)	Returns a **BitSet** that contains the bits in *v*.
static BitSet valueOf(long[ ] *v*)	Returns a **BitSet** that contains the bits in *v*.
static BitSet valueOf(LongBuffer *v*)	Returns a **BitSet** that contains the bits in *v*.
void xor(BitSet *bitSet*)	XORs the contents of the invoking **BitSet** object with that specified by *bitSet*. The result is placed into the invoking object.

Here is an example that demonstrates **BitSet**:

```
// BitSet Demonstration.
import java.util.BitSet;
class BitSetDemo {
public static void main(String args[]) {
BitSet bits1 = new BitSet(16);
BitSet bits2 = new BitSet(16);
// set some bits
for(int i=0; i<16; i++) {
if((i%2) == 0) bits1.set(i);
if((i%5) != 0) bits2.set(i);
}
System.out.println("Initial pattern in bits1: ");
System.out.println(bits1);
System.out.println("\nInitial pattern in bits2: ");
```

```
System.out.println(bits2);
// AND bits
bits2.and(bits1);
System.out.println("\nbits2 AND bits1: ");
System.out.println(bits2);
// OR bits
bits2.or(bits1);
System.out.println("\nbits2 OR bits1: ");
System.out.println(bits2);
// XOR bits
bits2.xor(bits1);
System.out.println("\nbits2 XOR bits1: ");
System.out.println(bits2);
}
}
```

The output from this program is shown here. When **toString( )** converts a **BitSet** object to its string equivalent, each set bit is represented by its bit position. Cleared bits are not shown.

```
Initial pattern in bits1:
{0, 2, 4, 6, 8, 10, 12, 14}
Initial pattern in bits2:
{1, 2, 3, 4, 6, 7, 8, 9, 11, 12, 13, 14}
bits2 AND bits1:
{2, 4, 6, 8, 12, 14}
bits2 OR bits1:
{0, 2, 4, 6, 8, 10, 12, 14}
bits2 XOR bits1:
{}
```

Random:

The **Random** class is a generator of pseudorandom numbers. These are called *pseudorandom* numbers because they are simply uniformly distributed sequences. **Random** defines the following constructors:

```
Random( )
Random(long seed)
```

The first version creates a number generator that uses a reasonably unique seed. The second form allows you to specify a seed value manually.

If you initialize a **Random** object with a seed, you define the starting point for the random sequence. If you use the same seed to initialize another **Random** object, you will extract the same random sequence.

If you want to generate different sequences, specify different seed values. One way to do this is to use the current time to seed a **Random** object. This approach reduces the possibility of getting repeated sequences. The core public methods defined by **Random** are shown in the table as follows:

Method	Description
boolean nextBoolean( )	Returns the next **boolean** random number.
void nextBytes(byte *vals*[ ])	Fills *vals* with randomly generated values.
double nextDouble( )	Returns the next **double** random number.
float nextFloat( )	Returns the next **float** random number.
double nextGaussian( )	Returns the next Gaussian random number.
int nextInt( )	Returns the next **int** random number.
int nextInt(int *n*)	Returns the next **int** random number within the range zero to *n*.
long nextLong( )	Returns the next **long** random number.
void setSeed(long *newSeed*)	Sets the seed value (that is, the starting point for the random number generator) to that specified by *newSeed*.

These are the methods that have been available in **Random** for several years (many since Java 1.0) and are widely used.

As you can see, there are seven types of random numbers that you can extract from a **Random** object. Random Boolean values are available from **nextBoolean( )**. Random bytes can be obtained by calling **nextBytes( )**. Integers can be extracted via the **nextInt( )** method.

Long integers, uniformly distributed over their range, can be obtained with **nextLong( )**.The **nextFloat( )** and **nextDouble( )** methods return a uniformly distributed **float** and **double**, respectively, between 0.0 and 1.0. Finally, **nextGaussian( )** returns a **double** value entered at 0.0 with a standard deviation of 1.0. This is what is known as a *bell curve*.

Here is an example that demonstrates the sequence produced by **nextGaussian( )**. It obtains 100 random Gaussian values and averages these values. The program also counts the number of values that fall within two standard deviations, plus or minus, using increments of0.5 for each category. The result is graphically displayed sideways on the screen.

```
// Demonstrate random Gaussian values.
import java.util.Random;
class RandDemo {
public static void main(String args[]) {
Random r = new Random();
double val;
double sum = 0;
int bell[] = new int[10];
for(int i=0; i<100; i++) {
val = r.nextGaussian();
sum += val;
double t = -2;
for(int x=0; x<10; x++, t += 0.5)
if(val < t) {
bell[x]++;
break;
}
}
```

```
System.out.println("Average of values: " +
(sum/100));
// display bell curve, sideways
for(int i=0; i<10; i++) {
for(int x=bell[i]; x>0; x--)
System.out.print("*");
System.out.println();
}
}
}
```

Here is a sample program run. As you can see, a bell-like distribution of numbers is obtained.

```
Average of values: 0.0702235271133344
**
*******
******
***************
******************
*****************
*************
**********
********
***
```

JDK 8 adds three new methods to **Random** that support the new stream API. They are called **doubles( )**, **ints( )**, and **longs( )**, and each returns a reference to a stream that contains a sequence of pseudorandom values of the specified type. Each method defines several overloads. Here are their simplest forms:

```
DoubleStream doubles( )

IntStream ints( )

LongStream longs( )
```

- ✓ The **doubles( )** method returns a stream that contains pseudorandom **double** values. (The range of these values will be less than 1.0 but greater than 0.0.)
- ✓ The **ints( )** method returns a stream that contains pseudorandom **int** values.
- ✓ The **longs( )** method returns a stream that contains pseudorandom **long** values.

For these three methods, the stream returned is effectively infinite. Several overloads of each method are provided that let you specify the size of the stream, an origin, and an upper bound.

Scanner:

Scanner is the complement of **Formatter**. It reads formatted input and converts it into its binary form. **Scanner** can be used to read input from the console, a file, a string, or any source that implements the **Readable** interface or **ReadableByteChannel**. For example, you can use **Scanner** to read a number from the keyboard and assign its value to a variable. As you will see, given its power, **Scanner** is surprisingly easy to use.

The Scanner Constructors: Scanner defines the constructors shown in the table as follows:

Method	Description
Scanner(File *from*) throws FileNotFoundException	Creates a **Scanner** that uses the file specified by *from* as a source for input.
Scanner(File *from*, String *charset*) throws FileNotFoundException	Creates a **Scanner** that uses the file specified by *from* with the encoding specified by *charset* as a source for input.
Scanner(InputStream *from*)	Creates a **Scanner** that uses the stream specified by *from* as a source for input.
Scanner(InputStream *from*, String *charset*)	Creates a **Scanner** that uses the stream specified by *from* with the encoding specified by *charset* as a source for input.
Scanner(Path *from*) throws IOException	Creates a **Scanner** that uses the file specified by *from* as a source for input.
Scanner(Path *from*, String *charset*) throws IOException	Creates a **Scanner** that uses the file specified by *from* with the encoding specified by *charset* as a source for input.
Scanner(Readable *from*)	Creates a **Scanner** that uses the **Readable** object specified by *from* as a source for input.
Scanner (ReadableByteChannel *from*)	Creates a **Scanner** that uses the **ReadableByteChannel** specified by *from* as a source for input.
Scanner(ReadableByteChannel *from*, String *charset*)	Creates a **Scanner** that uses the **ReadableByteChannel** specified by *from* with the encoding specified by *charset* as a source for input.
Scanner(String *from*)	Creates a **Scanner** that uses the string specified by *from* as a source for input.

In general, a **Scanner** can be created for a **String**, an **InputStream**, a **File**, or any object that implements the **Readable** or **ReadableByteChannel** interfaces. Here are some examples. The following sequence creates a **Scanner** that reads the file **Test.txt**:

```
FileReader fin = new FileReader("Test.txt");
Scanner src = new Scanner(fin);
```

This works because **FileReader** implements the **Readable** interface. Thus, the call to the constructor resolves to **Scanner(Readable)**. The next line creates a **Scanner** that reads from standard input, which is the keyboard by default:

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

This works because **System.in** is an object of type **InputStream**. Thus, the call to the constructor maps to **Scanner(InputStream)**.

The next sequence creates a **Scanner** that reads from a string.

```
String instr = "10 99.88 scanning is easy.";
Scanner conin = new Scanner(instr);
```

Scanning Basics:

Once you have created a **Scanner**, it is a simple matter to use it to read formatted input. In general, a **Scanner** reads *tokens* from the underlying source that you specified when the **Scanner** was created. As it relates to **Scanner**, a token is a portion of input that is delineated by a set of delimiters, which is whitespace by default.

A token is read by matching it with a particular *regular expression*, which defines the format of the data. Although **Scanner** allows you to define the specific type of expression that its next input operation will match, it includes many predefined patterns, which match the primitive types, such as **int** and **double**, and strings. Thus, often you won't need to specify a pattern to match. In general, to use **Scanner**, follow this procedure:

1. Determine if a specific type of input is available by calling one of **Scanner**'s **hasNext***X* methods, where *X* is the type of data desired.
2. If input is available, read it by calling one of **Scanner**'s **next***X* methods.
3. Repeat the process until input is exhausted.
4. Close the **Scanner** by calling **close( )**.

As the preceding indicates, **Scanner** defines two sets of methods that enable you to read input. The first are the **hasNext***X* methods, which are shown in Table below:

Method	Description
boolean hasNext( )	Returns **true** if another token of any type is available to be read. Returns **false** otherwise.
boolean hasNext(Pattern *pattern*)	Returns **true** if a token that matches the pattern passed in *pattern* is available to be read. Returns **false** otherwise.
boolean hasNext(String *pattern*)	Returns **true** if a token that matches the pattern passed in *pattern* is available to be read. Returns **false** otherwise.
boolean hasNextBigDecimal( )	Returns **true** if a value that can be stored in a **BigDecimal** object is available to be read. Returns **false** otherwise.
boolean hasNextBigInteger( )	Returns **true** if a value that can be stored in a **BigInteger** object is available to be read. Returns **false** otherwise. The default radix is used. (Unless changed, the default radix is 10.)
boolean hasNextBigInteger(int *radix*)	Returns **true** if a value in the specified radix that can be stored in a **BigInteger** object is available to be read. Returns **false** otherwise.
boolean hasNextBoolean( )	Returns **true** if a **boolean** value is available to be read. Returns **false** otherwise.
boolean hasNextByte( )	Returns **true** if a **byte** value is available to be read. Returns **false** otherwise. The default radix is used. (Unless changed, the default radix is 10.)
boolean hasNextByte(int *radix*)	Returns **true** if a **byte** value in the specified radix is available to be read. Returns **false** otherwise.
boolean hasNextDouble( )	Returns **true** if a **double** value is available to be read. Returns **false** otherwise.
boolean hasNextFloat( )	Returns **true** if a **float** value is available to be read. Returns **false** otherwise.

boolean hasNextInt( )	Returns **true** if an **int** value is available to be read. Returns **false** otherwise. The default radix is used. (Unless changed, the default radix is 10.)
boolean hasNextInt(int *radix*)	Returns **true** if an **int** value in the specified radix is available to be read. Returns **false** otherwise.
boolean hasNextLine( )	Returns **true** if a line of input is available.
boolean hasNextLong( )	Returns **true** if a **long** value is available to be read. Returns **false** otherwise. The default radix is used. (Unless changed, the default radix is 10.)
boolean hasNextLong(int *radix*)	Returns **true** if a **long** value in the specified radix is available to be read. Returns **false** otherwise.
boolean hasNextShort( )	Returns **true** if a **short** value is available to be read. Returns **false** otherwise. The default radix is used. (Unless changed, the default radix is 10.)
boolean hasNextShort(int *radix*)	Returns **true** if a **short** value in the specified radix is available to be read. Returns **false** otherwise.

These methods determine if the specified type of input is available. For example, calling **hasNextInt( )**returns **true** only if the next token to be read is an integer. If the desired data is available, then you read it by calling one of **Scanner**'s **next***X* methods, which are shown in Table below:

Method	Description
String next( )	Returns the next token of any type from the input source.
String next(Pattern *pattern*)	Returns the next token that matches the pattern passed in *pattern* from the input source.
String next(String *pattern*)	Returns the next token that matches the pattern passed in *pattern* from the input source.
BigDecimal nextBigDecimal( )	Returns the next token as a **BigDecimal** object.
BigInteger nextBigInteger( )	Returns the next token as a **BigInteger** object. The default radix is used. (Unless changed, the default radix is 10.)
BigInteger nextBigInteger(int *radix*)	Returns the next token (using the specified radix) as a **BigInteger** object.
boolean nextBoolean( )	Returns the next token as a **boolean** value.
byte nextByte( )	Returns the next token as a **byte** value. The default radix is used. (Unless changed, the default radix is 10.)
byte nextByte(int *radix*)	Returns the next token (using the specified radix) as a **byte** value.
double nextDouble( )	Returns the next token as a **double** value.
float nextFloat( )	Returns the next token as a **float** value.
int nextInt( )	Returns the next token as an **int** value. The default radix is used. (Unless changed, the default radix is 10.)
int nextInt(int *radix*)	Returns the next token (using the specified radix) as an **int** value.
String nextLine( )	Returns the next line of input as a string.
long nextLong( )	Returns the next token as a **long** value. The default radix is used. (Unless changed, the default radix is 10.)

long nextLong(int *radix*)	Returns the next token (using the specified radix) as a **long** value.
short nextShort( )	Returns the next token as a **short** value. The default radix is used. (Unless changed, the default radix is 10.)
short nextShort(int *radix*)	Returns the next token (using the specified radix) as a **short** value.

For example, to read the next integer, call **nextInt( )**. The following sequence shows how to read a list of integers from the keyboard.

```
Scanner conin = new Scanner(System.in);
int i;
// Read a list of integers.
while(conin.hasNextInt()) {
i = conin.nextInt();
// ...
}
```

The **while** loop stops as soon as the next token is not an integer. Thus, the loop stops reading integers as soon as a non-integer is encountered in the input stream. If a **next** method cannot find the type of data it is looking for, it throws an **InputMismatchException**.

A **NoSuchElementException** is thrown if no more input is available. For this reason, it is best to first confirm that the desired type of data is available by calling a **hasNext** method before calling its corresponding **next** method.

Some Scanner Examples:

Scanner makes what could be a tedious task into an easy one. To understand why, let's look at some examples. The following program averages a list of numbers entered at the keyboard:

```
// Use Scanner to compute an average of the values.
import java.util.*;
class AvgNums {
public static void main(String args[]) {
Scanner conin = new Scanner(System.in);
int count = 0;
double sum = 0.0;
System.out.println("Enter numbers to average.");
// Read and sum numbers.
while(conin.hasNext()) {
if(conin.hasNextDouble()) {
sum += conin.nextDouble();
count++;
}
else {
String str = conin.next();
if(str.equals("done")) break;
else {
```

```
System.out.println("Data format error.");
return;
}
}
}
conin.close();
System.out.println("Average is " + sum / count);
}
}
```

The program reads numbers from the keyboard, summing them in the process, until the user enters the string "done". It then stops input and displays the average of the numbers. Here is a sample run:

```
Enter numbers to average.
1.2
2
3.4
4
done
Average is 2.65
```

The program reads numbers until it encounters a token that does not represent a valid **double** value. When this occurs, it confirms that the token is the string "done". If it is, the program terminates normally. Otherwise, it displays an error.

Notice that the numbers are read by calling **nextDouble( )**. This method reads any number that can be converted into a **double** value, including an integer value, such as 2,and a floating-point value like 3.4.

Thus, a number read by **nextDouble( )** need not specify a decimal point. This same general principle applies to all **next** methods. They will match and read any data format that can represent the type of value being requested.

One thing that is especially nice about **Scanner** is that the same technique used to read from one source can be used to read from another. For example, here is the preceding program reworked to average a list of numbers contained in a text file:

```
// Use Scanner to compute an average of the values in a file.
import java.util.*;
import java.io.*;
class AvgFile {
public static void main(String args[])
throws IOException {
int count = 0;
double sum = 0.0;
// Write output to a file.
FileWriter fout = new FileWriter("test.txt");
fout.write("2 3.4 5 6 7.4 9.1 10.5 done");
fout.close();
FileReader fin = new FileReader("Test.txt");
```

```
Scanner src = new Scanner(fin);
// Read and sum numbers.
while(src.hasNext()) {
if(src.hasNextDouble()) {
sum += src.nextDouble();
count++;
}
else {
String str = src.next();
if(str.equals("done")) break;
else {
System.out.println("File format error.");
return;
}
}
}
src.close();
System.out.println("Average is " + sum / count);
}
}
```

Here is the output:

```
Average is 6.2
```

The preceding program illustrates another important feature of **Scanner**. Notice that the file reader referred to by **fin** is not closed directly. Rather, it is closed automatically when **src** calls **close( )**.

When you close a **Scanner**, the **Readable** associated with it is also closed (if that **Readable** implements the **Closeable** interface). Therefore, in this case, the file referred to by **fin** is automatically closed when **src** is closed.

Beginning with JDK 7, **Scanner** also implements the **AutoCloseable** interface. This means that it can be managed by a **try**-with-resources block. When **try**-with-resources is used, the scanner is automatically closed when the block ends. For example, **src** in the preceding program could have been managed like this:

```
try (Scanner src = new Scanner(fin))
{
// Read and sum numbers.
while(src.hasNext()) {
if(src.hasNextDouble()) {
sum += src.nextDouble();
count++;
}
else {
String str = src.next();
if(str.equals("done")) break;
else {
System.out.println("File format error.");
```

```
return;
}
}
}
}
```

You can use **Scanner** to read input that contains several different types of data—even if the order of that data is unknown in advance. You must simply check what type of data is available before reading it. For example, consider this program:

```
// Use Scanner to read various types of data from a file.
import java.util.*;
import java.io.*;
class ScanMixed {
public static void main(String args[])
throws IOException {
int i;
double d;
boolean b;
String str;
// Write output to a file.
FileWriter fout = new FileWriter("test.txt");
fout.write("Testing Scanner 10 12.2 one true two false");
fout.close();
FileReader fin = new FileReader("Test.txt");
Scanner src = new Scanner(fin);
// Read to end.
while(src.hasNext()) {
if(src.hasNextInt()) {
i = src.nextInt();
System.out.println("int: " + i);
}
else if(src.hasNextDouble()) {
d = src.nextDouble();
System.out.println("double: " + d);
}
else if(src.hasNextBoolean()) {
b = src.nextBoolean();
System.out.println("boolean: " + b);
}
else {
str = src.next();
System.out.println("String: " + str);
}
}
src.close();
}

}
```

Here is the output:

```
String: Testing
String: Scanner
int: 10
double: 12.2
String: one
boolean: true
String: two
boolean: false
```

When reading mixed data types, as the preceding program does, you need to be a bit careful about the order in which you call the **next** methods. For example, if the loop reversed the order of the calls to **nextInt( )** and **nextDouble( )**, both numeric values would have been read as **double**s, because **nextDouble( )** matches any numeric string that can be represented as a **double**.

Setting Delimiters:

Scanner defines where a token starts and ends based on a set of *delimiters*. The default delimiters are the whitespace characters, and this is the delimiter set that the preceding examples have used. However, it is possible to change the delimiters by calling the **useDelimiter( )** method, shown here:

```
Scanner useDelimiter(String pattern)
Scanner useDelimiter(Pattern pattern)
```

Here, *pattern* is a regular expression that specifies the delimiter set. Here is the program that reworks the average program shown earlier so that it reads a list of numbers that are separated by commas, and any number of spaces:

```
// Use Scanner to compute an average a list of
// comma-separated values.
import java.util.*;
import java.io.*;
class SetDelimiters {
public static void main(String args[])
throws IOException {
int count = 0;
double sum = 0.0;
// Write output to a file.
FileWriter fout = new FileWriter("test.txt");
// Now, store values in comma-separated list.
fout.write("2, 3.4, 5,6, 7.4, 9.1, 10.5, done");
fout.close();
FileReader fin = new FileReader("Test.txt");
Scanner src = new Scanner(fin);
// Set delimiters to space and comma.
src.useDelimiter(", *");
// Read and sum numbers.
while(src.hasNext()) {
```

```
if(src.hasNextDouble()) {
sum += src.nextDouble();
count++;
}
else {
String str = src.next();
if(str.equals("done")) break;
else {
System.out.println("File format error.");
return;
}
}
}
src.close();
System.out.println("Average is " + sum / count);
}
}
```

In this version, the numbers written to **test.txt** are separated by commas and spaces. The use of the delimiter pattern **", * "** tells **Scanner** to match a comma and zero or more spaces as delimiters.

Output:

```
C:\Users\Administrator\Desktop>javac SetDelimiters.java
C:\Users\Administrator\Desktop>java SetDelimiters
Average is 6.2
```

You can obtain the current delimiter pattern by calling **delimiter( )**, shown here:

```
Pattern delimiter( )
```

Other Scanner Features

Scanner defines several other methods in addition to those already discussed. One that is particularly useful in some circumstances is **findInLine( )**. Its general forms are shown here:

```
String findInLine(Pattern pattern)
String findInLine(String pattern)
```

This method searches for the specified pattern within the next line of text. If the pattern is found, the matching token is consumed and returned. Otherwise, null is returned. It operates independently of any delimiter set. This method is useful if you want to locate a specific pattern. For example, the following program locates the Age field in the input string and then displays the age:

```
// Demonstrate findInLine().
import java.util.*;
class FindInLineDemo {
public static void main(String args[]) {
String instr = "Name: Tom Age: 28 ID: 77";
```

```
Scanner conin = new Scanner(instr);
// Find and display age.
conin.findInLine("Age:"); // find Age
if(conin.hasNext())
System.out.println(conin.next());
else
System.out.println("Error!");
conin.close();
}
}
```

The output is **28**. In the program, **findInLine( )** is used to find an occurrence of the pattern "Age". Once found, the next token is read, which is the age. Related to **findInLine( )** is **findWithinHorizon( )**. It is shown here:

String findWithinHorizon(Pattern *pattern*, int *count*)
String findWithinHorizon(String *pattern*, int *count*)

This method attempts to find an occurrence of the specified pattern within the next *count* characters. If successful, it returns the matching pattern. Otherwise, it returns **null**. If *count* is zero, then all input is searched until either a match is found or the end of input is encountered.

You can bypass a pattern using **skip( )**, shown here:

Scanner skip(Pattern *pattern*)
Scanner skip(String *pattern*)

If *pattern* is matched, **skip( )** simply advances beyond it and returns a reference to the invoking object. If pattern is not found, **skip( )** throws **NoSuchElementException**.

Other **Scanner** methods include **radix( )**, which returns the default radix used by the **Scanner**; **useRadix( )**, which sets the radix; **reset( )**, which resets the scanner; and **close( )**,which closes the scanner.