

# CHAPTER 7

## A Closer Look at Methods and Classes

This chapter continues the discussion of methods and classes begun in the preceding chapter. It examines several topics relating to methods, including overloading, parameter passing, and recursion. The chapter then returns to the class, discussing access control, the use of the keyword **static**, and one of Java's most important built-in classes: **String**.

### Overloading Methods

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. If you have never used a language that allows the overloading of methods, then the concept may seem strange at first. But as you will see, method overloading is one of Java's most exciting and useful features.

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 to have its own name, even though all three functions do essentially the same thing. This makes the situation more complex, conceptually, than it actually is. Although the underlying concept of each function is the same, you still have three names to remember. 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. Although this example is fairly simple, if you expand the concept, you can see how overloading can help you manage greater complexity.

When you overload a method, each version of that method can perform any activity you desire. There is no rule stating that overloaded methods must relate to one another. However, from a stylistic point of view, method overloading implies a relationship. Thus, while you can use the same name to overload unrelated methods, you should not. For example, you could use the name **sqr** to create methods that return the *square* of an integer and the *square root* of a floating-point value. But these two operations are fundamentally different. Applying method overloading in this manner defeats its original purpose. In practice, you should only overload closely related operations.

## Overloading Constructors

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 developed in

the preceding chapter. Following is the latest version of **Box**:

```
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

```

As you can see, the proper overloaded constructor is called based upon the parameters

specified when **new** is executed.

## 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 equals(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.equals(ob2));
        System.out.println("ob1 == ob3: " + ob1.equals(ob3));
    }
}
```

This program generates the following output:

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

As you can see, the **equals( )** 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 **equals( )** 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.

## REMEMBER

When an object reference is passed to a method, the reference itself is passed by use of call-by-value. However, since the value being passed refers to an object, the copy of that value will still refer to the same object that its corresponding argument does.

## 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.

## 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  $1 \times 2 \times 3$ , 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.

To better understand how the **fact( )** method works, let's go through a short example. When you compute the factorial of 3, the first call to **fact( )** will cause a second call to be made with an argument of 2. This invocation will cause **fact( )** to be called a third time with an argument of 1. This call will return 1, which is then multiplied by 2 (the value of **n** in the second invocation). This result (which is 2) is then returned to the original invocation of **fact( )** and multiplied by 3 (the original value of **n**). This yields the answer, 6. You might find it interesting to insert **println( )** statements into **fact( )**, which will show at what level each call is and what the intermediate answers are.

When a method calls itself, new local variables and parameters are allocated storage on the stack, and the method code is executed with these new variables from the start. As each recursive call returns, the old local variables and parameters are removed from the stack, and execution resumes at the point of the call inside the method. Recursive methods could be said to “telescope” out and back.

Recursive versions of many routines may execute a bit more slowly than the iterative equivalent because of the added overhead of the additional function calls. Many recursive calls to a method could cause a stack overrun. Because storage for parameters and local variables is on the stack and each new call creates a new copy of these variables, it is possible that the stack could be exhausted. If this occurs, the Java run-time system will cause an exception. However, you probably will not have to worry about this unless a recursive routine runs wild.

The main advantage to recursive methods is that they can be used to create clearer and simpler versions of several algorithms than can their iterative relatives. For example, the QuickSort sorting algorithm is quite difficult to implement in an iterative way. Also, some types of AI-related algorithms are most easily implemented using recursive solutions.

When writing recursive methods, you must have an **if** statement somewhere to force the method to return without the recursive call being executed. If you don't do this, once you call the method, it will never return. This is a very common error in working with recursion. Use **println( )** statements liberally during development so that you can watch what is going on and abort execution if you see that you have made a mistake.

Here is one more example of recursion. The recursive method **printArray( )** prints the first **i** elements in the array **values**.

```
// Another example that uses recursion.

class RecTest {
    int values[];
    RecTest(int i) {
        values = new int[i];
    }

    // display array -- recursively
    void printArray(int i) {
        if(i==0) return;
        else printArray(i-1);
        System.out.println "[" + (i-1) + " ] " + values[i-1]);
    }
}

class Recursion2 {
    public static void main(String args[]) {
        RecTest ob = new RecTest(10);
        int i;

        for(i=0; i<10; i++) ob.values[i] = i;
```

```
        ob.printArray(10);  
    }  
}
```

This program generates the following output:

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

## Introducing Access Control

As you know, encapsulation links data with the code that manipulates it. However, encapsulation provides another important attribute: *access control*. Through encapsulation, you can control what parts of a program can access the members of a class. By controlling access, you can prevent misuse. For example, allowing access to data only through a well-defined set of methods, you can prevent the misuse of that data. Thus, when correctly implemented, a class creates a “black box” which may be used, but the inner workings of which are not open to tampering. However, the classes that were presented earlier do not completely meet this goal. For example, consider the **Stack** class shown at the end of [Chapter 6](#). While it is true that the methods **push( )** and **pop( )** do provide a controlled interface to the stack, this interface is not enforced. That is, it is possible for another part of the program to bypass these methods and access the stack directly. Of course, in the wrong hands, this could lead to trouble. In this section, you will be introduced to the mechanism by which you can precisely control access to the various members of a class.

How a member can be accessed is determined by the *access modifier* attached to its declaration. Java supplies a rich set of access modifiers. Some aspects of access control are related mostly to inheritance or packages. (A *package* is, essentially, a grouping of classes.) These parts of Java’s access control mechanism will be discussed later. Here, let’s begin by examining access control as it applies to a single class. Once you understand the fundamentals of access control, the rest will be easy.

Java's access modifiers are **public**, **private**, and **protected**. Java also defines a default access level. **protected** applies only when inheritance is involved. The other access modifiers are described next.

Let's begin by defining **public** and **private**. When a member of a class is modified by **public**, then that member can be accessed by any other code. When a member of a class is specified as **private**, then that member can only be accessed by other members of its class. Now you can understand why **main( )** has always been preceded by the **public** modifier. It is called by code that is outside the program—that is, by the Java run-time system. When no access modifier is used, then by default the member of a class is public within its own package, but cannot be accessed outside of its package. (Packages are discussed in the following chapter.)

In the classes developed so far, all members of a class have used the default access mode, which is essentially public. However, this is not what you will typically want to be the case. Usually, you will want to restrict access to the data members of a class—allowing access only through methods. Also, there will be times when you will want to define methods that are private to a class.

An access modifier precedes the rest of a member's type specification. That is, it must begin a member's declaration statement. Here is an example:

```
public int i;
private double j;

private int myMethod(int a, char b) { //...
```

To understand the effects of public and private access, consider the following program:

```
/* This program demonstrates the difference between
   public and private.
*/
class Test {
    int a; // default access
    public int b; // public access
    private int c; // private access

    // methods to access c
    void setc(int i) { // set c's value
        c = i;
    }
    int getc() { // get c's value
        return c;
    }
}
```



```

}
class AccessTest {
    public static void main(String args[]) {
        Test ob = new Test();

        // These are OK, a and b may be accessed directly
        ob.a = 10;
        ob.b = 20;

        // This is not OK and will cause an error
        // ob.c = 100; // Error!

        // You must access c through its methods
        ob.setc(100); // OK
        System.out.println("a, b, and c: " + ob.a + " " +
                           ob.b + " " + ob.getc());
    }
}

```

As you can see, inside the **Test** class, **a** uses default access, which for this example is the same as specifying **public**. **b** is explicitly specified as **public**. Member **c** is given private access. This means that it cannot be accessed by code outside of its class. So, inside the **AccessTest** class, **c** cannot be used directly. It must be accessed through its public methods: **setc( )** and **getc( )**. If you were to remove the comment symbol from the beginning of the following line,

```
// ob.c = 100; // Error!
```

then you would not be able to compile this program because of the access violation.

To see how access control can be applied to a more practical example, consider the following improved version of the **Stack** class shown at the end of [Chapter 6](#).

```

// This class defines an integer stack that can hold 10 values.
class Stack {
    /* Now, both stck and tos are private. This means
       that they cannot be accidentally or maliciously
       altered in a way that would be harmful to the stack.
    */
    private int stck[] = new int[10];
    private int tos;

    // Initialize top-of-stack
    Stack() {
        tos = -1;
    }

    // Push an item onto the stack
    void push(int item) {
        if(tos==9)
            System.out.println("Stack is full.");
        else
            stck[++tos] = item;
    }
}

```

```
// Pop an item from the stack
int pop() {
    if(tos < 0) {
        System.out.println("Stack underflow.");
        return 0;
    }
    else
        return stck[tos--];
}
}
```

As you can see, now both **stck**, which holds the stack, and **tos**, which is the index of the top of the stack, are specified as **private**. This means that they cannot be accessed or altered except through **push( )** and **pop( )**. Making **tos** private, for example, prevents other parts of your program from inadvertently setting it to a value that is beyond the end of the **stck** array.

The following program demonstrates the improved **Stack** class. Try removing the commented-out lines to prove to yourself that the **stck** and **tos** members are, indeed, inaccessible.

```
class TestStack {
    public static void main(String args[]) {
        Stack mystack1 = new Stack();
        Stack mystack2 = new Stack();

        // push some numbers onto the stack
        for(int i=0; i<10; i++) mystack1.push(i);
        for(int i=10; i<20; i++) mystack2.push(i);

        // pop those numbers off the stack
        System.out.println("Stack in mystack1:");
        for(int i=0; i<10; i++)
            System.out.println(mystack1.pop());

        System.out.println("Stack in mystack2:");

        for(int i=0; i<10; i++)
            System.out.println(mystack2.pop());

        // these statements are not legal
        // mystack1.tos = -2;
        // mystack2.stck[3] = 100;
    }
}
```

Although methods will usually provide access to the data defined by a class, this does not always have to be the case. It is perfectly proper to allow an instance variable to be public when there is good reason to do so. For example, most of the simple classes in this book were created with little concern about controlling access to instance variables

for the sake of simplicity. However, in most real-world classes, you will need to allow operations on data only through methods. The next chapter will return to the topic of access control. As you will see, it is particularly important when inheritance is involved.

## Understanding static

There will be times when you will want to define a class member that will be used independently of any object of that class. Normally, a class member must be accessed only in conjunction with an object of its class. However, it is possible to create a member that can be used by itself, without reference to a specific instance. To create such a member, precede its declaration with the keyword **static**. When a member is declared **static**, it can be accessed before any objects of its class are created, and without reference to any object. You can declare both methods and variables to be **static**. The most common example of a **static** member is **main( )**. **main( )** is declared as **static** because it must be called before any objects exist.

Instance variables declared as **static** are, essentially, global variables. When objects of its class are declared, no copy of a **static** variable is made. Instead, all instances of the class share the same **static** variable.

Methods declared as **static** have several restrictions:

- They can only directly call other **static** methods.
- They can only directly access **static** data.
- They cannot refer to **this** or **super** in any way. (The keyword **super** relates to inheritance and is described in the next chapter.)

If you need to do computation in order to initialize your **static** variables, you can declare a **static** block that gets executed exactly once, when the class is first loaded. The following example shows a class that has a **static** method, some **static** variables, and a **static** initialization block:

```
// Demonstrate static variables, methods, and blocks.
class UseStatic {
    static int a = 3;
    static int b;

    static void meth(int x) {
        System.out.println("x = " + x);
        System.out.println("a = " + a);
        System.out.println("b = " + b);
    }
}
```

```

    }

    static {
        System.out.println("Static block initialized.");
        b = a * 4;
    }

    public static void main(String args[]) {
        meth(42);
    }
}

```

As soon as the **UseStatic** class is loaded, all of the **static** statements are run. First, **a** is set to **3**, then the **static** block executes, which prints a message and then initializes **b** to **a\*4** or **12**. Then **main( )** is called, which calls **meth( )**, passing **42** to **x**. The three **println( )** statements refer to the two **static** variables **a** and **b**, as well as to the local variable **x**.

Here is the output of the program:

```

Static block initialized.
x = 42
a = 3
b = 12

```

Outside of the class in which they are defined, **static** methods and variables can be used independently of any object. To do so, you need only specify the name of their class followed by the dot operator. For example, if you wish to call a **static** method from outside its class, you can do so using the following general form:

*classname.method( )*

Here, *classname* is the name of the class in which the **static** method is declared. As you can see, this format is similar to that used to call non-**static** methods through object-reference variables. A **static** variable can be accessed in the same way—by use of the dot operator on the name of the class. This is how Java implements a controlled version of global methods and global variables.

Here is an example. Inside **main( )**, the **static** method **callme( )** and the **static** variable **b** are accessed through their class name **StaticDemo**.

```

class StaticDemo {
    static int a = 42;
    static int b = 99;

    static void callme() {

```

```

        System.out.println("a = " + a);
    }
}

class StaticByName {
    public static void main(String args[]) {
        StaticDemo.callme();
        System.out.println("b = " + StaticDemo.b);
    }
}

```

Here is the output of this program:

```

a = 42
b = 99

```

## Introducing final

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. This additional usage of **final** is described in the next chapter, when inheritance is described.

## Arrays Revisited

Arrays were introduced earlier in this book, before classes had been discussed. Now that you know about classes, an important point can be made about arrays: they are

implemented as objects. Because of this, there is a special array attribute that you will want to take advantage of. Specifically, the size of an array—that is, the number of elements that an array can hold—is found in its **length** instance variable. All arrays have this variable, and it will always hold the size of the array. Here is a program that demonstrates this property:

```
// This program demonstrates the length array member.
class Length {
    public static void main(String args[]) {
        int a1[] = new int[10];
        int a2[] = {3, 5, 7, 1, 8, 99, 44, -10};
        int a3[] = {4, 3, 2, 1};

        System.out.println("length of a1 is " + a1.length);
        System.out.println("length of a2 is " + a2.length);
        System.out.println("length of a3 is " + a3.length);
    }
}
```

This program displays the following output:

```
length of a1 is 10
length of a2 is 8
length of a3 is 4
```

As you can see, the size of each array is displayed. Keep in mind that the value of **length** has nothing to do with the number of elements that are actually in use. It only reflects the number of elements that the array is designed to hold.

You can put the **length** member to good use in many situations. For example, here is an improved version of the **Stack** class. As you might recall, the earlier versions of this class always created a ten-element stack. The following version lets you create stacks of any size. The value of **stck.length** is used to prevent the stack from overflowing.

// Improved Stack class that uses the length array member.

```
class Stack {
    private int stck[];
    private int tos;

    // allocate and initialize stack
    Stack(int size) {
        stck = new int[size];
        tos = -1;
    }

    // Push an item onto the stack
    void push(int item) {
        if(tos==stck.length-1) // use length member
            System.out.println("Stack is full.");
        else
            stck[++tos] = item;
    }

    // Pop an item from the stack
    int pop() {
        if(tos < 0) {
            System.out.println("Stack underflow.");
            return 0;
        }
        else
            return stck[tos--];
    }
}
```

```
class TestStack2 {
    public static void main(String args[]) {
        Stack mystack1 = new Stack(5);
        Stack mystack2 = new Stack(8);

        // push some numbers onto the stack
        for(int i=0; i<5; i++) mystack1.push(i);
        for(int i=0; i<8; i++) mystack2.push(i);

        // pop those numbers off the stack
        System.out.println("Stack in mystack1:");
        for(int i=0; i<5; i++)
            System.out.println(mystack1.pop());

        System.out.println("Stack in mystack2:");
        for(int i=0; i<8; i++)
            System.out.println(mystack2.pop());
    }
}
```

Notice that the program creates two stacks: one five elements deep and the other eight elements deep. As you can see, the fact that arrays maintain their own length information makes it easy to create stacks of any size.

## Introducing Nested and Inner Classes

It is possible to define a class within another class; such classes are known as *nested classes*. The scope of a nested class is bounded by the scope of its enclosing class. Thus, if

class B is defined within class A, then B does not exist independently of A. A nested class has access to the members, including private members, of the class in which it is nested. However, the enclosing class does not have access to the members of the nested class. A nested class that is declared directly within its enclosing class scope is a member of its enclosing class. It is also possible to declare a nested class that is local to a block.

There are two types of nested classes: *static* and *non-static*. A static nested class is one that has the **static** modifier applied. Because it is static, it must access the non-static members of its enclosing class through an object. That is, it cannot refer to non-static members of its enclosing class directly. Because of this restriction, static nested classes are seldom used.

The most important type of nested class is the *inner* class. An inner class is a non-static nested class. It has access to all of the variables and methods of its outer class and may refer to them directly in the same way that other non-static members of the outer class do.

The following program illustrates how to define and use an inner class. The class named **Outer** has one instance variable named **outer\_x**, one instance method named **test( )**, and defines one inner class called **Inner**.

```
// Demonstrate an inner class.
class Outer {
    int outer_x = 100;

    void test() {
        Inner inner = new Inner();
        inner.display();
    }

    // this is an inner class
    class Inner {
        void display() {
            System.out.println("display: outer_x = " + outer_x);
        }
    }
}

class InnerClassDemo {
    public static void main(String args[]) {
        Outer outer = new Outer();
        outer.test();
    }
}
```

Output from this application is shown here:



```
display: outer_x = 100
```

In the program, an inner class named **Inner** is defined within the scope of class **Outer**. Therefore, any code in class **Inner** can directly access the variable **outer\_x**. An instance method named **display( )** is defined inside **Inner**. This method displays **outer\_x** on the standard output stream. The **main( )** method of **InnerClassDemo** creates an instance of class **Outer** and invokes its **test( )** method. That method creates an instance of class **Inner** and the **display( )** method is called.

It is important to realize that an instance of **Inner** can be created only within the scope of class **Outer**. The Java compiler generates an error message if any code outside of class **Outer** attempts to instantiate class **Inner**. In general, an inner class instance must be created by an enclosing scope.

As explained, an inner class has access to all of the members of its enclosing class, but the reverse is not true. Members of the inner class are known only within the scope of the inner class and may not be used by the outer class. For example,

```
// This program will not compile.
class Outer {
    int outer_x = 100;

    void test() {
        Inner inner = new Inner();
        inner.display();
    }

    // this is an inner class
    class Inner {
        int y = 10; // y is local to Inner

        void display() {
            System.out.println("display: outer_x = " + outer_x);
        }
    }

    void showy() {
        System.out.println(y); // error, y not known here!
    }
}

class InnerClassDemo {
    public static void main(String args[]) {
        Outer outer = new Outer();
        outer.test();
    }
}
```

Here, **y** is declared as an instance variable of **Inner**. Thus, it is not known outside of

that class and it cannot be used by **showy()** ).

Although we have been focusing on inner classes declared as members within an outer class scope, it is possible to define inner classes within any block scope. For example, you can define a nested class within the block defined by a method or even within the body of a **for** loop, as this next program shows:

```
// Define an inner class within a for loop.
class Outer {
    int outer_x = 100;

    void test() {
        for(int i=0; i<10; i++) {
            class Inner {
                void display() {
                    System.out.println("display: outer_x = " + outer_x);
                }
            }
            Inner inner = new Inner();
            inner.display();
        }
    }
}

class InnerClassDemo {
    public static void main(String args[]) {
        Outer outer = new Outer();
        outer.test();
    }
}
```

The output from this version of the program is shown here:

```
display: outer_x = 100
display: outer_x = 100
display: outer_x = 100
display: outer_x = 100
display: outer_x = 100
display: outer_x = 100
display: outer_x = 100
display: outer_x = 100
display: outer_x = 100
display: outer_x = 100
display: outer_x = 100
```

While nested classes are not applicable to all situations, they are particularly helpful when handling events. We will return to the topic of nested classes in [Chapter 22](#). There you will see how inner classes can be used to simplify the code needed to handle certain types of events. You will also learn about *anonymous inner classes*, which are inner classes that don't have a name.

One final point: Nested classes were not allowed by the original 1.0 specification for

Java. They were added by Java 1.1.

## Exploring the String Class

Although the **String** class will be examined in depth in [Part II](#) of this book, a short exploration of it is warranted now, because we will be using strings in some of the example programs shown toward the end of [Part I](#). **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 a peer class of **String**, called **StringBuffer**, which allows strings to be altered, so all of the normal string manipulations are still available in Java. (**StringBuffer** is described in [Part II](#) of this book.)

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

```

As you will see in the following section, string arrays play an important part in many Java programs.

## Using Command-Line Arguments

Sometimes you will want to pass information into a program when you run it. This is accomplished by passing *command-line arguments* to **main( )**. A command-line argument is the information that directly follows the program's name on the command line when it is executed. To access the command-line arguments inside a Java program is quite easy—they are stored as strings in a **String** array passed to the **args** parameter of **main( )**. The first command-line argument is stored at **args[0]**, the second at **args[1]**, and so on. For example, the following program displays all of the command-line arguments that it is called with:

```
// Display all command-line arguments.
class CommandLine {
    public static void main(String args[]) {
        for(int i=0; i<args.length; i++)
            System.out.println("args[" + i + "]: " +
                               args[i]);
    }
}
```

Try executing this program, as shown here:

```
java CommandLine this is a test 100 -1
```

When you do, you will see the following output:

```
args[0]: this
args[1]: is
args[2]: a
args[3]: test
args[4]: 100
args[5]: -1
```

## REMEMBER

All command line arguments are passed as strings. You must convert numeric values to their internal forms manually, as explained in [Chapter 16](#).

## Varargs: Variable-Length Arguments

Beginning with JDK 5, Java has included a feature that simplifies the creation of methods that need to take a variable number of arguments. This feature is called *varargs* and it is short for *variable-length arguments*. A method that takes a variable number of arguments is called a *variable-arity method*, or simply a *varargs method*.

Situations that require that a variable number of arguments be passed to a method are not unusual. For example, a method that opens an Internet connection might take a user name, password, filename, protocol, and so on, but supply defaults if some of this information is not provided. In this situation, it would be convenient to pass only the arguments to which the defaults did not apply. Another example is the **printf( )** method that is part of Java's I/O library. As you will see in [Chapter 19](#), it takes a variable number of arguments, which it formats and then outputs.

Prior to JDK 5, variable-length arguments could be handled two ways, neither of which was particularly pleasing. First, if the maximum number of arguments was small and known, then you could create overloaded versions of the method, one for each way

the method could be called. Although this works and is suitable for some cases, it applies to only a narrow class of situations.

In cases where the maximum number of potential arguments was larger, or unknowable, a second approach was used in which the arguments were put into an array, and then the array was passed to the method. This approach is illustrated by the following program:

```
// Use an array to pass a variable number of
// arguments to a method. This is the old-style
// approach to variable-length arguments.
class PassArray {
    static void vaTest(int v[]) {
        System.out.print("Number of args: " + v.length +
                        " Contents: ");

        for(int x : v)
            System.out.print(x + " ");
        System.out.println();
    }

    public static void main(String args[])
    {
        // Notice how an array must be created to
        // hold the arguments.
        int n1[] = { 10 };
        int n2[] = { 1, 2, 3 };
        int n3[] = { };

        vaTest(n1); // 1 arg
        vaTest(n2); // 3 args
        vaTest(n3); // no args
    }
}
```

The output from the program is shown here:

```
Number of args: 1 Contents: 10
Number of args: 3 Contents: 1 2 3
Number of args: 0 Contents:
```

In the program, the method **vaTest( )** is passed its arguments through the array **v**. This old-style approach to variable-length arguments does enable **vaTest( )** to take an arbitrary number of arguments. However, it requires that these arguments be manually packaged into an array prior to calling **vaTest( )**. Not only is it tedious to construct an array each time **vaTest( )** is called, it is potentially error-prone. The **varargs** feature offers a simpler, better option.

A variable-length argument is specified by three periods (...). For example, here is how

**vaTest( )** is written using a vararg:

```
static void vaTest(int ... v) {
```

This syntax tells the compiler that **vaTest( )** can be called with zero or more arguments. As a result, **v** is implicitly declared as an array of type **int[ ]**. Thus, inside **vaTest( )**, **v** is accessed using the normal array syntax. Here is the preceding program rewritten using a vararg:

```
// Demonstrate variable-length arguments.
class VarArgs {

    // vaTest() now uses a vararg.
    static void vaTest(int ... v) {
        System.out.print("Number of args: " + v.length +
                        " Contents: ");

        for(int x : v)
            System.out.print(x + " ");

        System.out.println();
    }

    public static void main(String args[])
    {
        // Notice how vaTest() can be called with a
        // variable number of arguments.
        vaTest(10);          // 1 arg
        vaTest(1, 2, 3);     // 3 args
        vaTest();            // no args
    }
}
```

The output from the program is the same as the original version.

There are two important things to notice about this program. First, as explained, inside **vaTest( )**, **v** is operated on as an array. This is because **v** is an array. The ... syntax simply tells the compiler that a variable number of arguments will be used, and that these arguments will be stored in the array referred to by **v**. Second, in **main( )**, **vaTest( )** is called with different numbers of arguments, including no arguments at all. The arguments are automatically put in an array and passed to **v**. In the case of no arguments, the length of the array is zero.

A method can have “normal” parameters along with a variable-length parameter. However, the variable-length parameter must be the last parameter declared by the method. For example, this method declaration is perfectly acceptable:

```
int doIt(int a, int b, double c, int ... vals) {
```



In this case, the first three arguments used in a call to **doIt( )** are matched to the first three parameters. Then, any remaining arguments are assumed to belong to **vals**.

Remember, the **varargs** parameter must be last. For example, the following declaration is incorrect:

```
int doIt(int a, int b, double c, int ... vals, boolean stopFlag) { // Error!
```

Here, there is an attempt to declare a regular parameter after the **varargs** parameter, which is illegal.

There is one more restriction to be aware of: there must be only one **varargs** parameter. For example, this declaration is also invalid:

```
int doIt(int a, int b, double c, int ... vals, double ... morevals) { // Error!
```

The attempt to declare the second **varargs** parameter is illegal.

Here is a reworked version of the **vaTest( )** method that takes a regular argument and a variable-length argument:

```
// Use varargs with standard arguments.
class VarArgs2 {

    // Here, msg is a normal parameter and v is a
    // varargs parameter.
    static void vaTest(String msg, int ... v) {
        System.out.print(msg + v.length +
                        " Contents: ");

        for(int x : v)
            System.out.print(x + " ");

        System.out.println();
    }

    public static void main(String args[])
    {
        vaTest("One vararg: ", 10);
        vaTest("Three varargs: ", 1, 2, 3);
        vaTest("No varargs: ");
    }
}
```

The output from this program is shown here:

```
One vararg: 1 Contents: 10
Three varargs: 3 Contents: 1 2 3
No varargs: 0 Contents:
```

## Overloading Vararg Methods

You can overload a method that takes a variable-length argument. For example, the following program overloads **vaTest( )** three times:

```
// Varargs and overloading.
class VarArgs3 {

    static void vaTest(int ... v) {
        System.out.print("vaTest(int ...): " +
            "Number of args: " + v.length +
            " Contents: ");

        for(int x : v)
            System.out.print(x + " ");

        System.out.println();
    }

    static void vaTest(boolean ... v) {
        System.out.print("vaTest(boolean ...) " +
            "Number of args: " + v.length +
            " Contents: ");

        for(boolean x : v)
            System.out.print(x + " ");

        System.out.println();
    }

    static void vaTest(String msg, int ... v) {
        System.out.print("vaTest(String, int ...): " +
            msg + v.length +
            " Contents: ");

        for(int x : v)
            System.out.print(x + " ");

        System.out.println();
    }

    public static void main(String args[])
    {
        vaTest(1, 2, 3);
        vaTest("Testing: ", 10, 20);
        vaTest(true, false, false);
    }
}
```

The output produced by this program is shown here:

```
vaTest(int ...): Number of args: 3 Contents: 1 2 3
vaTest(String, int ...): Testing: 2 Contents: 10 20
vaTest(boolean ...) Number of args: 3 Contents: true false false
```

This program illustrates both ways that a varargs method can be overloaded. First, the types of its vararg parameter can differ. This is the case for **vaTest(int ...)** and **vaTest(boolean ...)**. Remember, the ... causes the parameter to be treated as an array of the specified type. Therefore, just as you can overload methods by using different types of array parameters, you can overload vararg methods by using different types of varargs. In this case, Java uses the type difference to determine which overloaded

method to call.

The second way to overload a varargs method is to add one or more normal parameters. This is what was done with **vaTest(String, int ...)**. In this case, Java uses both the number of arguments and the type of the arguments to determine which method to call.

## NOTE

A varargs method can also be overloaded by a non-varargs method. For example, **vaTest(int x)** is a valid overload of **vaTest( )** in the foregoing program. This version is invoked only when one **int** argument is present. When two or more **int** arguments are passed, the varargs version **vaTest (int...v)** is used.

## Varargs and Ambiguity

Somewhat unexpected errors can result when overloading a method that takes a variable-length argument. These errors involve ambiguity because it is possible to create an ambiguous call to an overloaded varargs method. For example, consider the following program:

```

// Varargs, overloading, and ambiguity.
//
// This program contains an error and will
// not compile!
class VarArgs4 {

    static void vaTest(int ... v) {
        System.out.print("vaTest(int ...): " +
            "Number of args: " + v.length +
            " Contents: ");

        for(int x : v)
            System.out.print(x + " ");

        System.out.println();
    }

    static void vaTest(boolean ... v) {
        System.out.print("vaTest(boolean ...) " +
            "Number of args: " + v.length +
            " Contents: ");

        for(boolean x : v)
            System.out.print(x + " ");

        System.out.println();
    }

    public static void main(String args[])
    {
        vaTest(1, 2, 3); // OK
        vaTest(true, false, false); // OK

        vaTest(); // Error: Ambiguous!
    }
}

```

In this program, the overloading of `vaTest( )` is perfectly correct. However, this program will not compile because of the following call:

```
vaTest(); // Error: Ambiguous!
```

Because the vararg parameter can be empty, this call could be translated into a call to `vaTest(int ...)` or `vaTest(boolean ...)`. Both are equally valid. Thus, the call is inherently ambiguous.

Here is another example of ambiguity. The following overloaded versions of `vaTest( )` are inherently ambiguous even though one takes a normal parameter:

```

static void vaTest(int ... v) { // ...

static void vaTest(int n, int ... v) { // ...

```

Although the parameter lists of `vaTest( )` differ, there is no way for the compiler to resolve the following call:

```
vaTest(1)
```

Does this translate into a call to **vaTest(int ...)**, with one varargs argument, or into a call to **vaTest(int, int ...)** with no varargs arguments? There is no way for the compiler to answer this question. Thus, the situation is ambiguous.

Because of ambiguity errors like those just shown, sometimes you will need to forego overloading and simply use two different method names. Also, in some cases, ambiguity errors expose a conceptual flaw in your code, which you can remedy by more carefully crafting a solution.