JAVA PROGRAMMING

The Complete Reference 8/e , Herbert Schildt, TMH

Edited by

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Text Book: Java, The Complete Reference 8/e , Herbert Schildt, TMH

Class II CS **Semestr III**

CHAPTER 1
Data Types, Variables and Arrays

Introduction

Java was conceived by James Gosling, Patrick Naughton, Chris Warth, Ed Frank, and Mike Sheridan at Sun Microsystems, Inc. in 1991. It took 18 months to develop the first working version. This language was initially called "Oak," but was renamed "Java" in 1995. Between the initial implementation of Oak in the fall of 1992 and the public announcement of Java in the spring of 1995, many more people contributed to the design and evolution of the language. Bill Joy, Arthur van Hoff, Jonathan Payne, Frank Yellin, and Tim Lindholm were key contributors to the maturing of the original prototype. Java is related to C++, which is a direct descendant of C. Much of the character of Java is inherited from these two languages. From C, Java derives its syntax. Many of Java's objectoriented features were influenced by C++.

The Java Features

The following are the important features of Java

- Simple
- Secure
- Portable
- Object-oriented
- Robust
- Multithreaded
- Architecture-neutral
- Interpreted
- High performance
- Distributed
- Dynamic

This chapter explains Java's most fundamental elements: data types, variables, and arrays. As Java supports several types of data.

1. Data Types: Java Is a Strongly Typed Language

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. 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 referred to as *simple* types. These can be put in four groups:

• **Integers:** This group includes **byte**, **short**, **int**, and **long**, which are for whole-valued signed 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.

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. 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 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

byte

The smallest integer type is **byte**. This is a signed 8-bit type that has a range from -128 to 127. Variables of type **byte** are especially useful when working with a stream of data from a network or file. They are also useful when working with raw binary data that may not be directly compatible with Java's other built-in type. 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. Here are some examples of **int** variable declarations:

```
int x;
int y;
```

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. Here are some examples of **long** variable declarations

```
long days;
long seconds;
long distance;
```

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 transcendental 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. Variables of type **float** are useful when you need a fractional component, but don't require a large degree of precision. 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.

Here is a short program that uses **double** variables to compute the area of a circle:

```
// 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**. 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. For this purpose, it requires 16 bits. Thus, in Java **char** is a 16-bit type. The range of a **char** is 0 to 65,536. There are no negative **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. Since Java is designed to allow programs to be written for worldwide use, it makes sense that it would use Unicode to represent characters. 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 127 values 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 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.

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 things to notice about this program. First, as we 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. 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 >.

2. A Closer Look at Literals

Integer Literals

Integers are probably the most commonly used type in the typical program. Any whole number value is an integer literal. Examples are 1, 2, 3, and 42. These are all decimal values, meaning they are describing a base 10 number.

There are two other bases which can be used in integer literals, *octal* (base eight) and *hexadecimal* (base 16). Octal values are denoted in Java by a leading zero. For example 06, 05, 03 represents octal numbers. Thus, the seemingly valid value 09 will produce an error from the compiler, since 9 is outside of octal's 0 to 7 range.

A more common base for numbers used by programmers is hexadecimal, which matches cleanly with modulo 8 word sizes, such as 8, 16, 32, and 64 bits. We signify a hexadecimal constant with a leading zero-x, (**0x** or **0X**). The range of a hexadecimal digit is 0 to 15, so *A* through *F* (or *a* through *f*) are substituted for 10 through 15. . For example 0x6B, 0x52, 0x A3 represents hexadecimal numbers.

Beginning with JDK 7, we can also specify integer literals using binary. To do so, prefix the value with **0b** or **0B**. For example, this specifies the decimal value 10 using a binary literal:

int x = 0b1010;

Also beginning with JDK 7, it can embed one or more underscores in an integer literal. Doing so makes it easier to read large integer literals. When the literal is compiled, the underscores are discarded. For example, given

int x = 123_456_789;

the value given to **x** will be 123,456,789. The underscores will be ignored. Underscores can only be used to separate digits. They cannot come at the beginning or the end of a literal. It is, however, permissible for more than one underscore to be used between two digits. For example, this is valid:

int x = 123___456___789;

The use of underscores in an integer literal is especially useful when encoding such things as telephone numbers, customer ID numbers, part numbers, and so on.

Floating-Point Literals

Floating-point numbers represent decimal values with a fractional component. They can be expressed in either standard or scientific notation.

Standard notation consists of a whole number component followed by a decimal point followed by a fractional component. For example, 2.0, 3.14159, and 0.6667 represent valid standard-notation floating-point numbers. *Scientific notation* uses a standard-notation, floating-point number plus a suffix that specifies a power of 10 by which the number is to be multiplied. The exponent is indicated by an *E* or *e* followed by a decimal number, which can be positive or negative. Examplesinclude 6.022E23, 314159E–05, and 2e+100.

Floating-point literals in Java default to **double** precision. To specify a **float** literal, you must append an *F* or *f* to the constant. It can also explicitly specify a **double** literal by appending a *D* or *d*. Doing so is, of course, redundant. The default **double** type consumes 64 bits of storage, while the smaller **float** type requires only 32 bits.

Hexadecimal floating-point literals are also supported, but they are rarely used. They must be in a form similar to scientific notation, but a **P** or **p**, rather than an **E** or **e**, is used. For example, 0x12.2P2 is a valid floating-point literal. The value following the **P**, called the *binary exponent*, indicates the power-of-two by which the number is multiplied. Therefore, **0x12.2P2** represents 72.5. Beginning with JDK 7, it can embed one or more underscores in a floating-point literal. Its purpose is to make it easier to read large floating-point literals. When the literal is compiled, the underscores are discarded. For example, given

```
double num = 9_423_497_862.0;
```

the value given to **num** will be 9,423,497,862.0. The underscores will be ignored. They cannot come at the beginning or the end of a literal. It is, however, permissible for more than one underscore to be used between two digits. It is also permissible to use underscores in the fractional portion of the number. For example,

```
double num = 9_423_497.1_0_9;
```

Boolean Literals

Boolean literals are simple. There are only two logical values that a **boolean** value can have, **true** and **false**. The values of **true** and **false** do not convert into any numerical representation. The **true** literal in Java does not equal 1, nor does the **false** literal equal 0.

Character Literals

Characters in Java are indices into the Unicode character set. They are 16-bit values that can be converted into integers and manipulated with the integer operators, such as the addition and subtraction operators. A literal character is represented inside a pair of single quotes. All of the visible ASCII characters can be directly entered inside the quotes, such as '*a*', '*z*', and '@'. For characters that are impossible to enter directly, there are several escape sequences that allow us to enter the character we need, such as ' \' 'for the single-quote character itself and ' **n**' for the newline character. There is also a mechanism for directly entering the value of a character in octal or hexadecimal. For octal notation, use the backslash followed by the three-digit number. For example, ' *141*' is the letter '*a*'. For hexadecimal, you enter a backslash-u (**u**), then exactly four hexadecimal digits. For example ' *u0061*'. The following are some of the character escape sequences.

Escape Sequence	**Description**
\ddd	Octal character (ddd)
\uxxxx	Hexadecimal Unicode character (xxxx)
\'	Single quote
\"	Double quote
\\	Backslash
\r	Carriage return
\n	New line (also known as line feed)
\f	Form feed
\t	Tab
\b	Backspace

String Literals

String literals in Java are specified by enclosing a sequence of characters between a pair of double quotes. Examples of string literals are

```
"Hello World"
"two\nlines"
" \"This is in quotes\""
```

One important thing to note about Java strings is that they must begin and end on the same line. There is no line-continuation escape sequence as there is in some other languages.

3. **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 initialize. In addition, all

variables have a scope, which defines their visibility, and a lifetime. These elements are examined next.

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*] …];

The *type* is one of Java's atomic types, or the name of a class or interface. The *identifier* is the name of the variable. We can initialize the variable by specifying an equal sign and a value. 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 int a, b, and c.
int d = 3, e, f = 5; // declares three more int initializing/ d 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'.
```

Dynamic Initialization

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 a right 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 Scope and Lifetime of Variables

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 we start a new block, we 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.

In Java, the two major scopes are those defined by a class and those defined by a method. The scope defined by a method begins with its opening curly brace. 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 we create a block of code, we 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 is accessible 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.

4. Type Conversion and Casting

It is common to assign a value of one type to a variable of another type in most programming languages. If the two types are compatible, 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.

Casting Incompatible Types

If we 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 we are explicitly making the value narrower so that it will fit into the target type. To create a conversion between two incompatible types, we 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;
```

The 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("\nConversion of double to int.");
i = (int) d;
System.out.println("d and i " + d + " " + i);
System.out.println("\nConversion 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
```

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.

5. Automatic Type Promotion in Expressions

There is cases where type conversions may occur: in expressions. Consider the following expression, the precision required of an intermediate value will sometimes exceed the range of either operand.

```
byte a = 40;
byte b = 50;
byte c = 100;
int d = a * b / c;
```

The result of the intermediate term **a * b** easily exceeds the range of either of its **byte** operands. To handle this kind of problem, Java automatically promotes each **byte**, **short**, or **char** operand to **int** when evaluating an expression. This means that the subexpression **a*b** is performed using integers—not bytes. Thus, 2,000, the result of the intermediate expression, **50 * 40**, is legal even though **a** and **b** are both specified as type **byte**.

The Type Promotion Rules

Java defines several *type promotion* rules that apply to expressions. They are as follows:

- First, all **byte**, **short**, and **char** values are promoted to **int**.
- Then, if one operand is a **long**, the whole expression is promoted to **long**.
- If one operand is a **float**, the entire expression is promoted to **float**.
- If any of the operands are **double**, the result is **double**.

6. 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.

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. For example, the following declares an array named **month_days** with the type "array of int":

int month_days[];

In fact, the value of **month_days** is set to **null**, which represents an array with no value. 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**. 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. In Java obtaining an array is a two-step process.

- First, you must declare a variable of the desired array type.
- Second, you must allocate the memory that will hold the array, using **new**, and assign it to the array variable.

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]);
The following program 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 we 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];
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 we 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.");
}
}
```

The output is same s the previous program.

7. Multidimensional Arrays

In Java, *multidimensional arrays* are actually arrays of arrays. 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**. 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 we allocate memory for a multidimensional array, we need only specify the memory for the first (leftmost) dimension. We 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];
```

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.

CHAPTER 2

Introducing Classes

1. Introducing Classes

The class is at the core of Java. It is the logical construct upon which the entire Java language is built because it defines the shape and nature of an object. As such, the class forms the basis for object-oriented programming in Java. Any concept we wish to implement in a Java program must be encapsulated within a class. Because the class is fundamental to Java.

Class Fundamentals

Class is defines a new data type. Once defined, this new type can be used to create objects of that type. Thus, a class is a *template* for an object, and an object is an *instance* of a class. Because an object is an instance of a class, we will often see the two words *object* and *instance* used interchangeably.

The General Form of a Class

When we define a class, we declare its exact form and nature. We do this by specifying the data that it contains and the code that operates on that data. While very simple classes may contain only code or only data, most real-world classes contain both. A class' code defines the interface to its data. A class is declared by use of the **class** keyword. A simplified general form of a **class** definition is shown here:

class *classname* {
type instance-variable1;
// ...
type instance-variableN;
type methodname1(*parameter-list*) {

```
// body of method
}
type methodname2(parameter-list) {
// body of method
}
type methodnameN(parameter-list) {
// body of method
}
}
```

The data, or variables, defined within a **class** are called *instance variables*. The code is contained within *methods*. Collectively, the methods and variables defined within a class are called *members* of the class. In most classes, the instance variables are acted upon and accessed by the methods defined for that class. Thus, as a general rule, it is the methods that determine how a class' data can be used. Variables defined within a class are called instance variables because each instance of the class (that is, each object of the class) contains its own copy of these variables. Thus, the data for one object is separate and unique from the data for another. All methods have the same general form as **main( )**. However, most methods will not be specified as **static** or **public**. Notice that the general form of a class does not specify a **main( )** method. Java classes do not need to have a **main( )** method. We only specify one if that class is the starting point for our program. Further, some kinds of Java applications, such as applets, don't require a **main( )** method at all.

A Simple Class

Here is a class called **Box** that defines three instance variables: **width**, **height**, and **depth**.

```
class Box {
double width;
double height;
double depth;
}
```

As stated, a class defines a new type of data.The new data type is called **Box**. It is important to remember that a class declaration only creates a template; it does not create an actual object. To create a **Box** object, use the statement like the following:

```
Box mybox = new Box(); // create a Box object called mybox
```

After this statement executes, **mybox** will be an instance of **Box**. Every **Box** object will contain its own copies of the instance variables **width**, **height**, and **depth**. To

access these variables, we will use the *dot* (.) operator. The dot operator links the name of the object with the name of an instance variable. For example, to assign the **width** variable of **mybox** the value 100, we would use the following statement:

```
mybox.width = 100;
```

In general, use the dot operator to access both the instance variables and the methods within an object. Java categorizes the. (dot) as a separator. Here is a complete program that uses the **Box** class:

```
/* A program that uses the Box class. Call this file BoxDemo.java */
class Box {
double width;
double height;
double depth;
}
// This class declares an object of type Box.
class BoxDemo {
public static void main(String args[]) {
Box mybox = new Box();
double vol;
// assign values to mybox's instance variables
mybox.width = 10;
mybox.height = 20;
mybox.depth = 15;
// compute volume of box
vol = mybox.width * mybox.height * mybox.depth;
System.out.println("Volume is " + vol);
}
}
```

We should call the file that contains this program **BoxDemo.java**, because the **main( )** method is in the class called **BoxDemo**, not the class called **Box**. When we compile this program, you will find that two **.class** files have been created, one for **Box** and one for **BoxDemo**. The Java compiler automatically puts each class into its own **.class** file. It is not necessary for both the **Box** and the **BoxDemo** class to actually be in the same source file. You could put each class in its own file, called **Box.java** and **BoxDemo.java**, respectively. To run this program, you must execute **BoxDemo.class**.

Output:

```
Volume is 3000.0
```

As stated earlier, each object has its own copies of the instance variables. This means that if we have two **Box** objects, each has its own copy of **depth**, **width**, and **height**. It is important to understand that changes to the instance variables of one object have no effect on the instance variables of another. For example, the following program declares two **Box** objects:

```
// This program declares two Box objects.
class Box {
double width;
double height;
double depth;
}
class BoxDemo2 {
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;
// compute volume of first box
vol = mybox1.width * mybox1.height * mybox1.depth;
System.out.println("Volume is " + vol);
// compute volume of second box
vol = mybox2.width * mybox2.height * mybox2.depth;
System.out.println("Volume is " + vol);
}
}
```

Output:

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

mybox1's data is completely separate from the data contained in **mybox2**.

2. Declaring Objects

When we create a class, we are creating a new data type. We can use this type to declare objects of that type. Obtaining objects of a class is a two-step process. First, we must declare a variable of the class type. This variable does not define an object. Instead, it is simply a variable that can *refer* to an object.
Second, we must acquire an actual, physical copy of the object and assign it to that variable. We can do this using the **new** operator. The **new** operator dynamically allocates (that is, allocates at run time) memory for an object and returns a reference to it. This reference is, more or less, the address in memory of the object allocated by **new**. This reference is then stored in the variable. Thus, in Java, all class objects must be dynamically allocated. The following step is used to declare an object of type **Box**:

```
Box mybox = new Box();
```

This statement combines the two steps just described.

```
Box mybox; // declare reference to object
mybox = new Box(); // allocate a Box object
```

The first line declares **mybox** as a reference to an object of type **Box**. After this line executes, **mybox** contains the value **null**, which indicates that it does not yet point to an actual object. Any attempt to use **mybox** at this point will result in a compile-time error. The next line allocates an actual object and assigns a reference to it to **mybox**. After the second line executes, we can use **mybox** as if it were a **Box** object. But in reality, **mybox** simply holds the memory address of the actual **Box** object.

A Closer Look at new

As just explained, the **new** operator dynamically allocates memory for an object. It has this general form:

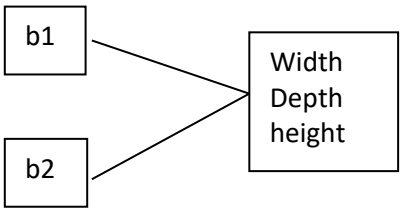
class-var = new *classname* ( );

Here, *class-var* is a variable of the class type being created. The *classname* is the name of the class that is being instantiated. The class name followed by parentheses specifies the *constructor* for the class. A constructor defines what occurs when an object of a class is created. Constructors are an important part of all classes and have many significant attributes. Most real-world classes explicitly define their own constructors within their class definition. However, if no explicit constructor is specified, then Java will automatically supply a default constructor. This is the case with **Box**. For now, we will use the default constructor. It is important to understand that **new** allocates memory for an object during run time. Generally a class creates a new data type that can be used to create objects. That

is, a class creates a logical framework that defines the relationship between its members. When you declare an object of a class, you are creating an instance of that class. Thus, a class is a logical construct. An object has physical reality.

3. Assigning Object Reference Variables

Consider the following statements
Box b1 = new Box();
Box b2 = b1;



The **b2** is being assigned a reference to a copy of the object referred to by **b1**. That is, you might think that **b1** and **b2** refer to separate and distinct objects. However, this would be wrong. Instead, after this fragment executes, **b1** and **b2** will both refer to the *same* object. The assignment of **b1** to **b2** did not allocate any memory or copy any part of the original object. It simply makes **b2** refer to the same object as does **b1**. Thus, any changes made to the object through **b2** will affect the object to which **b1** is referring, since they are the same object. Although **b1** and **b2** both refer to the same object, they are not linked in any other way. For example, a subsequent assignment to **b1** will simply *unhook* **b1** from the original object without affecting the object or affecting **b2**. For example:

```
Box b1 = new Box();
Box b2 = b1;
// ...
b1 = null;
```

Here, **b1** has been set to null, but **b2** still points to the original object. When we assign one object reference variable to another object reference variable, we are not creating a copy of the object, we are only making a copy of the reference.

4. Introducing Methods

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

```
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 we 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.

Adding a Method to the Box Class

Let's begin by adding a method to the **Box** class, 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 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

Returning a Value

In the following example volume **( )** compute the volume of the box and return the result to the caller.

```
// 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);
}
}
```

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

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. 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 we modify the method so that it takes a parameter, as shown next, then we 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. It is important to keep the two terms *parameter* and *argument*. 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.
```
// 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.

5. Constructors

Java allows objects to initialize themselves when they are created. This automatic initialization is performed through the use of a constructor. A *constructor* initializes an object immediately upon creation. It has the same name as the class in which it resides and is syntactically similar to a method. Once defined, the constructor is automatically called immediately after the object is created, before the **new** operator completes. Constructors have no return type, not even **void**. This is because the implicit return type of a class' constructor is the class type itself. It is the constructor's job to initialize the internal state of an object so that the code creating an instance will have a fully initialized, usable object immediately. We can see the **Box** example so that the dimensions of a box are automatically

initialized when an object is constructed. For that replace **setDim( )** with a constructor. Here, Box uses a constructor to initialize the dimensions of a box.

```
class Box {
double width;
double height;
double depth;
// This is the constructor for Box.
Box()
{
System.out.println("Constructing Box");
width = 10;
height = 10;
depth = 10;
}
// compute and return volume
double volume()
{
return width * height * depth;
}
}
class BoxDemo6
{
public static void main(String args[])
{
// declare, allocate, and initialize Box objects
Box mybox1 = new Box();
Box mybox2 = new Box();
double vol;
// 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);
}
}
```

When this program is run, it generates the following results:

```
Constructing Box
Constructing Box
Volume is 1000.0
```

Volume is 1000.0

As you can see, both **mybox1** and **mybox2** were initialized by the **Box( )** constructor when they were created. Since the constructor gives all boxes the same dimensions, 10 by 10 by 10, both **mybox1** and **mybox2** will have the same volume. Most constructors will not display anything. They will simply initialize an object. when we allocate an object, we use the general form:

class-var = new *classname* ( );

Now we can understand why the parentheses are needed after the class name. What is actually happening is that the constructor for the class is being called. Thus, in the line

Box mybox1 = new Box();

new Box( ) is calling the **Box( )** constructor. When we do not explicitly define a constructor for a class, then Java creates a **default** constructor for the class. The default constructor automatically initializes all instance variables to zero. Once we define your own constructor, the default constructor is no longer used.

Parameterized Constructors

It is easy to add parameters to the constructor. The following example of **Box** defines a parameterized constructor that sets the dimensions of a box as specified by those parameters.

```
/* Here, Box uses a parameterized constructor to
initialize the dimensions of a 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;
}
}
class BoxDemo7 {
```

```
public static void main(String args[]) {
// declare, allocate, and initialize Box objects
Box mybox1 = new Box(10, 20, 15);
Box mybox2 = new Box(3, 6, 9);
double vol;
// 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);
}
}
```

The output from this program is shown here:

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

As you can see, each object is initialized as specified in the parameters to its constructor. For example, in the following line,

```
Box mybox1 = new Box(10, 20, 15);
```

the values 10, 20, and 15 are passed to the Box( ) constructor when new creates the object. Thus, mybox1's copy of width, height, and depth will contain the values 10, 20, and 15, respectively. Sometimes the *this* Keyword in a method will need to refer to the object that invoked it. That is, *this* is always a reference to the object on which the method was invoked. You can use this anywhere a reference to an object of the current class' type is permitted. To better understand what this refers to, consider the following version of Box( ):

```
Box(double w, double h, double d) {
this.width = w;
this.height = h;
this.depth = d;
}
```

The use of this is redundant, but perfectly correct. Inside Box( ), this will always refer to the invoking object.

6. Garbage Collection

Since objects are dynamically allocated by using the **new** operator, we might be wondering how such objects are destroyed and their memory released for later reallocation. In some languages, such as C++, dynamically allocated objects must be manually released by use of a **delete** operator. Java takes a different approach; it handles deallocation for us automatically. The technique that accomplishes this is called *garbage collection*. It works like this: when no references to an object exist, that object is assumed to be no longer needed, and the memory occupied by the object can be reclaimed. There is no explicit need to destroy objects as in C++. Garbage collection only occurs sporadically during the execution of your program. It will not occur simply because one or more objects exist that are no longer used.

7. The finalize( ) Method

Sometimes an object will need to perform some action when it is destroyed. For example, if an object is holding some non-Java resource such as a file handle or character font, then we might want to make sure these resources are freed before an object is destroyed. To handle such situations, Java provides a mechanism called *finalization*. By using finalization, we can define specific actions that will occur when an object is just about to be reclaimed by the garbage collector. To add a finalizer to a class, we simply define the **finalize( )** method. The Java run time calls that method whenever it is about to recycle an object of that class. Inside the **finalize( )** method, we will specify those actions that must be performed before an object is destroyed. The garbage collector runs periodically, checking for objects that are no longer referenced by any running state or indirectly through other referenced objects. Right before an asset is freed, the Java run time calls the **finalize( )** method on the object.

The **finalize( )** method has this general form:

```
protected void finalize( )
{
// finalization code here
}
```

Here, the keyword **protected** is a specifier that prevents access to **finalize( )** by code defined outside its class. It is important to understand that **finalize( )** is only called just prior to garbage collection. It is not called when an object goes out-of-scope, for example. This means that you cannot know when—or even if—**finalize( )** will be executed. Therefore, our program should provide other means of releasing system resources, etc., used by the object. It must not rely on **finalize( )** for normal program operation.

****
***

CHAPTER 3

A Closer Look at Methods and Classes

1. 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. These kind of 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. 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. 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.

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.

2. Overloading Constructors

In addition to overloading normal methods, we can also overload constructor methods. The following program explains the use of overloading constructor

```
/* 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.

3. Using Objects as Parameters

So far, we have only been using simple types as parameters to methods. It is both correct and common to pass objects to methods. For example, consider the following 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. The following **Box program** 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.

4. 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, whenyou 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.

5. 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 object will continue to exist as long as there is a reference to it somewhere in your program. When there are noreferences to it, the object will be reclaimed the next time garbage collection takes place.

6. 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
```

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 nethod begin returning. 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.

7. Introducing Access Control

Encapsulation links data with the code that manipulates it. However, encapsulation provides another important attribute: *access control*. Through encapsulation, we can control what parts of a program can access the members of a class. By controlling access, we can prevent misuse. For example, allowing access to data only through a well defined set of methods, we 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. 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.) Here, let’s begin byexamining 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. 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 isspecified

as **private**, then that member can only be accessed by other embers of its class.Now we 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 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.

8. 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. 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, we 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 we 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
```

9. 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. This can be done one of two ways: First, we can give it a value when it is declared. Second, we 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
when inheritance is used.

10. 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.

11. Exploring the String Class

String is probably the most commonly used class in Java's class library. 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.

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
```
Methods:
The **String** class contains several methods that you can use.

equals( ) to test two strings for equality.
```
boolean equals(secondStr)
```

length( ) to obtain the length of a string.
```
int length( )
```

charAt( ) to obtain the character at a specified index within a string.
```
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
```

We can also have arrays of strings, just like we 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
```

12. Using Command-Line Arguments

Sometimes we will want to pass information into a program when we 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]);
}
}
```

Execute the program with the following statement

java CommandLine this is a test 100 -1
The following output will be displayed.
args[0]: this
args[1]: is
args[2]: a
args[3]: test
args[4]: 100
args[5]: -1

CHPTER 4
INHERITANCE

Introduction

Inheritance is one of the cornerstones of object-oriented programming because it allows the creation of hierarchical classifications. Using inheritance, we can create a general class that defines traits common to a set of related items. This class can then be inherited by other, more specific classes, each adding those things that are unique to it. In the terminology of Java, a class that is inherited is called a *superclass*. The class that does the inheriting is called a *subclass*. Therefore, a subclass is a specialized version of a superclass. It inherits all of the members defined by the superclass and adds its own, unique elements.

1. Inheritance Basics

To inherit a class, we simply incorporate the definition of one class into another by using the **extends** keyword. The following program creates a superclass called **A** and a subclass called **B**. Notice how the keyword **extends** is used to create a subclass of **A**.

```
// A simple example of inheritance.
// Create a superclass.
class A {
int i, j;
void showij() {
System.out.println("i and j: " + i + " " + j);
}
}
// Create a subclass by extending class A.
class B extends A {
int k;
void showk() {
System.out.println("k: " + k);
}
void sum() {
System.out.println("i+j+k: " + (i+j+k));
}
}
class SimpleInheritance {
public static void main(String args []) {
```

```
A superOb = new A();
B subOb = new B();
// The superclass may be used by itself.
superOb.i = 10;
superOb.j = 20;
System.out.println("Contents of superOb: ");
superOb.showij();
System.out.println();
/* The subclass has access to all public members of
its superclass. */
subOb.i = 7;
subOb.j = 8;
subOb.k = 9;
System.out.println("Contents of subOb: ");
subOb.showij();
subOb.showk();
System.out.println();
System.out.println("Sum of i, j and k in subOb:");
subOb.sum();
}
}
```

The output for this program is shown here:

```
Contents of superOb:
i and j: 10 20
Contents of subOb:
i and j: 7 8
k: 9
Sum of i, j and k in subOb:
i+j+k: 24
```

The subclass **B** includes all of the members of its superclass **A**. This is why **subOb** can access **i** and **j** and call **showij( )**. Also, inside **sum( )**, **i** and **j** can be referred to directly, as if they were part of **B**. Even though **A** is a superclass for **B**, it is also a completely independent, stand-alone class. Being a superclass for a subclass does not mean that the superclass cannot be used by itself. Further, a subclass can be a superclass for another subclass.

The general form of a **class** declaration that inherits a superclass is shown here:

```
class subclass-name extends superclass-name {
// body of class
}
```

We can only specify one superclass for any subclass that we create. Java does not support the inheritance of multiple superclasses into a single subclass. We can, as stated, create a hierarchy of inheritance in which a subclass becomes a superclass of another subclass. However, no class can be a superclass of itself.

Member Access and Inheritance

Although a subclass includes all of the members of its superclass, it cannot access those members of the superclass that have been declared as **private**. For example, consider the following simple class hierarchy:

```
/* In a class hierarchy, private members remain
private to their class.
This program contains an error and will not
compile.
*/
// Create a superclass.
class A {
int i; // public by default
private int j; // private to A
void setij(int x, int y) {
i = x;
j = y;
}
}
// A's j is not accessible here.
class B extends A {
int total;
void sum() {
total = i + j; // ERROR, j is not accessible here
}
}
class Access {
public static void main(String args[]) {
B subOb = new B();
subOb.setij(10, 12);
subOb.sum();
System.out.println("Total is " + subOb.total);
}
}
```

This program will not compile because the use of **j** inside the **sum( )** method of **B** causes an access violation. Since **j** is declared as **private**, it is only accessible by other members of its own class. Subclasses have no access to it.
A class member that has been declared as private will remain private to its class. It is not accessible by any code outside its class, including subclasses.

2. Using super
Whenever a subclass needs to refer to its immediate superclass, it can do so by use of the keyword **super**.
super has two general forms.

- The first calls the superclass' constructor.
- The second is used to access a member of the superclass that has been hidden by a member of a subclass.

Using super to Call Superclass Constructors
A subclass can call a constructor defined by its superclass by use of the following form of **super**:

super(*arg-list*);

Here, *arg-list* specifies any arguments needed by the constructor in the superclass. **super( )** must always be the first statement executed inside a subclass' constructor. To see how **super( )** is used, consider this improved version of the **BoxWeight** class:

```
// BoxWeight now uses super to initialize its Box attributes.
class BoxWeight extends Box {
double weight; // weight of box
// initialize width, height, and depth using super()
BoxWeight(double w, double h, double d, double m) {
super(w, h, d); // call superclass constructor
weight = m;
}
}
```

Here, **BoxWeight( )** calls **super( )** with the arguments **w**, **h**, and **d**. This causes the **Box** constructor to be called, which initializes **width**, **height**, and **depth** using these values. **BoxWeight** no longer initializes these values itself. It only needs to initialize the value unique to it: **weight**. This leaves **Box** free to make these values **private** if desired.
In the preceding example, **super( )** was called with three arguments. Since constructors can be overloaded, **super( )** can be called using any form defined by

the superclass. The constructor executed will be the one that matches the arguments. For example, here is a complete implementation of **BoxWeight** that provides constructors for the various ways that a box can be constructed. In each case, **super( )** is called using the appropriate arguments.
Notice that **width**, **height**, and **depth** have been made private within **Box**.

```
// A complete implementation of BoxWeight.
class Box {
private double width;
private double height;
private double depth;
// construct clone of an object
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;
}
}
// BoxWeight now fully implements all constructors.
class BoxWeight extends Box {
```

```
double weight; // weight of box
// construct clone of an object
BoxWeight(BoxWeight ob) { // pass object to constructor
super(ob);
weight = ob.weight;
}
// constructor when all parameters are specified
BoxWeight(double w, double h, double d, double m) {

super(w, h, d); // call superclass constructor
weight = m;
}
// default constructor
BoxWeight() {
super();
weight = -1;
}
// constructor used when cube is created
BoxWeight(double len, double m) {
super(len);
weight = m;
}
}
class DemoSuper {
public static void main(String args[]) {
BoxWeight mybox1 = new BoxWeight(10, 20, 15, 34.3);
BoxWeight mybox2 = new BoxWeight(2, 3, 4, 0.076);
BoxWeight mybox3 = new BoxWeight(); // default
BoxWeight mycube = new BoxWeight(3, 2);
BoxWeight myclone = new BoxWeight(mybox1);
double vol;
vol = mybox1.volume();
System.out.println("Volume of mybox1 is " + vol);
System.out.println("Weight of mybox1 is " + mybox1.weight);
System.out.println();
vol = mybox2.volume();
System.out.println("Volume of mybox2 is " + vol);
System.out.println("Weight of mybox2 is " + mybox2.weight);
System.out.println();
vol = mybox3.volume();
System.out.println("Volume of mybox3 is " + vol);
```

```
System.out.println("Weight of mybox3 is " + mybox3.weight);
System.out.println();
vol = myclone.volume();
System.out.println("Volume of myclone is " + vol);
System.out.println("Weight of myclone is " + myclone.weight);
System.out.println();
vol = mycube.volume();
System.out.println("Volume of mycube is " + vol);
System.out.println("Weight of mycube is " + mycube.weight);
System.out.println();
}
}
```

This program generates the following output:

```
Volume of mybox1 is 3000.0
Weight of mybox1 is 34.3
Volume of mybox2 is 24.0
Weight of mybox2 is 0.076
Volume of mybox3 is -1.0
Weight of mybox3 is -1.0
Volume of myclone is 3000.0
Weight of myclone is 34.3
Volume of mycube is 27.0
Weight of mycube is 2.0
```

Notice that **super( )** is passed an object of type **BoxWeight**—not of type **Box**. This still invokes the constructor **Box(Box ob)**. As mentioned earlier, a superclass variable can be used to reference any object derived from that class. Thus, we are able to pass a **BoxWeight** object to the **Box** constructor. Of course, **Box** only has knowledge of its own members. Let's review the key concepts behind **super( )**. When a subclass calls **super( )**, it is calling the constructor of its immediate superclass. Thus, **super( )** always refers to the superclass immediately above the calling class. This is true even in a multileveled hierarchy. Also, **super( )** must always be the first statement executed inside a subclass constructor.

A Second Use for super

The second form of **super** acts somewhat like **this**, except that it always refers to the superclass of the subclass in which it is used. This usage has the following general form:

super.*member*

Here, *member* can be either a method or an instance variable. This second form of **super** is most applicable to situations in which member names of a subclass hide members by the same name in the superclass. Consider this simple class hierarchy:

```
// Using super to overcome name hiding.
class A {
int i;
}
// Create a subclass by extending class A.

class B extends A {
int i; // this i hides the i in A
B(int a, int b) {
super.i = a; // i in A
i = b; // i in B
}
void show() {
System.out.println("i in superclass: " + super.i);
System.out.println("i in subclass: " + i);
}
}
class UseSuper {
public static void main(String args[]) {
B subOb = new B(1, 2);
subOb.show();
}
}
```

This program displays the following:

```
i in superclass: 1
i in subclass: 2
```

Although the instance variable **i** in **B** hides the **i** in **A**, **super** allows access to the **i** defined in the superclass. As we will see, **super** can also be used to call methods that are hidden by a subclass.

3. Creating a Multilevel Hierarchy

We have been using simple class hierarchies that consist of only a superclass and a subclass. However, we can build hierarchies that contain as many layers of inheritance as we like. As mentioned, it is perfectly acceptable to use a subclass as a superclass of another. For example, given three classes called **A**, **B**, and **C**, **C** can be a subclass of **B**, which is a subclass of **A**. When this type of situation occurs, each subclass inherits all of the traits found in all of its superclasses. In this case, **C**

inherits all aspects of **B** and **A**. In it, the subclass **BoxWeight** is used as a superclass to create the subclass called **Shipment**. **Shipment** inherits all of the traits of **BoxWeight** and **Box**, and adds a field called **cost**, which holds the cost of shipping such a parcel.

```
// Extend BoxWeight to include shipping costs.
// Start with Box.
class Box {
private double width;
private double height;
private double depth;

// construct clone of an object
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;
}
}
// Add weight.
class BoxWeight extends Box {
```

```
double weight; // weight of box
// construct clone of an object
BoxWeight(BoxWeight ob) { // pass object to constructor
super(ob);
weight = ob.weight;
}
// constructor when all parameters are specified
BoxWeight(double w, double h, double d, double m) {
super(w, h, d); // call superclass constructor
weight = m;
}
// default constructor
BoxWeight() {
super();
weight = -1;
}

// constructor used when cube is created
BoxWeight(double len, double m) {
super(len);
weight = m;
}
}
// Add shipping costs.
class Shipment extends BoxWeight {
double cost;
// construct clone of an object
Shipment(Shipment ob) { // pass object to constructor
super(ob);
cost = ob.cost;
}
// constructor when all parameters are specified
Shipment(double w, double h, double d,
double m, double c) {
super(w, h, d, m); // call superclass constructor
cost = c;
}
// default constructor
Shipment() {
super();
cost = -1;
```

```
}
// constructor used when cube is created
Shipment(double len, double m, double c) {
super(len, m);
cost = c;
}
}
class DemoShipment {
public static void main(String args[]) {
Shipment shipment1 =
new Shipment(10, 20, 15, 10, 3.41);
Shipment shipment2 =
new Shipment(2, 3, 4, 0.76, 1.28);
double vol;
vol = shipment1.volume();
System.out.println("Volume of shipment1 is " + vol);
System.out.println("Weight of shipment1 is "
+ shipment1.weight);
System.out.println("Shipping cost: $" + shipment1.cost);
System.out.println();

vol = shipment2.volume();
System.out.println("Volume of shipment2 is " + vol);
System.out.println("Weight of shipment2 is "
+ shipment2.weight);
System.out.println("Shipping cost: $" + shipment2.cost);
}
}
```

The output of this program is shown here:

```
Volume of shipment1 is 3000.0
Weight of shipment1 is 10.0
Shipping cost: $3.41
Volume of shipment2 is 24.0
Weight of shipment2 is 0.76
Shipping cost: $1.28
```

Because of inheritance, **Shipment** can make use of the previously defined classes of **Box** and **BoxWeight**, adding only the extra information it needs for its own, specific application. This is part of the value of inheritance; it allows the reuse of code. This example illustrates one other important point: **super( )** always refers to the constructor in the closest superclass. The **super( )** in **Shipment** calls the constructor in **BoxWeight**. The **super( )** in **BoxWeight** calls the constructor in

Box. In a class hierarchy, if a superclass constructor requires parameters, then all subclasses must pass those parameters "up the line." This is true whether or not a subclass needs parameters of its own. In Java, all three classes could have been placed into their own files and compiled separately. In fact, using separate files is the norm, not the exception, in creating class hierarchies.

4. Method Overriding

In a class hierarchy, when a method in a subclass has the same name and type signature as a method in its superclass, then the method in the subclass is said to *override* the method in the superclass. When an overridden method is called from within its subclass, it will always refer to the version of that method defined by the subclass. The version of the method defined by the superclass will be hidden. Consider the following:

```
// Method overriding.
class A {
int i, j;
A(int a, int b) {
i = a;
j = b;
}
// display i and j
void show() {
System.out.println("i and j: " + i + " " + j);
}
} class B extends A {
int k;
B(int a, int b, int c) {
super(a, b);
k = c;
}
// display k – this overrides show() in A
void show() {
System.out.println("k: " + k);
}
}
class Override {
public static void main(String args[]) {
B subOb = new B(1, 2, 3);
subOb.show(); // this calls show() in B
```

```
}
}
```
The output produced by this program is shown here:
```
k: 3
```
When **show( )** is invoked on an object of type **B**, the version of **show( )** defined within **B** is used. That is, the version of **show( )** inside **B** overrides the version declared in **A**. If you wish to access the superclass version of an overridden method, we can do so by using **super**. For example, in **B**, the superclass version of **show( )** is invoked within the subclass' version. This allows all instance variables to be displayed.
```
class B extends A {
int k;
B(int a, int b, int c) {
super(a, b);
k = c;
}
void show() {
super.show(); // this calls A's show()
System.out.println("k: " + k);
}
}
```
If you substitute this version of **A** into the previous program, you will see the following output:
```
i and j: 1 2
k: 3
```
Here, **super.show( )** calls the superclass version of **show( )** methods are identical. If they are not, then the two methods are simply overloaded. For example, consider this modified version of the preceding example:

```
// Methods with differing type signatures are overloaded – not
// overridden.
class A {
int i, j;
A(int a, int b) {
i = a;
j = b;
}
// display i and j
void show() {
System.out.println("i and j: " + i + " " + j);
```

```
}
}
// Create a subclass by extending class A.
class B extends A {
int k;
B(int a, int b, int c) {
super(a, b);
k = c;
}
// overload show()
void show(String msg) {
System.out.println(msg + k);
}
}
class Override {
public static void main(String args[]) {
B subOb = new B(1, 2, 3);
subOb.show("This is k: "); // this calls show() in B
subOb.show(); // this calls show() in A
}
}
```

The output produced by this program is shown here:

```
This is k: 3
i and j: 1 2
```

The version of **show( )** in **B** takes a string parameter. This makes its type signature different from the one in **A**, which takes no parameters. Therefore, no overriding (or name hiding) takes place. Instead, the version of **show( )** in **B** simply overloads the version of **show( )** in **A**.