

Module 7

Inheritance

CRITICAL SKILLS

- 7.1 Understand inheritance basics
- 7.2 Call superclass constructors
- 7.3 Use **super** to access superclass members
- 7.4 Create a multilevel class hierarchy
- 7.5 Know when constructors are called
- 7.6 Understand superclass references to subclass objects
- 7.7 Override methods
- 7.8 Use overridden methods to achieve dynamic method dispatch
- 7.9 Use abstract classes
- 7.10 Use **final**
- 7.11 Know the **Object** class

251

Inheritance is one of the three foundation principles of object-oriented programming because it allows the creation of hierarchical classifications. Using inheritance, you 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 language 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 variables and methods defined by the superclass and adds its own, unique elements.

CRITICAL SKILL

7.1

Inheritance Basics

Java supports inheritance by allowing one class to incorporate another class into its declaration. This is done by using the **extends** keyword. Thus, the subclass adds to (extends) the superclass.

Let's begin with a short example that illustrates several of the key features of inheritance. The following program creates a superclass called **TwoDShape**, which stores the width and height of a two-dimensional object, and a subclass called **Triangle**. Notice how the keyword **extends** is used to create a subclass.

```
// A simple class hierarchy.

// A class for two-dimensional objects.
class TwoDShape {
    double width;
    double height;

    void showDim() {
        System.out.println("Width and height are " +
            width + " and " + height);
    }
}

// A subclass of TwoDShape for triangles.
class Triangle extends TwoDShape {
    String style;

    double area() {
        return width * height / 2;
    }

    void showStyle() {
        System.out.println("Triangle is " + style);
    }
}
```

Triangle inherits TwoDShape.

Triangle can refer to the members of TwoDShape as if they were part of Triangle.

```

    }
}

class Shapes {
    public static void main(String args[]) {
        Triangle t1 = new Triangle();
        Triangle t2 = new Triangle();

        t1.width = 4.0;
        t1.height = 4.0;
        t1.style = "isosceles";

        t2.width = 8.0;
        t2.height = 12.0;
        t2.style = "right";

        System.out.println("Info for t1: ");
        t1.showStyle();
        t1.showDim();
        System.out.println("Area is " + t1.area());

        System.out.println();

        System.out.println("Info for t2: ");
        t2.showStyle();
        t2.showDim();
        System.out.println("Area is " + t2.area());
    }
}

```

← All members of **Triangle** are available to **Triangle** objects, even those inherited from **TwoDShape**.

The output from this program is shown here:

```

Info for t1:
Triangle is isosceles
Width and height are 4.0 and 4.0
Area is 8.0

Info for t2:
Triangle is right
Width and height are 8.0 and 12.0
Area is 48.0

```

Here, **TwoDShape** defines the attributes of a “generic” two-dimensional shape, such as a square, rectangle, triangle, and so on. The **Triangle** class creates a specific type of **TwoDShape**, in this case, a triangle. The **Triangle** class includes all of **TwoDObject** and adds the field **style**,

the method `area()`, and the method `showStyle()`. A description of the type of triangle is stored in `style`, `area()` computes and returns the area of the triangle, and `showStyle()` displays the triangle style.

Because **Triangle** includes all of the members of its superclass, **TwoDShape**, it can access `width` and `height` inside `area()`. Also, inside `main()`, objects `t1` and `t2` can refer to `width` and `height` directly, as if they were part of **Triangle**. Figure 7-1 depicts conceptually how **TwoDShape** is incorporated into **Triangle**.

Even though **TwoDShape** is a superclass for **Triangle**, 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. For example, the following is perfectly valid.

```
TwoDShape shape = new TwoDShape();

shape.width = 10;
shape.height = 20;

shape.showDim();
```

Of course, an object of **TwoDShape** has no knowledge of or access to any subclasses of **TwoDShape**.

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

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

You can specify only one superclass for any subclass that you create. Java does not support the inheritance of multiple superclasses into a single subclass. (This differs from C++, in which you can inherit multiple base classes. Be aware of this when converting C++ code to Java.) You can, however, create a hierarchy of inheritance in which a subclass becomes a superclass of another subclass. Of course, no class can be a superclass of itself.

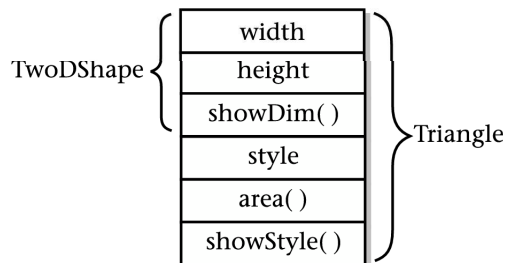


Figure 7-1 A conceptual depiction of the **Triangle** class

A major advantage of inheritance is that once you have created a superclass that defines the attributes common to a set of objects, it can be used to create any number of more specific subclasses. Each subclass can precisely tailor its own classification. For example, here is another subclass of **TwoDShape** that encapsulates rectangles.

```
// A subclass of TwoDShape for rectangles.
class Rectangle extends TwoDShape {
    boolean isSquare() {
        if(width == height) return true;
        return false;
    }

    double area() {
        return width * height;
    }
}
```

The **Rectangle** class includes **TwoDShape** and adds the methods **isSquare()**, which determines if the rectangle is square, and **area()**, which computes the area of a rectangle.

Member Access and Inheritance

As you learned in Module 6, often an instance variable of a class will be declared **private** to prevent its unauthorized use or tampering. Inheriting a class *does not* overrule the **private** access restriction. Thus, even though a subclass includes all of the members of its superclass, it cannot access those members of the superclass that have been declared **private**. For example, if, as shown here, **width** and **height** are made private in **TwoDShape**, then **Triangle** will not be able to access them.

```
// Private members are not inherited.

// This example will not compile.

// A class for two-dimensional objects.
class TwoDShape {
    private double width; // these are
    private double height; // now private

    void showDim() {
        System.out.println("Width and height are " +
            width + " and " + height);
    }
}
```

```
// A subclass of TwoDShape for triangles.
class Triangle extends TwoDShape {
    String style;

    double area() {
        return width * height / 2; // Error! can't access
    }

    void showStyle() {
        System.out.println("Triangle is " + style);
    }
}
```

Can't access a **private** member of a superclass.

The **Triangle** class will not compile because the reference to **width** and **height** inside the **area()** method causes an access violation. Since **width** and **height** are declared **private**, they are accessible only by other members of their own class. Subclasses have no access to them.

Remember that a class member that has been declared **private** will remain private to its class. It is not accessible by any code outside its class, including subclasses.

At first, you might think that the fact that subclasses do not have access to the private members of superclasses is a serious restriction that would prevent the use of private members in many situations. However this is not true. As explained in Module 6, Java programmers typically use accessor methods to provide access to the private methods of a class. Here is a rewrite of the **TwoDShape** and **Triangle** classes that uses methods to access the private instance variables **width** and **height**.

```
// Use accessor methods to set and get private members.

// A class for two-dimensional objects.
class TwoDShape {
    private double width; // these are
    private double height; // now private

    // Accessor methods for width and height.
    double getWidth() { return width; }
    double getHeight() { return height; } ← Accessor methods for
    void setWidth(double w) { width = w; } width and height
    void setHeight(double h) { height = h; }

    void showDim() {
        System.out.println("Width and height are " +
            width + " and " + height);
    }
}
```

```
// A subclass of TwoDShape for triangles.
class Triangle extends TwoDShape {
    String style;

    double area() {
        return getWidth() * getHeight() / 2;
    }

    void showStyle() {
        System.out.println("Triangle is " + style);
    }
}

class Shapes2 {
    public static void main(String args[]) {
        Triangle t1 = new Triangle();
        Triangle t2 = new Triangle();

        t1.setWidth(4.0);
        t1.setHeight(4.0);
        t1.style = "isosceles";

        t2.setWidth(8.0);
        t2.setHeight(12.0);
        t2.style = "right";

        System.out.println("Info for t1: ");
        t1.showStyle();
        t1.showDim();
        System.out.println("Area is " + t1.area());

        System.out.println();

        System.out.println("Info for t2: ");
        t2.showStyle();
        t2.showDim();
        System.out.println("Area is " + t2.area());
    }
}
```

Use accessor methods provided by superclass.

Ask the Expert

Q: When should I make an instance variable private?

A: There are no hard and fast rules, but here are two general principles. If an instance variable is to be used only by methods defined within its class, then it should be made private. If an instance variable must be within certain bounds, then it should be private and made available only through accessor methods. This way, you can prevent invalid values from being assigned.



Progress Check

1. When creating a subclass, what keyword is used to include a superclass?
2. Does a subclass include the members of its superclass?
3. Does a subclass have access to the private members of its superclass?

CRITICAL SKILL

7.2

Constructors and Inheritance

In a hierarchy, it is possible for both superclasses and subclasses to have their own constructors. This raises an important question: what constructor is responsible for building an object of the subclass—the one in the superclass, the one in the subclass, or both? The answer is this: the constructor for the superclass constructs the superclass portion of the object, and the constructor for the subclass constructs the subclass part. This makes sense because the superclass has no knowledge of or access to any element in a subclass. Thus, their construction must be separate. The preceding examples have relied upon the default constructors created automatically by Java, so this was not an issue. However, in practice, most classes will have explicit constructors. Here you will see how to handle this situation.

1. **extends**
2. Yes.
3. No.

When only the subclass defines a constructor, the process is straightforward: simply construct the subclass object. The superclass portion of the object is constructed automatically using its default constructor. For example, here is a reworked version of **Triangle** that defines a constructor. It also makes **style** private since it is now set by the constructor.

```
// Add a constructor to Triangle.

// A class for two-dimensional objects.
class TwoDShape {
    private double width; // these are
    private double height; // now private

    // Accessor methods for width and height.
    double getWidth() { return width; }
    double getHeight() { return height; }
    void setWidth(double w) { width = w; }
    void setHeight(double h) { height = h; }

    void showDim() {
        System.out.println("Width and height are " +
                           width + " and " + height);
    }
}

// A subclass of TwoDShape for triangles.
class Triangle extends TwoDShape {
    private String style;

    // Constructor
    Triangle(String s, double w, double h) {
        setWidth(w);
        setHeight(h);

        style = s;
    }

    double area() {
        return getWidth() * getHeight() / 2;
    }

    void showStyle() {
        System.out.println("Triangle is " + style);
    }
}
```

← Initialize **TwoDShape**
portion of object.

```
class Shapes3 {
    public static void main(String args[]) {
        Triangle t1 = new Triangle("isosceles", 4.0, 4.0);
        Triangle t2 = new Triangle("right", 8.0, 12.0);

        System.out.println("Info for t1: ");
        t1.showStyle();
        t1.showDim();
        System.out.println("Area is " + t1.area());

        System.out.println();

        System.out.println("Info for t2: ");
        t2.showStyle();
        t2.showDim();
        System.out.println("Area is " + t2.area());
    }
}
```

Here, **Triangle**'s constructor initializes the members of **TwoDClass** that it inherits along with its own **style** field.

When both the superclass and the subclass define constructors, the process is a bit more complicated because both the superclass and subclass constructors must be executed. In this case you must use another of Java's keywords, **super**, which has two general forms. The first calls a superclass constructor. The second is used to access a member of the superclass that has been hidden by a member of a subclass. Here, we will look at its first use.

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(parameter-list);
```

Here, *parameter-list* specifies any parameters 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 the version of **TwoDShape** in the following program. It defines a constructor that initializes **width** and **height**.

```
// Add constructors to TwoDShape.
class TwoDShape {
    private double width;
    private double height;

    // Parameterized constructor.
    TwoDShape(double w, double h) {
        width = w;
        height = h;
    }

    // Accessor methods for width and height.
    double getWidth() { return width; }
    double getHeight() { return height; }
    void setWidth(double w) { width = w; }
    void setHeight(double h) { height = h; }

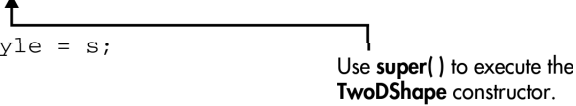
    void showDim() {
        System.out.println("Width and height are " +
            width + " and " + height);
    }
}

// A subclass of TwoDShape for triangles.
class Triangle extends TwoDShape {
    private String style;

    Triangle(String s, double w, double h) {
        super(w, h); // call superclass constructor
        style = s;
    }

    double area() {
        return getWidth() * getHeight() / 2;
    }

    void showStyle() {
        System.out.println("Triangle is " + style);
    }
}
```



Use `super()` to execute the `TwoDShape` constructor.

```
class Shapes4 {
    public static void main(String args[]) {
        Triangle t1 = new Triangle("isosceles", 4.0, 4.0);
        Triangle t2 = new Triangle("right", 8.0, 12.0);

        System.out.println("Info for t1: ");
        t1.showStyle();
        t1.showDim();
        System.out.println("Area is " + t1.area());

        System.out.println();

        System.out.println("Info for t2: ");
        t2.showStyle();
        t2.showDim();
        System.out.println("Area is " + t2.area());
    }
}
```

Here, **Triangle()** calls **super()** with the parameters **w** and **h**. This causes the **TwoDShape()** constructor to be called, which initializes **width** and **height** using these values. **Triangle** no longer initializes these values itself. It need only initialize the value unique to it: **style**. This leaves **TwoDShape** free to construct its subobject in any manner that it so chooses. Furthermore, **TwoDShape** can add functionality about which existing subclasses have no knowledge, thus preventing existing code from breaking.

Any form of constructor defined by the superclass can be called by **super()**. The constructor executed will be the one that matches the arguments. For example, here are expanded versions of both **TwoDShape** and **Triangle** that include default constructors and constructors that take one argument.

```
// Add more constructors to TwoDShape.
class TwoDShape {
    private double width;
    private double height;

    // A default constructor.
    TwoDShape() {
        width = height = 0.0;
    }
}
```

```

// Parameterized constructor.
TwoDShape(double w, double h) {
    width = w;
    height = h;
}

// Construct object with equal width and height.
TwoDShape(double x) {
    width = height = x;
}

// Accessor methods for width and height.
double getWidth() { return width; }
double getHeight() { return height; }
void setWidth(double w) { width = w; }
void setHeight(double h) { height = h; }

void showDim() {
    System.out.println("Width and height are " +
        width + " and " + height);
}
}

// A subclass of TwoDShape for triangles.
class Triangle extends TwoDShape {
    private String style;

    // A default constructor.
    Triangle() {
        super();
        style = "null";
    }

    // Constructor
    Triangle(String s, double w, double h) {
        super(w, h); // call superclass constructor

        style = s;
    }

    // Construct an isosceles triangle.
    Triangle(double x) {
        super(x); // call superclass constructor
    }
}

```

Use **super()** to call the various forms of the **TwoDShape** constructor.

```
        style = "isosceles";
    }

    double area() {
        return getWidth() * getHeight() / 2;
    }

    void showStyle() {
        System.out.println("Triangle is " + style);
    }
}

class Shapes5 {
    public static void main(String args[]) {
        Triangle t1 = new Triangle();
        Triangle t2 = new Triangle("right", 8.0, 12.0);
        Triangle t3 = new Triangle(4.0);

        t1 = t2;

        System.out.println("Info for t1: ");
        t1.showStyle();
        t1.showDim();
        System.out.println("Area is " + t1.area());

        System.out.println();

        System.out.println("Info for t2: ");
        t2.showStyle();
        t2.showDim();
        System.out.println("Area is " + t2.area());

        System.out.println();

        System.out.println("Info for t3: ");
        t3.showStyle();
        t3.showDim();
        System.out.println("Area is " + t3.area());

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

Here is the output from this version.

```
Info for t1:  
Triangle is right  
Width and height are 8.0 and 12.0  
Area is 48.0
```

```
Info for t2:  
Triangle is right  
Width and height are 8.0 and 12.0  
Area is 48.0
```

```
Info for t3:  
Triangle is isosceles  
Width and height are 4.0 and 4.0  
Area is 8.0
```

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 multilevel hierarchy. Also, **super()** must always be the first statement executed inside a subclass constructor.

Progress Check

1. How does a subclass execute its superclass' constructor?
2. Can parameters be passed via **super()**?
3. Can **super()** go anywhere within a subclass' constructor?

-
1. It calls **super()**.
 2. Yes.
 3. No, it must be the first statement executed.

CRITICAL SKILL

7.3

Using `super` to Access Superclass Members

There is a second form of **super** that 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 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 ← Here, super.i refers
        i = b; // i in B           to the i in A.
    }

    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. **super** can also be used to call methods that are hidden by a subclass.

Project 7-1 Extending the Vehicle Class

TruckDemo.java

To illustrate the power of inheritance, we will extend the **Vehicle** class first developed in Module 4. As you should recall, **Vehicle** encapsulates information about vehicles, including the number of passengers they can carry, their fuel capacity, and fuel consumption rate. We can use the **Vehicle** class as a starting point from which more specialized classes are developed. For example, one type of vehicle is a truck. An important attribute of a truck is its cargo capacity. Thus, to create a **Truck** class, you can extend **Vehicle**, adding an instance variable that stores the carrying capacity. Here is a version of **Vehicle** that does this. In the process, the instance variables in **Vehicle** will be made **private**, and accessor methods are provided to get and set their values.

Step by Step

1. Create a file called **TruckDemo.java** and copy the last implementation of **Vehicle** from Module 4 into the file.
2. Create the **Truck** class as shown here.

```
// Extend Vehicle to create a Truck specialization.
class Truck extends Vehicle {
    private int cargocap; // cargo capacity in pounds

    // This is a constructor for Truck.
    Truck(int p, int f, int m, int c) {
        /* Initialize Vehicle members using
         * Vehicle's constructor. */
        super(p, f, m);

        cargocap = c;
    }

    // Accessor methods for cargocap.
    int getCargo() { return cargocap; }
    void putCargo(int c) { cargocap = c; }
}
```

Here, **Truck** inherits **Vehicle**, adding **cargocap**, **getCargo()**, and **putCargo()**. Thus, **Truck** includes all of the general vehicle attributes defined by **Vehicle**. It need add only those items that are unique to its own class.

(continued)

7

Inheritance

Project
7-1

Extending the Vehicle Class

3. Next, make the instance variables of **Vehicle** private, as shown here.

```
private int passengers; // number of passengers
private int fuelcap;    // fuel capacity in gallons
private int mpg;       // fuel consumption in miles per gallon
```

4. Here is an entire program that demonstrates the **Truck** class.

```
// Build a subclass of Vehicle for trucks.
class Vehicle {
    private int passengers; // number of passengers
    private int fuelcap;    // fuel capacity in gallons
    private int mpg;       // fuel consumption in miles per gallon

    // This is a constructor for Vehicle.
    Vehicle(int p, int f, int m) {
        passengers = p;
        fuelcap = f;
        mpg = m;
    }

    // Return the range.
    int range() {
        return mpg * fuelcap;
    }

    // Compute fuel needed for a given distance.
    double fuelneeded(int miles) {
        return (double) miles / mpg;
    }

    // Access methods for instance variables.
    int getPassengers() { return passengers; }
    void setPassengers(int p) { passengers = p; }
    int getFuelcap() { return fuelcap; }
    void setFuelcap(int f) { fuelcap = f; }
    int getMpg() { return mpg; }
    void setMpg(int m) { mpg = m; }
}

// Extend Vehicle to create a Truck specialization.
class Truck extends Vehicle {
    private int cargocap; // cargo capacity in pounds

    // This is a constructor for Truck.
    Truck(int p, int f, int m, int c) {
```

```

        /* Initialize Vehicle members using
           Vehicle's constructor. */
        super(p, f, m);

        cargocap = c;
    }

    // Accessor methods for cargocap.
    int getCargo() { return cargocap; }
    void putCargo(int c) { cargocap = c; }
}

class TruckDemo {
    public static void main(String args[]) {

        // construct some trucks
        Truck semi = new Truck(2, 200, 7, 44000);
        Truck pickup = new Truck(3, 28, 15, 2000);
        double gallons;
        int dist = 252;

        gallons = semi.fuelneeded(dist);

        System.out.println("Semi can carry " + semi.getCargo() +
            " pounds.");
        System.out.println("To go " + dist + " miles semi needs " +
            gallons + " gallons of fuel.\n");

        gallons = pickup.fuelneeded(dist);

        System.out.println("Pickup can carry " + pickup.getCargo() +
            " pounds.");
        System.out.println("To go " + dist + " miles pickup needs " +
            gallons + " gallons of fuel.");
    }
}

```

5. The output from this program is shown here:

```

Semi can carry 44000 pounds.
To go 252 miles semi needs 36.0 gallons of fuel.

Pickup can carry 2000 pounds.
To go 252 miles pickup needs 16.8 gallons of fuel.

```

(continued)

6. Many other types of classes can be derived from **Vehicle**. For example, the following skeleton creates an off-road class that stores the ground clearance of the vehicle.

```
// Create an off-road vehicle class
class OffRoad extends Vehicle {
    private int groundClearance; // ground clearance in inches

    // ...
}
```

The key point is that once you have created a superclass that defines the general aspects of an object, that superclass can be inherited to form specialized classes. Each subclass simply adds its own, unique attributes. This is the essence of inheritance.

CRITICAL SKILL

7.4

Creating a Multilevel Hierarchy

Up to this point, we have been using simple class hierarchies that consist of only a superclass and a subclass. However, you can build hierarchies that contain as many layers of inheritance as you 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**.

To see how a multilevel hierarchy can be useful, consider the following program. In it, the subclass **Triangle** is used as a superclass to create the subclass called **ColorTriangle**. **ColorTriangle** inherits all of the traits of **Triangle** and **TwoDShape** and adds a field called **color**, which holds the color of the triangle.

```
// A multilevel hierarchy.
class TwoDShape {
    private double width;
    private double height;

    // A default constructor.
    TwoDShape() {
        width = height = 0.0;
    }

    // Parameterized constructor.
    TwoDShape(double w, double h) {
        width = w;
        height = h;
    }
}
```

```
// Construct object with equal width and height.
TwoDShape(double x) {
    width = height = x;
}

// Accessor methods for width and height.
double getWidth() { return width; }
double getHeight() { return height; }
void setWidth(double w) { width = w; }
void setHeight(double h) { height = h; }

void showDim() {
    System.out.println("Width and height are " +
        width + " and " + height);
}

// Extend TwoDShape.
class Triangle extends TwoDShape {
    private String style;

    // A default constructor.
    Triangle() {
        super();
        style = "null";
    }

    Triangle(String s, double w, double h) {
        super(w, h); // call superclass constructor

        style = s;
    }

    // Construct an isosceles triangle.
    Triangle(double x) {
        super(x); // call superclass constructor

        style = "isosceles";
    }

    double area() {
        return getWidth() * getHeight() / 2;
    }
}
```

```
void showStyle() {
    System.out.println("Triangle is " + style);
}
}

// Extend Triangle.
class ColorTriangle extends Triangle {
    private String color;

    ColorTriangle(String c, String s,
                  double w, double h) {
        super(s, w, h);

        color = c;
    }

    String getColor() { return color; }

    void showColor() {
        System.out.println("Color is " + color);
    }
}

class Shapes6 {
    public static void main(String args[]) {
        ColorTriangle t1 =
            new ColorTriangle("Blue", "right", 8.0, 12.0);
        ColorTriangle t2 =
            new ColorTriangle("Red", "isosceles", 2.0, 2.0);

        System.out.println("Info for t1: ");
        t1.showStyle();
        t1.showDim();
        t1.showColor();
        System.out.println("Area is " + t1.area());

        System.out.println();

        System.out.println("Info for t2: ");
        t2.showStyle();
        t2.showDim();
        t2.showColor();
        System.out.println("Area is " + t2.area());
    }
}
}
```

ColorTriangle inherits Triangle, which is descended from **TwoDShape**, so **ColorTriangle** includes all members of **Triangle** and **TwoDShape**.

← **A ColorTriangle object can call methods defined by itself and its superclasses.**

The output of this program is shown here:

```
Info for t1:
Triangle is right
Width and height are 8.0 and 12.0
Color is Blue
Area is 48.0
```

```
Info for t2:
Triangle is isosceles
Width and height are 2.0 and 2.0
Color is Red
Area is 2.0
```

Because of inheritance, **ColorTriangle** can make use of the previously defined classes of **Triangle** and **TwoDShape**, 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 **ColorTriangle** calls the constructor in **Triangle**. The **super()** in **Triangle** calls the constructor in **TwoDShape**. 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.

CRITICAL SKILL

7.5

When Are Constructors Called?

In the foregoing discussion of inheritance and class hierarchies, an important question may have occurred to you: When a subclass object is created, whose constructor is executed first, the one in the subclass or the one defined by the superclass? For example, given a subclass called **B** and a superclass called **A**, is **A**'s constructor called before **B**'s, or vice versa? The answer is that in a class hierarchy, constructors are called in order of derivation, from superclass to subclass. Further, since **super()** must be the first statement executed in a subclass' constructor, this order is the same whether or not **super()** is used. If **super()** is not used, then the default (parameterless) constructor of each superclass will be executed. The following program illustrates when constructors are executed:

```
// Demonstrate when constructors are called.

// Create a super class.
class A {
    A() {
        System.out.println("Constructing A.");
    }
}
```

```
// Create a subclass by extending class A.
class B extends A {
    B() {
        System.out.println("Constructing B.");
    }
}

// Create another subclass by extending B.
class C extends B {
    C() {
        System.out.println("Constructing C.");
    }
}

class OrderOfConstruction {
    public static void main(String args[]) {
        C c = new C();
    }
}
```

The output from this program is shown here:

```
Constructing A.
Constructing B.
Constructing C.
```

As you can see, the constructors are called in order of derivation.

If you think about it, it makes sense that constructors are executed in order of derivation. Because a superclass has no knowledge of any subclass, any initialization it needs to perform is separate from and possibly prerequisite to any initialization performed by the subclass. Therefore, it must be executed first.

CRITICAL SKILL

7.6

Superclass References and Subclass Objects

As you know, Java is a strongly typed language. Aside from the standard conversions and automatic promotions that apply to its primitive types, type compatibility is strictly enforced. Therefore, a reference variable for one class type cannot normally refer to an object of another class type. For example, consider the following program.

```
// This will not compile.
class X {
    int a;
```



```
    X(int i) { a = i; }
}

class Y {
    int a;

    Y(int i) { a = i; }
}

class IncompatibleRef {
    public static void main(String args[]) {
        X x = new X(10);
        X x2;
        Y y = new Y(5);

        x2 = x; // OK, both of same type

        x2 = y; // Error, not of same type
    }
}
```

Here, even though class **X** and class **Y** are physically the same, it is not possible to assign an **X** reference to a **Y** object because they have different types. In general, an object reference variable can refer only to objects of its type.

There is, however, an important exception to Java's strict type enforcement. A reference variable of a superclass can be assigned a reference to any subclass derived from that superclass. Here is an example:

```
// A superclass reference can refer to a subclass object.
class X {
    int a;

    X(int i) { a = i; }
}

class Y extends X {
    int b;

    Y(int i, int j) {
        super(j);
        b = i;
    }
}
```

```

class SupSubRef {
    public static void main(String args[]) {
        X x = new X(10);
        X x2;
        Y y = new Y(5, 6);

        x2 = x; // OK, both of same type
        System.out.println("x2.a: " + x2.a);           OK because Y is a subclass of X;
                                                       thus x2 can refer to y.
        x2 = y; // still Ok because Y is derived from X
        System.out.println("x2.a: " + x2.a);

        // X references know only about X members
        x2.a = 19; // OK
        // x2.b = 27; // Error, X doesn't have a b member
    }
}

```

Here, **Y** is now derived from **X**; thus it is permissible for **x2** to be assigned a reference to a **Y** object.

It is important to understand that it is the type of the reference variable—not the type of the object that it refers to—that determines what members can be accessed. That is, when a reference to a subclass object is assigned to a superclass reference variable, you will have access only to those parts of the object defined by the superclass. This is why **x2** can't access **b** even when it refers to a **Y** object. If you think about it, this makes sense, because the superclass has no knowledge of what a subclass adds to it. This is why the last line of code in the program is commented out.

Although the preceding discussion may seem a bit esoteric, it has some important practical applications. One is described here. The other is discussed later in this module, when method overriding is covered.

An important place where subclass references are assigned to superclass variables is when constructors are called in a class hierarchy. As you know, it is common for a class to define a constructor that takes an object of the class as a parameter. This allows the class to construct a copy of an object. Subclasses of such a class can take advantage of this feature. For example, consider the following versions of **TwoDShape** and **Triangle**. Both add constructors that take an object as a parameter.

```

class TwoDShape {
    private double width;
    private double height;
}

```

```
// A default constructor.
TwoDShape() {
    width = height = 0.0;
}

// Parameterized constructor.
TwoDShape(double w, double h) {
    width = w;
    height = h;
}

// Construct object with equal width and height.
TwoDShape(double x) {
    width = height = x;
}

// Construct an object from an object.
TwoDShape(TwoDShape ob) { ← Construct object from an object.
    width = ob.width;
    height = ob.height;
}

// Accessor methods for width and height.
double getWidth() { return width; }
double getHeight() { return height; }
void setWidth(double w) { width = w; }
void setHeight(double h) { height = h; }

void showDim() {
    System.out.println("Width and height are " +
        width + " and " + height);
}

// A subclass of TwoDShape for triangles.
class Triangle extends TwoDShape {
    private String style;

    // A default constructor.
    Triangle() {
        super();
        style = "null";
    }
}
```

```
// Constructor for Triangle.
Triangle(String s, double w, double h) {
    super(w, h); // call superclass constructor

    style = s;
}

// Construct an isosceles triangle.
Triangle(double x) {
    super(x); // call superclass constructor

    style = "isosceles";
}

// Construct an object from an object.
Triangle(Triangle ob) {
    super(ob); // pass object to TwoDShape constructor
    style = ob.style;
}

double area() {
    return getWidth() * getHeight() / 2;
}

void showStyle() {
    System.out.println("Triangle is " + style);
}

}

class Shapes7 {
    public static void main(String args[]) {
        Triangle t1 =
            new Triangle("right", 8.0, 12.0);

        // make a copy of t1
        Triangle t2 = new Triangle(t1);

        System.out.println("Info for t1: ");
        t1.showStyle();
        t1.showDim();
        System.out.println("Area is " + t1.area());

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

Pass a **Triangle** reference to **TwoDShape**'s constructor.

```

        System.out.println("Info for t2: ");
        t2.showStyle();
        t2.showDim();
        System.out.println("Area is " + t2.area());
    }
}

```

In this program, **t2** is constructed from **t1** and is, thus, identical. The output is shown here.

```

Info for t1:
Triangle is right
Width and height are 8.0 and 12.0
Area is 48.0

```

```

Info for t2:
Triangle is right
Width and height are 8.0 and 12.0
Area is 48.0

```

Pay special attention to this **Triangle** constructor:

```

// Construct an object from an object.
Triangle(Triangle ob) {
    super(ob); // pass object to TwoDShape constructor
    style = ob.style;
}

```

It receives an object of type **Triangle** and it passes that object (through **super**) to this **TwoDShape** constructor:

```

// Construct an object from an object.
TwoDShape(TwoDShape ob) {
    width = ob.width;
    height = ob.height;
}

```

The key point is that **TwoDshape()** is expecting a **TwoDShape** object. However, **Triangle()** passes it a **Triangle** object. The reason this works is because, as explained, a superclass reference can refer to a subclass object. Thus it is perfectly acceptable to pass **TwoDShape()** a reference to an object of a class derived from **TwoDShape**. Because the **TwoDShape()** constructor is initializing only those portions of the subclass object that are members of **TwoDShape**, it doesn't matter that the object might also contain other members added by derived classes.

 Progress Check

1. Can a subclass be used as a superclass for another subclass?
 2. In a class hierarchy, in what order are the constructors called?
 3. Given that **Jet** extends **Airplane**, can an **Airplane** reference refer to a **Jet** object?
-

CRITICAL SKILL

7.7

Method Overriding

In a class hierarchy, when a method in a subclass has the same return type and 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 a 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;
    }
}
```

-
1. Yes.
 2. Constructors are called in order of derivation.
 3. Yes. In all cases, a superclass reference can refer to a subclass object, but not vice versa.

```

// display k - this overrides show() in A
void show() { ← This show() in B overrides
    System.out.println("k: " + k);           the one defined by A.
}
}

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 want to access the superclass version of an overridden method, you can do so by using **super**. For example, in this version of **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);
    }
}

```

Use **super** to call the version of **show()** defined by superclass **A**.

If you substitute this version of **show()** 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()**.

Method overriding occurs *only* when the return types and signatures of the two 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 signatures are
   overloaded and 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;

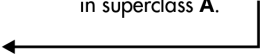
    B(int a, int b, int c) {
        super(a, b);
        k = c; }

    // overload show()
    void show(String msg) {
        System.out.println(msg + k);
    }
}

class Overload {
    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
    }
}
```

Because signatures differ, this **show()** simply overloads **show()** in superclass **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 signature different from the one in **A**, which takes no parameters. Therefore, no overriding (or name hiding) takes place.

CRITICAL SKILL

7.8

Overridden Methods Support Polymorphism

While the examples in the preceding section demonstrate the mechanics of method overriding, they do not show its power. Indeed, if there were nothing more to method overriding than a name space convention, then it would be, at best, an interesting curiosity but of little real value. However, this is not the case. Method overriding forms the basis for one of Java's most powerful concepts: *dynamic method dispatch*. Dynamic method dispatch is the mechanism by which a call to an overridden method is resolved at run time rather than compile time. Dynamic method dispatch is important because this is how Java implements run-time polymorphism.

Let's begin by restating an important principle: a superclass reference variable can refer to a subclass object. Java uses this fact to resolve calls to overridden methods at run time. Here's how. When an overridden method is called through a superclass reference, Java determines which version of that method to execute based upon the type of the object being referred to at the time the call occurs. Thus, this determination is made at run time. When different types of objects are referred to, different versions of an overridden method will be called. In other words, *it is the type of the object being referred to* (not the type of the reference variable) that determines which version of an overridden method will be executed. Therefore, if a superclass contains a method that is overridden by a subclass, then when different types of objects are referred to through a superclass reference variable, different versions of the method are executed.

Here is an example that illustrates dynamic method dispatch:

```
// Demonstrate dynamic method dispatch.  
  
class Sup {  
    void who() {  
        System.out.println("who() in Sup");  
    }  
}
```

```
class Sub1 extends Sup {
    void who() {
        System.out.println("who() in Sub1");
    }
}

class Sub2 extends Sup {
    void who() {
        System.out.println("who() in Sub2");
    }
}

class DynDispDemo {
    public static void main(String args[]) {
        Sup superOb = new Sup();
        Sub1 subOb1 = new Sub1();
        Sub2 subOb2 = new Sub2();

        Sup supRef;

        supRef = superOb;
        supRef.who(); ← In each case,
                       the version of
                       who() to call
                       is determined
                       at run time by
                       the type of
                       object being
                       referred to.

        supRef = subOb1;
        supRef.who(); ←

        supRef = subOb2;
        supRef.who(); ←
    }
}
```

The output from the program is shown here:

```
who() in Sup
who() in Sub1
who() in Sub2
```

This program creates a superclass called **Sup** and two subclasses of it, called **Sub1** and **Sub2**. **Sup** declares a method called **who()**, and the subclasses override it. Inside the **main()** method, objects of type **Sup**, **Sub1**, and **Sub2** are declared. Also, a reference of type **Sup**, called **supRef**, is declared. The program then assigns a reference to each type of object to **supRef** and uses that reference to call **who()**. As the output shows, the version of **who()** executed is determined by the type of object being referred to at the time of the call, not by the class type of **supRef**.

Ask the Expert

Q: Overridden methods in Java look a lot like virtual functions in C++. Is there a similarity?

A: Yes. Readers familiar with C++ will recognize that overridden methods in Java are equivalent in purpose and similar in operation to virtual functions in C++.

7

Inheritance

Why Overridden Methods?

As stated earlier, overridden methods allow Java to support run-time polymorphism. Polymorphism is essential to object-oriented programming for one reason: it allows a general class to specify methods that will be common to all of its derivatives, while allowing subclasses to define the specific implementation of some or all of those methods. Overridden methods are another way that Java implements the “one interface, multiple methods” aspect of polymorphism.

Part of the key to successfully applying polymorphism is understanding that the superclasses and subclasses form a hierarchy that moves from lesser to greater specialization. Used correctly, the superclass provides all elements that a subclass can use directly. It also defines those methods that the derived class must implement on its own. This allows the subclass the flexibility to define its own methods, yet still enforces a consistent interface. Thus, by combining inheritance with overridden methods, a superclass can define the general form of the methods that will be used by all of its subclasses.

Applying Method Overriding to TwoDShape

To better understand the power of method overriding, we will apply it to the **TwoDShape** class. In the preceding examples, each class derived from **TwoDShape** defines a method called **area()**. This suggests that it might be better to make **area()** part of the **TwoDShape** class, allowing each subclass to override it, defining how the area is calculated for the type of shape that the class encapsulates. The following program does this. For convenience, it also adds a name field to **TwoDShape**. (This makes it easier to write demonstration programs.)

```
// Use dynamic method dispatch.
class TwoDShape {
    private double width;
    private double height;
    private String name;
```

```
// A default constructor.
TwoDShape() {
    width = height = 0.0;
    name = "null";
}

// Parameterized constructor.
TwoDShape(double w, double h, String n) {
    width = w;
    height = h;
    name = n;
}

// Construct object with equal width and height.
TwoDShape(double x, String n) {
    width = height = x;
    name = n;
}

// Construct an object from an object.
TwoDShape(TwoDShape ob) {
    width = ob.width;
    height = ob.height;
    name = ob.name;
}

// Accessor methods for width and height.
double getWidth() { return width; }
double getHeight() { return height; }
void setWidth(double w) { width = w; }
void setHeight(double h) { height = h; }

String getName() { return name; }

void showDim() {
    System.out.println("Width and height are " +
        width + " and " + height);
}

double area() {
    System.out.println("area() must be overridden");
    return 0.0;
}
}
```

The `area()` method defined by `TwoDShape`.

```

// A subclass of TwoDShape for triangles.
class Triangle extends TwoDShape {
    private String style;

    // A default constructor.
    Triangle() {
        super();
        style = "null";
    }

    // Constructor for Triangle.
    Triangle(String s, double w, double h) {
        super(w, h, "triangle");

        style = s;
    }

    // Construct an isosceles triangle.
    Triangle(double x) {
        super(x, "triangle"); // call superclass constructor

        style = "isosceles";
    }

    // Construct an object from an object.
    Triangle(Triangle ob) {
        super(ob); // pass object to TwoDShape constructor
        style = ob.style;
    }

    // Override area() for Triangle.
    double area() { ←————— Override area() for Triangle.
        return getWidth() * getHeight() / 2;
    }

    void showStyle() {
        System.out.println("Triangle is " + style);
    }
}

// A subclass of TwoDShape for rectangles.
class Rectangle extends TwoDShape {
    // A default constructor.
    Rectangle() {
        super();
    }
}

```

```
// Constructor for Rectangle.
Rectangle(double w, double h) {
    super(w, h, "rectangle"); // call superclass constructor
}

// Construct a square.
Rectangle(double x) {
    super(x, "rectangle"); // call superclass constructor
}

// Construct an object from an object.
Rectangle(Rectangle ob) {
    super(ob); // pass object to TwoDShape constructor
}

boolean isSquare() {
    if(getWidth() == getHeight()) return true;
    return false;
}

// Override area() for Rectangle.
double area() { ← Override area() for Rectangle.
    return getWidth() * getHeight();
}

}

class DynShapes {
    public static void main(String args[]) {
        TwoDShape shapes[] = new TwoDShape[5];

        shapes[0] = new Triangle("right", 8.0, 12.0);
        shapes[1] = new Rectangle(10);
        shapes[2] = new Rectangle(10, 4);
        shapes[3] = new Triangle(7.0);
        shapes[4] = new TwoDShape(10, 20, "generic");

        for(int i=0; i < shapes.length; i++) {
            System.out.println("object is " + shapes[i].getName());
            System.out.println("Area is " + shapes[i].area()); ← The proper version of area()
                                                                    is called for each shape.
        }
    }
}
```

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

The output from the program is shown here:

```
object is triangle
Area is 48.0

object is rectangle
Area is 100.0

object is rectangle
Area is 40.0

object is triangle
Area is 24.5

object is generic
area() must be overridden
Area is 0.0
```

Let's examine this program closely. First, as explained, **area()** is now part of the **TwoDShape** class and is overridden by **Triangle** and **Rectangle**. Inside **TwoDShape**, **area()** is given a placeholder implementation that simply informs the user that this method must be overridden by a subclass. Each override of **area()** supplies an implementation that is suitable for the type of object encapsulated by the subclass. Thus, if you were to implement an ellipse class, for example, then **area()** would need to compute the **area()** of an ellipse.

There is one other important feature in the preceding program. Notice in **main()** that **shapes** is declared as an array of **TwoDShape** objects. However, the elements of this array are assigned **Triangle**, **Rectangle**, and **TwoDShape** references. This is valid because, as explained, a superclass reference can refer to a subclass object. The program then cycles through the array, displaying information about each object. Although quite simple, this illustrates the power of both inheritance and method overriding. The type of object referred to by a superclass reference variable is determined at run time and acted on accordingly. If an object is derived from **TwoDShape**, then its area can be obtained by calling **area()**. The interface to this operation is the same no matter what type of shape is being used.



Progress Check

1. What is method overriding?
2. Why is method overriding important?
3. When an overridden method is called through a superclass reference, which version of the method is executed?

CRITICAL SKILL**7.9**

Using Abstract Classes

Sometimes you will want to create a superclass that defines only a generalized form that will be shared by all of its subclasses, leaving it to each subclass to fill in the details. Such a class determines the nature of the methods that the subclasses must implement but does not, itself, provide an implementation of one or more of these methods. One way this situation can occur is when a superclass is unable to create a meaningful implementation for a method. This is the case with the version of **TwoDShape** used in the preceding example. The definition of **area()** is simply a placeholder. It will not compute and display the area of any type of object.

As you will see as you create your own class libraries, it is not uncommon for a method to have no meaningful definition in the context of its superclass. You can handle this situation two ways. One way, as shown in the previous example, is to simply have it report a warning message. While this approach can be useful in certain situations—such as debugging—it is not usually appropriate. You may have methods which must be overridden by the subclass in order for the subclass to have any meaning. Consider the class **Triangle**. It has no meaning if **area()** is not defined. In this case, you want some way to ensure that a subclass does, indeed, override all necessary methods. Java's solution to this problem is the *abstract method*.

An abstract method is created by specifying the **abstract** type modifier. An abstract method contains no body and is, therefore, not implemented by the superclass. Thus, a subclass must override it—it cannot simply use the version defined in the superclass. To declare an abstract method, use this general form:

```
abstract type name(parameter-list);
```

As you can see, no method body is present. The **abstract** modifier can be used only on normal methods. It cannot be applied to **static** methods or to constructors.

1. Method overriding occurs when a subclass defines a method that has the same signature as a method in its superclass.
2. Overridden methods allow Java to support run-time polymorphism.
3. The version of an overridden method that is executed is determined by the type of the object being referred to at the time of the call. Thus, this determination is made at run time.

A class that contains one or more abstract methods must also be declared as abstract by preceding its **class** declaration with the **abstract** specifier. Since an abstract class does not define a complete implementation, there can be no objects of an abstract class. Thus, attempting to create an object of an abstract class by using **new** will result in a compile-time error.

When a subclass inherits an abstract class, it must implement all of the abstract methods in the superclass. If it doesn't, then the subclass must also be specified as **abstract**. Thus, the **abstract** attribute is inherited until such time as a complete implementation is achieved.

Using an abstract class, you can improve the **TwoDShape** class. Since there is no meaningful concept of area for an undefined two-dimensional figure, the following version of the preceding program declares **area()** as **abstract** inside **TwoDShape**, and **TwoDShape** as **abstract**. This, of course, means that all classes derived from **TwoDShape** must override **area()**.

```
// Create an abstract class.
abstract class TwoDShape { ←————— TwoDShape is now abstract.
    private double width;
    private double height;
    private String name;

    // A default constructor.
    TwoDShape() {
        width = height = 0.0;
        name = "null";
    }

    // Parameterized constructor.
    TwoDShape(double w, double h, String n) {
        width = w;
        height = h;
        name = n;
    }

    // Construct object with equal width and height.
    TwoDShape(double x, String n) {
        width = height = x;
        name = n;
    }

    // Construct an object from an object.
    TwoDShape(TwoDShape ob) {
        width = ob.width;
        height = ob.height;
        name = ob.name;
    }
}
```

```
// Accessor methods for width and height.
double getWidth() { return width; }
double getHeight() { return height; }
void setWidth(double w) { width = w; }
void setHeight(double h) { height = h; }

String getName() { return name; }

void showDim() {
    System.out.println("Width and height are " +
        width + " and " + height);
}

// Now, area() is abstract.
abstract double area(); ← Make area() into an
                           abstract method.
}

// A subclass of TwoDShape for triangles.
class Triangle extends TwoDShape {
    private String style;

    // A default constructor.
    Triangle() {
        super();
        style = "null";
    }

    // Constructor for Triangle.
    Triangle(String s, double w, double h) {
        super(w, h, "triangle");

        style = s;
    }

    // Construct an isosceles triangle.
    Triangle(double x) {
        super(x, "triangle"); // call superclass constructor

        style = "isosceles";
    }

    // Construct an object from an object.
    Triangle(Triangle ob) {
        super(ob); // pass object to TwoDShape constructor
        style = ob.style;
    }
}
```

```
double area() {
    return getWidth() * getHeight() / 2;
}

void showStyle() {
    System.out.println("Triangle is " + style);
}
}

// A subclass of TwoDShape for rectangles.
class Rectangle extends TwoDShape {
    // A default constructor.
    Rectangle() {
        super();
    }

    // Constructor for Rectangle.
    Rectangle(double w, double h) {
        super(w, h, "rectangle"); // call superclass constructor
    }

    // Construct a square.
    Rectangle(double x) {
        super(x, "rectangle"); // call superclass constructor
    }

    // Construct an object from an object.
    Rectangle(Rectangle ob) {
        super(ob); // pass object to TwoDShape constructor
    }

    boolean isSquare() {
        if(getWidth() == getHeight()) return true;
        return false;
    }

    double area() {
        return getWidth() * getHeight();
    }
}

class AbsShape {
    public static void main(String args[]) {
        TwoDShape shapes[] = new TwoDShape[4];
    }
}
```

```
shapes[0] = new Triangle("right", 8.0, 12.0);
shapes[1] = new Rectangle(10);
shapes[2] = new Rectangle(10, 4);
shapes[3] = new Triangle(7.0);

for(int i=0; i < shapes.length; i++) {
    System.out.println("object is " +
        shapes[i].getName());
    System.out.println("Area is " + shapes[i].area());

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

As the program illustrates, all subclasses of **TwoDShape** *must* override **area()**. To prove this to yourself, try creating a subclass that does not override **area()**. You will receive a compile-time error. Of course, it is still possible to create an object reference of type **TwoDShape**, which the program does. However, it is no longer possible to declare objects of type **TwoDShape**. Because of this, in **main()** the **shapes** array has been shortened to 4, and a generic **TwoDShape** object is no longer created.

One last point: notice that **TwoDShape** still includes the **showDim()** and **getName()** methods and that these are not modified by **abstract**. It is perfectly acceptable—indeed, quite common—for an abstract class to contain concrete methods which a subclass is free to use as is. Only those methods declared as **abstract** need be overridden by subclasses.



Progress Check

1. What is an abstract method? How is one created?
 2. What is an abstract class?
 3. Can an object of an abstract class be instantiated?
-

-
1. An abstract method is a method without a body. Thus it consists of a return type, name, and parameter list and is preceded by the keyword **abstract**.
 2. An abstract class contains at least one abstract method.
 3. No.

Using final

As powerful and useful as method overriding and inheritance are, sometimes you will want to prevent them. For example, you might have a class that encapsulates control of some hardware device. Further, this class might offer the user the ability to initialize the device, making use of private, proprietary information. In this case, you don't want users of your class to be able to override the initialization method. Whatever the reason, in Java it is easy to prevent a method from being overridden or a class from being inherited by using the keyword **final**.

final Prevents Overriding

To prevent a method from being overridden, specify **final** as a modifier at the start of its declaration. Methods declared as **final** cannot be overridden. The following fragment illustrates **final**:

```
class A {
    final void meth() {
        System.out.println("This is a final method.");
    }
}

class B extends A {
    void meth() { // ERROR! Can't override.
        System.out.println("Illegal!");
    }
}
```

Because **meth()** is declared as **final**, it cannot be overridden in **B**. If you attempt to do so, a compile-time error will result.

final Prevents Inheritance

You can prevent a class from being inherited by preceding its declaration with **final**. Declaring a class as **final** implicitly declares all of its methods as **final**, too. As you might expect, it is illegal to declare a class as both **abstract** and **final** since an abstract class is incomplete by itself and relies upon its subclasses to provide complete implementations.

Here is an example of a **final** class:

```
final class A {
    // ...
}
```

```
// The following class is illegal.
class B extends A { // ERROR! Can't subclass A
    // ...
}
```

As the comments imply, it is illegal for **B** to inherit **A** since **A** is declared as **final**.

Using final with Data Members

In addition to the uses of **final** just shown, **final** can also be applied to variables to create what amounts to named constants. If you precede a class variable's name with **final**, its value cannot be changed throughout the lifetime of your program. You can, of course, give that variable an initial value. For example, in Module 6 a simple error-management class called **ErrorMsg** was shown. That class mapped a human-readable string to an error code. Here, that original class is improved by the addition of **final** constants which stand for the errors. Now, instead of passing **getErrorMsg()** a number such as 2, you can pass the named integer constant **DISKERR**.

```
// Return a String object.
class ErrorMsg {
    // Error codes.
    final int OUTERR = 0;
    final int INERR = 1; ← Declare final constants.
    final int DISKERR = 2;
    final int INDEXERR = 3;

    String msgs[] = {
        "Output Error",
        "Input Error",
        "Disk Full",
        "Index Out-Of-Bounds"
    };

    // Return the error message.
    String getErrorMsg(int i) {
        if(i >=0 & i < msgs.length)
            return msgs[i];
        else
            return "Invalid Error Code";
    }
}
```

```

class FinalD {
    public static void main(String args[]) {
        ErrorMsg err = new ErrorMsg();
        System.out.println(err.getErrorMsg(err.OUTERR));
        System.out.println(err.getErrorMsg(err.DISKERR));
    }
}

```

Use **final** constants.

Notice how the **final** constants are used in **main()**. Since they are members of the **ErrorMsg** class, they must be accessed via an object of that class. Of course, they can also be inherited by subclasses and accessed directly inside those subclasses.

As a point of style, many Java programmers use uppercase identifiers for **final** constants, as does the preceding example. But this is not a hard and fast rule.

Ask the Expert

Q: Can final variables be made static?

A: Yes. Doing so allows you to refer to the constant through its class name rather than through an object. For example, if the constants in **ErrorMsg** were modified by **static**, then the **println()** statements in **main()** could look like this:

```

System.out.println(err.getErrorMsg(ErrorMsg.OUTERR));
System.out.println(err.getErrorMsg(ErrorMsg.DISKERR));

```

Progress Check

1. How do you prevent a method from being overridden?
2. If a class is declared as **final**, can it be inherited?

-
1. Precede its declaration with the keyword **final**.
 2. No.

CRITICAL SKILL

7.11

The Object Class

Java defines one special class called **Object** that is an implicit superclass of all other classes. In other words, all other classes are subclasses of **Object**. This means that a reference variable of type **Object** can refer to an object of any other class. Also, since arrays are implemented as classes, a variable of type **Object** can also refer to any array.

Object defines the following methods, which means that they are available in every object.

Method	Purpose
<code>Object clone()</code>	Creates a new object that is the same as the object being cloned.
<code>boolean equals(Object object)</code>	Determines whether one object is equal to another.
<code>void finalize()</code>	Called before an unused object is recycled.
<code>Class<? extends Object> getClass()</code>	Obtains the class of an object at run time.
<code>int hashCode()</code>	Returns the hash code associated with the invoking object.
<code>void notify()</code>	Resumes execution of a thread waiting on the invoking object.
<code>void notifyAll()</code>	Resumes execution of all threads waiting on the invoking object.
<code>String toString()</code>	Returns a string that describes the object.
<code>void wait()</code> <code>void wait(long milliseconds)</code> <code>void wait(long milliseconds, int nanoseconds)</code>	Waits on another thread of execution.

The methods `getClass()`, `notify()`, `notifyAll()`, and `wait()` are declared as **final**. You can override the others. Several of these methods are described later in this book. However, notice two methods now: `equals()` and `toString()`. The `equals()` method compares the contents of two objects. It returns **true** if the objects are equivalent, and **false** otherwise. The `toString()` method returns a string that contains a description of the object on which it is called. Also, this method is automatically called when an object is output using `println()`. Many classes override this method. Doing so allows them to tailor a description specifically for the types of objects that they create.

One last point: notice the unusual syntax in the return type for `getClass()`. This is a *generic type*. Generic types are a recent (and powerful) addition to Java that enables the type of data used by a class or method to be specified as a parameter. Generic types are discussed in Module 13.