```
  void show() {
    System.out.println(a + " " + b);
  }
  //...
}
```

Here, the class **Incomplete** does not implement **callback( )** and must be declared
as **abstract**. Any class that inherits **Incomplete** must implement **callback( )** or be declared
abstract itself.

Nested Interfaces

An interface can be declared a member of a class or another interface. Such an interface
is called a *member interface* or a *nested interface*. A nested interface can be declared as **public**,
private, or **protected**. This differs from a top-level interface, which must either be declared
as **public** or use the default access level, as previously described. When a nested interface is
used outside of its enclosing scope, it must be qualified by the name of the class or interface
of which it is a member. Thus, outside of the class or interface in which a nested interface is
declared, its name must be fully qualified.

Here is an example that demonstrates a nested interface:

```
// A nested interface example.

// This class contains a member interface.
class A {
  // this is a nested interface
  public interface NestedIF {
    boolean isNotNegative(int x);
  }
}

// B implements the nested interface.
class B implements A.NestedIF {
  public boolean isNotNegative(int x) {
    return x < 0 ? false: true;
  }
}

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

    // use a nested interface reference
    A.NestedIF nif = new B();

    if(nif.isNotNegative(10))
      System.out.println("10 is not negative");
    if(nif.isNotNegative(-12))
      System.out.println("this won't be displayed");
  }
}
```

Notice that **A** defines a member interface called **NestedIF** and that it is declared **public**. Next, **B** implements the nested interface by specifying

```
implements A.NestedIF
```

Notice that the name is fully qualified by the enclosing class' name. Inside the **main( )** method, an **A.NestedIF** reference called **nif** is created, and it is assigned a reference to a **B** object. Because **B** implements **A.NestedIF**, this is legal.

Applying Interfaces

To understand the power of interfaces, let's look at a more practical example. In earlier chapters, you developed a class called **Stack** that implemented a simple fixed-size stack. However, there are many ways to implement a stack. For example, the stack can be of a fixed size or it can be "growable." The stack can also be held in an array, a linked list, a binary tree, and so on. No matter how the stack is implemented, the interface to the stack remains the same. That is, the methods **push( )** and **pop( )** define the interface to the stack independently of the details of the implementation. Because the interface to a stack is separate from its implementation, it is easy to define a stack interface, leaving it to each implementation to define the specifics. Let's look at two examples.

First, here is the interface that defines an integer stack. Put this in a file called **IntStack.java**. This interface will be used by both stack implementations.

```
// Define an integer stack interface.
interface IntStack {
  void push(int item); // store an item
  int pop(); // retrieve an item
}
```

The following program creates a class called **FixedStack** that implements a fixed-length version of an integer stack:

```
// An implementation of IntStack that uses fixed storage.
class FixedStack implements IntStack {
  private int stck[];
  private int tos;

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

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

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

    class IFTest {
      public static void main(String args[]) {
        FixedStack mystack1 = new FixedStack(5);
        FixedStack mystack2 = new FixedStack(8);

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

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

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

Following is another implementation of **IntStack** that creates a dynamic stack by use of the same **interface** definition. In this implementation, each stack is constructed with an initial length. If this initial length is exceeded, then the stack is increased in size. Each time more room is needed, the size of the stack is doubled.

```
// Implement a "growable" stack.
class DynStack implements IntStack {
  private int stck[];
  private int tos;

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

  // Push an item onto the stack
  public void push(int item) {
    // if stack is full, allocate a larger stack
    if(tos==stck.length-1) {
      int temp[] = new int[stck.length * 2]; // double size
      for(int i=0; i<stck.length; i++) temp[i] = stck[i];
```

```
        stck = temp;
        stck[++tos] = item;
      }
      else
        stck[++tos] = item;
  }

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

class IFTest2 {
  public static void main(String args[]) {
    DynStack mystack1 = new DynStack(5);
    DynStack mystack2 = new DynStack(8);

    // these loops cause each stack to grow
    for(int i=0; i<12; i++) mystack1.push(i);
    for(int i=0; i<20; i++) mystack2.push(i);

    System.out.println("Stack in mystack1:");
    for(int i=0; i<12; i++)
      System.out.println(mystack1.pop());

    System.out.println("Stack in mystack2:");
    for(int i=0; i<20; i++)
      System.out.println(mystack2.pop());
  }
}
```

The following class uses both the **FixedStack** and **DynStack** implementations. It does so through an interface reference. This means that calls to **push( )** and **pop( )** are resolved at run time rather than at compile time.

```
/* Create an interface variable and
   access stacks through it.
*/
class IFTest3 {
  public static void main(String args[]) {
    IntStack mystack; // create an interface reference variable
    DynStack ds = new DynStack(5);
    FixedStack fs = new FixedStack(8);

    mystack = ds; // load dynamic stack
    // push some numbers onto the stack
    for(int i=0; i<12; i++) mystack.push(i);
```

```
      mystack = fs; // load fixed stack
      for(int i=0; i<8; i++) mystack.push(i);

      mystack = ds;
      System.out.println("Values in dynamic stack:");
      for(int i=0; i<12; i++)
         System.out.println(mystack.pop());

      mystack = fs;
      System.out.println("Values in fixed stack:");
      for(int i=0; i<8; i++)
         System.out.println(mystack.pop());
   }
}
```

In this program, **mystack** is a reference to the **IntStack** interface. Thus, when it refers to **ds**, it uses the versions of **push( )** and **pop( )** defined by the **DynStack** implementation. When it refers to **fs**, it uses the versions of **push( )** and **pop( )** defined by **FixedStack**. As explained, these determinations are made at run time. Accessing multiple implementations of an interface through an interface reference variable is the most powerful way that Java achieves run-time polymorphism.

Variables in Interfaces

You can use interfaces to import shared constants into multiple classes by simply declaring an interface that contains variables that are initialized to the desired values. When you include that interface in a class (that is, when you "implement" the interface), all of those variable names will be in scope as constants. (This is similar to using a header file in C/C++ to create a large number of **#defined** constants or **const** declarations.) If an interface contains no methods, then any class that includes such an interface doesn't actually implement anything. It is as if that class were importing the constant fields into the class name space as **final** variables. The next example uses this technique to implement an automated "decision maker":

```
import java.util.Random;

interface SharedConstants {
  int NO = 0;
  int YES = 1;
  int MAYBE = 2;
  int LATER = 3;
  int SOON = 4;
  int NEVER = 5;
}

class Question implements SharedConstants {
  Random rand = new Random();
  int ask() {
    int prob = (int) (100 * rand.nextDouble());
    if (prob < 30)
```

```
      return NO;           // 30%
    else if (prob < 60)
      return YES;          // 30%
    else if (prob < 75)
      return LATER;        // 15%
    else if (prob < 98)
      return SOON;         // 13%

    else
      return NEVER;        // 2%
  }
}

class AskMe implements SharedConstants {
  static void answer(int result) {
    switch(result) {
      case NO:
        System.out.println("No");
        break;
      case YES:
        System.out.println("Yes");
        break;
      case MAYBE:
        System.out.println("Maybe");
        break;
      case LATER:
        System.out.println("Later");
        break;
      case SOON:
        System.out.println("Soon");
        break;
      case NEVER:
        System.out.println("Never");
        break;
    }
  }

  public static void main(String args[]) {
    Question q = new Question();

    answer(q.ask());
    answer(q.ask());
    answer(q.ask());
    answer(q.ask());
  }
}
```

Notice that this program makes use of one of Java's standard classes: **Random**. This class provides pseudorandom numbers. It contains several methods that allow you to obtain random numbers in the form required by your program. In this example, the method **nextDouble( )** is used. It returns random numbers in the range 0.0 to 1.0.

In this sample program, the two classes, **Question** and **AskMe**, both implement the **SharedConstants** interface where **NO**, **YES**, **MAYBE**, **SOON**, **LATER**, and **NEVER** are

defined. Inside each class, the code refers to these constants as if each class had defined or inherited them directly. Here is the output of a sample run of this program. Note that the results are different each time it is run.

```
Later
Soon
No
Yes
```

NOTE The technique of using an interface to define shared constants, as just described, is controversial. It is described here for completeness.

Interfaces Can Be Extended

One interface can inherit another by use of the keyword **extends**. The syntax is the same as for inheriting classes. When a class implements an interface that inherits another interface, it must provide implementations for all methods required by the interface inheritance chain. Following is an example:

```java
// One interface can extend another.
interface A {
  void meth1();
  void meth2();
}

// B now includes meth1() and meth2() -- it adds meth3().
interface B extends A {
  void meth3();
}

// This class must implement all of A and B
class MyClass implements B {
  public void meth1() {
    System.out.println("Implement meth1().");
  }

  public void meth2() {
    System.out.println("Implement meth2().");
  }

  public void meth3() {
    System.out.println("Implement meth3().");
  }
}

class IFExtend {
  public static void main(String arg[]) {
    MyClass ob = new MyClass();
```

```
      ob.meth1();
      ob.meth2();
      ob.meth3();
   }
}
```

As an experiment, you might want to try removing the implementation for **meth1( )** in **MyClass**. This will cause a compile-time error. As stated earlier, any class that implements an interface must implement all methods required by that interface, including any that are inherited from other interfaces.

Default Interface Methods

As explained earlier, prior to JDK 8, an interface could not define any implementation whatsoever. This meant that for all previous versions of Java, the methods specified by an interface were abstract, containing no body. This is the traditional form of an interface and is the type of interface that the preceding discussions have used. The release of JDK 8 has changed this by adding a new capability to **interface** called the *default method*. A default method lets you define a default implementation for an interface method. In other words, by use of a default method, it is now possible for an interface method to provide a body, rather than being abstract. During its development, the default method was also referred to as an *extension method,* and you will likely see both terms used.

A primary motivation for the default method was to provide a means by which interfaces could be expanded without breaking existing code. Recall that there must be implementations for all methods defined by an interface. In the past, if a new method were added to a popular, widely used interface, then the addition of that method would break existing code because no implementation would be found for that new method. The default method solves this problem by supplying an implementation that will be used if no other implementation is explicitly provided. Thus, the addition of a default method will not cause preexisting code to break.

Another motivation for the default method was the desire to specify methods in an interface that are, essentially, optional, depending on how the interface is used. For example, an interface might define a group of methods that act on a sequence of elements. One of these methods might be called **remove( )**, and its purpose is to remove an element from the sequence. However, if the interface is intended to support both modifiable and nonmodifiable sequences, then **remove( )** is essentially optional because it won't be used by nonmodifiable sequences. In the past, a class that implemented a nonmodifiable sequence would have had to define an empty implementation of **remove( )**, even though it was not needed. Today, a default implementation for **remove( )** can be specified in the interface that does nothing (or throws an exception). Providing this default prevents a class used for nonmodifiable sequences from having to define its own, placeholder version of **remove( )**. Thus, by providing a default, the interface makes the implementation of **remove( )** by a class optional.

It is important to point out that the addition of default methods does not change a key aspect of **interface**: its inability to maintain state information. An interface still cannot have instance variables, for example. Thus, the defining difference between an interface and a class is that a class can maintain state information, but an interface cannot. Furthermore, it