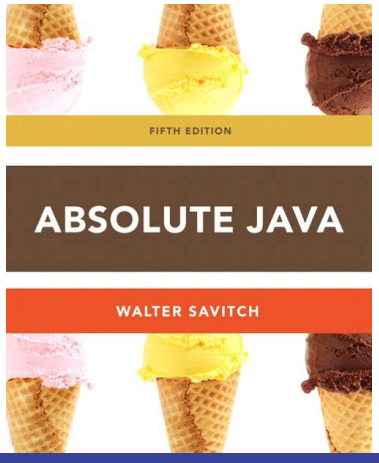

Chapter 13

Interfaces and Inner Classes

Slides prepared by Rose Williams, *Binghamton University*

Kenrick Mock, *University of Alaska Anchorage*

PEARSON ALWAYS LEARNING

Interfaces

- An *interface* is something like an extreme case of an abstract class
  - However, *an interface is not a class*
  - *It is a type that can be satisfied by any class that implements the interface*
- The syntax for defining an interface is similar to that of defining a class
  - Except the word **`interface`** is used in place of **`class`**
- An interface specifies a set of methods that any class that implements the interface must have
  - It contains method headings and constant definitions only
  - It contains no instance variables nor any complete method definitions

Interfaces

- An interface serves a function similar to a base class, though it is not a base class
  - Some languages allow one class to be derived from two or more different base classes
  - This *multiple inheritance* is not allowed in Java
  - Instead, Java's way of approximating multiple inheritance is through interfaces

Interfaces

- An interface and all of its method headings should be declared public
  - They cannot be given private, protected, or package access
- When a class implements an interface, it must make all the methods in the interface public
- Because an interface is a type, a method may be written with a parameter of an interface type
  - That parameter will accept as an argument any class that implements the interface

The `Ordered` Interface

Display 13.1 The Ordered Interface

```
1  public interface Ordered
2  {
3      public boolean precedes(Object other);

4      /**
5       For objects of the class o1 and o2,
6       o1.follows(o2) == o2.preceded(o1).
7      */
8      public boolean follows(Object other);
9  }
```

Do not forget the semicolons at the end of the method headings.

Neither the compiler nor the run-time system will do anything to ensure that this comment is satisfied. It is only advisory to the programmer implementing the interface.

Interfaces

- To *implement an interface*, a concrete class must do two things:
  1. It must include the phrase
     `implements` *`Interface_Name`*
     at the start of the class definition
     - If more than one interface is implemented, each is listed, separated by commas
  2. The class must implement *all* the method headings listed in the definition(s) of the interface(s)
- Note the use of **`Object`** as the parameter type in the following examples

Implementation of an Interface

Display 13.2 Implementation of an Interface

```
1  public class OrderedHourlyEmployee
2          extends HourlyEmployee implements Ordered
3  {
4      public boolean precedes(Object other)
5      {
6          if (other == null)
7              return false;
8          else if (!(other instanceof HourlyEmployee))
9              return false;
10         else
11         {
12             OrderedHourlyEmployee otherOrderedHourlyEmployee =
13                                 (OrderedHourlyEmployee)other;
14             return (getPay() < otherOrderedHourlyEmployee.getPay());
15         }
16     }
```

Although `getClass` works better than `instanceof` for defining `equals`, `instanceof` works better here. However, either will do for the points being made here.

Implementation of an Interface

Display 13.2 Implementation of an Interface (continued)

```
17     public boolean follows(Object other)
18     {
19         if (other == null)
20             return false;
21         else if (!(other instanceof OrderedHourlyEmployee))
22             return false;
23         else
24         {
25             OrderedHourlyEmployee otherOrderedHourlyEmployee =
26                                 (OrderedHourlyEmployee)other;
27             return (otherOrderedHourlyEmployee.precedes(this));
28         }
29     }
30 }
```

Abstract Classes Implementing Interfaces

- Abstract classes may implement one or more interfaces
  - Any method headings given in the interface that are not given definitions are made into abstract methods
- A concrete class must give definitions for all the method headings given in the abstract class *and the interface*

An Abstract Class Implementing an Interface

Display 13.3 **An Abstract Class Implementing an Interface**

```
1  public abstract class MyAbstractClass implements Ordered
2  {
3      int number;
4      char grade;
5
6      public boolean precedes(Object other)
7      {
8          if (other == null)
9              return false;
10         else if (!(other instanceof HourlyEmployee))
11             return false;
12         else
13         {
14             MyAbstractClass otherOfMyAbstractClass =
15                                              (MyAbstractClass)other;
16             return (this.number < otherOfMyAbstractClass.number);
17         }
18     }

19     public abstract boolean follows(Object other);

20 }
```


Derived Interfaces

- Like classes, an interface may be derived from a base interface
  - This is called *extending* the interface
  - The derived interface must include the phrase

`extends BaseInterfaceName`

- A concrete class that implements a derived interface must have definitions for any methods in the derived interface as well as any methods in the base interface

Extending an Interface

Display 13.4 **Extending an Interface**

```
1  public interface ShowablyOrdered extends Ordered
2  {
3      /**
4        Outputs an object of the class that precedes the calling object.
5      */
6      public void showOneWhoPrecedes();
7  }
```

Neither the compiler nor the run-time system will do anything to ensure that this comment is satisfied.

A (concrete) class that implements the `ShowablyOrdered` interface must have a definition for the method `showOneWhoPrecedes` and also have definitions for the methods `precedes` and `follows` given in the `Ordered` interface.

Pitfall: Interface Semantics Are Not Enforced

- When a class implements an interface, the compiler and run-time system check the syntax of the interface and its implementation
  - However, neither checks that the body of an interface is consistent with its intended meaning
- Required semantics for an interface are normally added to the documentation for an interface
  - It then becomes the responsibility of each programmer implementing the interface to follow the semantics
- If the method body does not satisfy the specified semantics, then software written for classes that implement the interface may not work correctly

The `Comparable` Interface

- Chapter 6 discussed the Selection Sort algorithm, and examined a method for sorting a partially filled array of type `double` into increasing order
- This code could be modified to sort into decreasing order, or to sort integers or strings instead
  - Each of these methods would be essentially the same, but making each modification would be a nuisance
  - The only difference would be the types of values being sorted, and the definition of the ordering
- Using the `Comparable` interface could provide a single sorting method that covers all these cases

The `Comparable` Interface

- The `Comparable` interface is in the `java.lang` package, and so is automatically available to any program
- It has only the following method heading that must be implemented:

```
public int compareTo(Object other);
```

- It is the programmer's responsibility to follow the semantics of the `Comparable` interface when implementing it

The `Comparable` Interface Semantics

- The method `compareTo` must return
  - A negative number if the calling object "comes before" the parameter other
  - A zero if the calling object "equals" the parameter other
  - A positive number if the calling object "comes after" the parameter other
- If the parameter `other` is not of the same type as the class being defined, then a `ClassCastException` should be thrown

The **Comparable** Interface Semantics

- Almost any reasonable notion of "comes before" is acceptable
  - In particular, all of the standard less-than relations on numbers and lexicographic ordering on strings are suitable
- The relationship "comes after" is just the reverse of "comes before"

The **Comparable** Interface Semantics

- Other orderings may be considered, as long as they are a *total ordering*
- Such an ordering must satisfy the following rules:
  - (*Irreflexivity*) For no object **o** does **o** come before **o**
  - (*Trichotomy*) For any two object **o1** and **o2**, one and only one of the following holds true: **o1** comes before **o2**, **o1** comes after **o2**, or **o1** equals **o2**
  - (*Transitivity*) If **o1** comes before **o2** and **o2** comes before **o3**, then **o1** comes before **o3**
- The "equals" of the **compareTo** method semantics should coincide with the **equals** method if possible, but this is not absolutely required

Using the **Comparable** Interface

- The following example reworks the **SelectionSort** class from Chapter 6
- The new version, **GeneralizedSelectionSort**, includes a method that can sort any partially filled array *whose base type implements the* ***Comparable*** *interface*
  - It contains appropriate **indexOfSmallest** and **interchange** methods as well
- Note: Both the **Double** and **String** classes implement the **Comparable** interface
  - Interfaces apply to classes only
  - A primitive type (e.g., **double**) cannot implement an interface

GeneralizedSelectionSort class: **sort** Method

Display 13.5 **Sorting Method for Array of Comparable** *(Part 1 of 2)*

```
1  public class GeneralizedSelectionSort
2  {
3      /**
4       Precondition: numberUsed <= a.length;
5                     The first numberUsed indexed variables have values.
6       Action: Sorts a so that a[0], a[1], ... , a[numberUsed - 1] are in
7       increasing order by the compareTo method.
8      */
9      public static void sort(Comparable[] a, int numberUsed)
10     {
11         int index, indexOfNextSmallest;
12         for (index = 0; index < numberUsed - 1; index++)
13         {//Place the correct value in a[index]:
14             indexOfNextSmallest = indexOfSmallest(index, a, numberUsed);
15             interchange(index,indexOfNextSmallest, a);
16              //a[0], a[1],..., a[index] are correctly ordered and these are
17              //the smallest of the original array elements. The remaining
18              //positions contain the rest of the original array elements.
19         }
20     }
```

`GeneralizedSelectionSort` class: `sort` Method

Display 13.5 **Sorting Method for Array of Comparable** ***(Part 1 of 2)*** (continued)

```
21      /**
22       Returns the index of the smallest value among
23       a[startIndex], a[startIndex+1], ... a[numberUsed - 1]
24      */
25      private static int indexOfSmallest(int startIndex,
26                                         Comparable[] a, int numberUsed)
27      {
28          Comparable min = a[startIndex];
29          int indexOfMin = startIndex;
30          int index;
31          for (index = startIndex + 1; index < numberUsed; index++)
32              if (a[index].compareTo(min) < 0)//if a[index] is less than min
33              {
34                  min = a[index];
35                  indexOfMin = index;
36                  //min is smallest of a[startIndex] through a[index]
37              }
38          return indexOfMin;
39      }
```


`GeneralizedSelectionSort` class: `interchange` Method

Display 13.5 **Sorting Method for Array of Comparable** ***(Part 2 of 2)***

```
    /**
     Precondition: i and j are legal indices for the array a.
     Postcondition: Values of a[i] and a[j] have been interchanged.
    */
    private static void interchange(int i, int j, Comparable[] a)
    {
        Comparable temp;
        temp = a[i];
        a[i] = a[j];
        a[j] = temp; //original value of a[i]
    }

}
```


Sorting Arrays of `Comparable`

Display 13.6 **Sorting Arrays of Comparable** ***(Part 1 of 2)***

```
1   /**
2    Demonstrates sorting arrays for classes that
3    implement the Comparable interface.
4   */
5   public class ComparableDemo
6   {
7       public static void main(String[] args)
8       {
9           Double[] d = new Double[10];
10          for (int i = 0; i < d.length; i++)
11              d[i] = new Double(d.length - i);

12          System.out.println("Before sorting:");
13          int i;
14          for (i = 0; i < d.length; i++)
15              System.out.print(d[i].doubleValue() + ", ");
16          System.out.println();

17          GeneralizedSelectionSort.sort(d, d.length);

18          System.out.println("After sorting:");
19          for (i = 0; i < d.length; i++)
20              System.out.print(d[i].doubleValue() + ", ");
21          System.out.println();
```

The classes Double and String do implement the Comparable interface.

Sorting Arrays of `Comparable`

Display 13.6 **Sorting Arrays of Comparable** ***(Part 2 of 2)***

```
22          String[] a = new String[10];
23          a[0] = "dog";
24          a[1] = "cat";
25          a[2] = "cornish game hen";
26          int numberUsed = 3;

27          System.out.println("Before sorting:");
28          for (i = 0; i < numberUsed; i++)
29              System.out.print(a[i] + ", ");
30          System.out.println();
31
32          GeneralizedSelectionSort.sort(a, numberUsed);
```

Sorting Arrays of `Comparable`

Display 13.6 **Sorting Arrays of** `Comparable` ***(Part 2 of 2)*** (continued)

```
33          System.out.println("After sorting:");
34          for (i = 0; i < numberUsed; i++)
35              System.out.print(a[i] + ", ");
36          System.out.println();
37      }
38  }
```

SAMPLE DIALOGUE

```
Before Sorting
10.0, 9.0, 8.0, 7.0, 6.0, 5.0, 4.0, 3.0, 2.0, 1.0,
After sorting:
1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0,
Before sorting:
dog, cat, cornish game hen,
After sorting:
cat, cornish game hen, dog,
```


Defined Constants in Interfaces

- An interface can contain defined constants in addition to or instead of method headings
  - Any variables defined in an interface must be public, static, and final
  - Because this is understood, Java allows these modifiers to be omitted
- Any class that implements the interface has access to these defined constants

Pitfall: Inconsistent Interfaces

- In Java, a class can have only one base class
  - This prevents any inconsistencies arising from different definitions having the same method heading
- In addition, a class may implement any number of interfaces
  - Since interfaces do not have method bodies, the above problem cannot arise
  - However, there are other types of inconsistencies that can arise

Pitfall: Inconsistent Interfaces

- When a class implements two interfaces:
  - One type of inconsistency will occur if the interfaces have constants with the same name, but with different values
  - Another type of inconsistency will occur if the interfaces contain methods with the same name but different return types
- If a class definition implements two inconsistent interfaces, then that is an error, and the class definition is illegal

The `Serializable` Interface

- An extreme but commonly used example of an interface is the **`Serializable`** interface
  - It has no method headings and no defined constants: It is completely empty
  - It is used merely as a type tag that indicates to the system that it may implement file I/O in a particular way

The `Cloneable` Interface

- The **`Cloneable`** interface is another unusual example of a Java interface
  - It does not contain method headings or defined constants
  - It is used to indicate how the method **`clone`** (inherited from the **`Object`** class) should be used and redefined

The `Cloneable` Interface

- The method **`Object.clone()`** does a bit-by-bit copy of the object's data in storage
- If the data is all primitive type data or data of immutable class types (such as **`String`**), then this is adequate
  - This is the simple case
- The following is an example of a simple class that has no instance variables of a mutable class type, and no specified base class
  - So the base class is **`Object`**

Implementation of the Method `clone`: Simple Case

Display 13.7 **Implementation of the Method `clone` (Simple Case)**

```
1  public class YourCloneableClass implements Cloneable
2  {
3          .                          Works correctly if each instance variable is of a
4          .                          primitive type or of an immutable type like String.
5          .
6      public Object clone()
7      {
8          try
9          {
10             return super.clone();//Invocation of clone
11                                   //in the base class Object
12         }
13         catch(CloneNotSupportedException e)
14         {//This should not happen.
15             return null; //To keep the compiler happy.
16         }
17     }
18         .
19         .
20         .
21 }
```

The `Cloneable` Interface

- If the data in the object to be cloned includes instance variables whose type is a mutable class, then the simple implementation of **`clone`** would cause a *privacy leak*
- When implementing the **`Cloneable`** interface for a class like this:
  - First invoke the **`clone`** method of the base class **`Object`** (or whatever the base class is)
  - Then reset the values of any new instance variables whose types are mutable class types
  - This is done by making copies of the instance variables by invoking *their* clone methods

The `Cloneable` Interface

- Note that this will work properly only if the **`Cloneable`** interface is implemented properly for the classes to which the instance variables belong
  - And for the classes to which any of the instance variables of the above classes belong, and so on and so forth
- The following shows an example

Implementation of the Method `clone`: Harder Case

Display 13.8 Implementation of the Method `clone` (Harder Case)

```
1  public class YourCloneableClass2 implements Cloneable
2  {
3      private DataClass someVariable;
4          .
5          .
6          .
7      public Object clone()
8      {
9          try
10         {
11             YourCloneableClass2 copy =
12                                 (YourCloneableClass2)super.clone();
13             copy.someVariable = (DataClass)someVariable.clone();
14             return copy;
15         }
16         catch(CloneNotSupportedException e)
17         {//This should not happen.
18             return null; //To keep the compiler happy.
19         }
20     }
21         .
22         .
23         .
24 }
```

DataClass is a mutable class. Any other instance variables are each of a primitive type or of an immutable type like `String`.

If the clone method return type is `DataClass` *rather than* `Object`*, then this type cast is not needed.*

The class `DataClass` *must also properly implement the* `Cloneable` *interface including defining the* `clone` *method as we are describing.*

Simple Uses of Inner Classes

- Inner classes are classes defined within other classes
  - The class that includes the inner class is called the outer class
  - There is no particular location where the definition of the inner class (or classes) must be place within the outer class
  - Placing it first or last, however, will guarantee that it is easy to find

Simple Uses of Inner Classes

- An inner class definition is a member of the outer class in the same way that the instance variables and methods of the outer class are members
  - An inner class is local to the outer class definition
  - The name of an inner class may be reused for something else outside the outer class definition
  - If the inner class is private, then the inner class cannot be accessed by name outside the definition of the outer class

Simple Uses of Inner Classes

- There are two main advantages to inner classes
  - They can make the outer class more self-contained since they are defined inside a class
  - Both of their methods have access to each other's private methods and instance variables
- Using an inner class as a helping class is one of the most useful applications of inner classes
  - If used as a helping class, an inner class should be marked private

Tip: Inner and Outer Classes Have Access to Each Other's Private Members

- Within the definition of a method of an inner class:
  - It is legal to reference a private instance variable of the outer class
  - It is legal to invoke a private method of the outer class
- Within the definition of a method of the outer class
  - It is legal to reference a private instance variable of the inner class on an object of the inner class
  - It is legal to invoke a (nonstatic) method of the inner class as long as an object of the inner class is used as a calling object
- Within the definition of the inner or outer classes, the modifiers **`public`** and **`private`** are equivalent

Class with an Inner Class

Display 13.9 Class with an Inner Class *(Part 1 of 2)*

```
1  public class BankAccount
2  {
3      private class Money
4      {
5          private long dollars;
6          private int cents;
7
8          public Money(String stringAmount)
9          {
10             abortOnNull(stringAmount);
11             int length = stringAmount.length();
12             dollars = Long.parseLong(
13                         stringAmount.substring(0, length - 3));
14             cents = Integer.parseInt(
15                         stringAmount.substring(length - 2, length));
16         }
17
18         public String getAmount()
19         {
20             if (cents > 9)
21                return (dollars + "." + cents);
22             else
               return (dollars + ".0" + cents);
           }
```

The modifier `private` in this line should not be changed to `public`. However, the modifiers `public` and `private` inside the inner class `Money` can be changed to anything else and it would have no effect on the class `BankAccount`.

Class with an Inner Class

Display 13.9 Class with an Inner Class *(Part 1 of 2)* (continued)

```
23      public void addIn(Money secondAmount)
24      {
25          abortOnNull(secondAmount);
26          int newCents = (cents + secondAmount.cents)%100;
27          long carry = (cents + secondAmount.cents)/100;
28          cents = newCents;
29          dollars = dollars + secondAmount.dollars + carry;
30      }

31      private void abortOnNull(Object o)
32      {
33          if (o == null)
34          {
35              System.out.println("Unexpected null argument.");
36              System.exit(0);
37          }
38      }
39  }
```

The definition of the inner class ends here, but the definition of the outer class continues in Part 2 of this display.

Class with an Inner Class

Display 13.9 Class with an Inner Class *(Part 2 of 2)*

```
40      private Money balance;

41      public BankAccount()
42      {
43          balance = new Money("0.00");
44      }

45      public String getBalance()
46      {
47          return balance.getAmount();
48      }

49      public void makeDeposit(String depositAmount)
50      {
51          balance.addIn(new Money(depositAmount));
52      }

53      public void closeAccount()
54      {
55          balance.dollars = 0;
56          balance.cents = 0;
57      }
58  }
```

To invoke a nonstatic method of the inner class outside of the inner class, you need to create an object of the inner class.

This invocation of the inner class method `getAmount()` would be allowed even if the method `getAmount()` were marked as `private`.

Notice that the outer class has access to the private instance variables of the inner class.

This class would normally have more methods, but we have only included the methods we need to illustrate the points covered here.

The `.class` File for an Inner Class

- Compiling any class in Java produces a **`.class`** file named ***`ClassName`*`.class`**
- Compiling a class with one (or more) inner classes causes both (or more) classes to be compiled, and produces two (or more) .class files
  - Such as ***`ClassName`*`.class` and *`ClassName$InnerClassName`*`.class`**

Static Inner Classes

- A normal inner class has a connection between its objects and the outer class object that created the inner class object
  - This allows an inner class definition to reference an instance variable, or invoke a method of the outer class
- There are certain situations, however, when an inner class must be static
  - If an object of the inner class is created within a static method of the outer class
  - If the inner class must have static members

Static Inner Classes

- Since a static inner class has no connection to an object of the outer class, within an inner class method
  - Instance variables of the outer class cannot be referenced
  - Nonstatic methods of the outer class cannot be invoked
- To invoke a static method or to name a static variable of a static inner class within the outer class, preface each with the name of the inner class and a dot

Public Inner Classes

- If an inner class is marked **`public`**, then it can be used outside of the outer class
- In the case of a nonstatic inner class, it must be created using an object of the outer class

```
BankAccount account = new BankAccount();
BankAccount.Money amount =
  account.new Money("41.99");
```

  - Note that the prefix ***`account.`*** must come before ***`new`***
  - The new object **`amount`** can now invoke methods from the inner class, but only from the inner class

Public Inner Classes

- In the case of a static inner class, the procedure is similar to, but simpler than, that for nonstatic inner classes

```
OuterClass.InnerClass innerObject =
                new OuterClass.InnerClass();
```

  - Note that all of the following are acceptable

```
innerObject.nonstaticMethod();
innerObject.staticMethod();
OuterClass.InnerClass.staticMethod();
```


Tip: Referring to a Method of the Outer Class

- If a method is invoked in an inner class
  - If the inner class has no such method, then it is assumed to be an invocation of the method of that name in the outer class
  - If both the inner and outer class have a method with the same name, then it is assumed to be an invocation of the method in the inner class
  - If both the inner and outer class have a method with the same name, and the intent is to invoke the method in the outer class, then the following invocation must be used:

```
OuterClassName.this.methodName()
```

Nesting Inner Classes

- It is legal to nest inner classes within inner classes
  - The rules are the same as before, but the names get longer
  - Given class **A**, which has public inner class **B**, which has public inner class **C**, then the following is valid:

```
A aObject = new A();
A.B bObject = aObject.new B();
A.B.C cObject = bObject.new C();
```


Inner Classes and Inheritance

- Given an **OuterClass** that has an **InnerClass**
  - Any **DerivedClass** of **OuterClass** will automatically have **InnerClass** as an inner class
  - In this case, the **DerivedClass** cannot override the **InnerClass**
- An outer class can be a derived class
- An inner class can be a derived class also

Anonymous Classes

- If an object is to be created, but there is no need to name the object's class, then an *anonymous class* definition can be used
  - The class definition is embedded inside the expression with the **new** operator
- Anonymous classes are sometimes used when they are to be assigned to a variable of another type
  - The other type must be such that an object of the anonymous class is also an object of the other type
  - The other type is usually a Java interface

Anonymous Classes

Display 13.11 Anonymous Classes *(Part 1 of 2)*

This is just a toy example to demonstrate the Java syntax for anonymous classes.

```
1  public class AnonymousClassDemo
2  {
3      public static void main(String[] args)
4      {
5          NumberCarrier anObject =
6                  new NumberCarrier()
7                  {
8                      private int number;
9                      public void setNumber(int value)
10                     {
11                         number = value;
12                     }
13                     public int getNumber()
14                     {
15                        return number;
16                     }
17                 };
```

Anonymous Classes

Display 13.11 **Anonymous Classes** ***(Part 1 of 2)***

```
18          NumberCarrier anotherObject =
19                  new NumberCarrier()
20                  {
21                      private int number;
22                      public void setNumber(int value)
23                      {
24                          number = 2*value;
25                      }
26                      public int getNumber()
27                      {
28                          return number;
29                      }
30                  };

31          anObject.setNumber(42);
32          anotherObject.setNumber(42);
33          showNumber(anObject);
34          showNumber(anotherObject);
35          System.out.println("End of program.");
36      }

37      public static void showNumber(NumberCarrier o)
38      {
39          System.out.println(o.getNumber());
40      }
                                    This is still the file
                                    AnonymousClassDemo.java.
41  }
```


Anonymous Classes

Display 13.11 **Anonymous Classes** ***(Part 2 of 2)***

SAMPLE DIALOGUE

```
42
84
End of program.
```

```
1  public interface NumberCarrier
2  {
3      public void setNumber(int value);
4      public int getNumber();
5  }
```

This is the file NumberCarrier.java.