STUDENT OUTLINE

Lesson 29 - Inheritance, Polymorphism, and Abstract Classes

INTRODUCTION: A class represents a set of objects that share the same structure and behaviors. The class determines the structure of objects by specifying variables that are contained in each instance of the class, and it determines behavior by providing the instance methods that express the behavior of the objects. This is a powerful idea. However, something like this can be done in most programming languages. The central new idea in object-oriented programming is to allow classes to express the similarities among objects that share some, but not all, of their structure and behavior. Such similarities can be expressed using inheritance and polymorphism.

The key topics for this lesson are:

A. Inheritance
B. Abstract Classes
C. Polymorphism
D. Interfaces

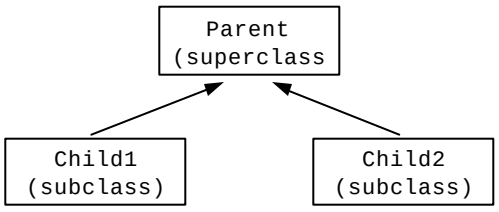
VOCABULARY:

ABSTRACT	CONCRETE CLASS
SUPERCLASS	SUBCLASS
INSTANCE	POLYMORPHISM
INTERFACE	EARLY BINDING
LATE BINDING	

DISCUSSION:

A. Inheritance

1. A key element in Object Oriented Programming is the ability to derive new classes from existing classes by adding new methods and redefining existing methods. The new class can inherit many of its attributes and behaviors from the existing class. This process of deriving new classes from existing classes is called *inheritance*, which we introduced in Lesson 14.



The more general class that forms the basis for inheritance is called the *superclass*. The more specialized class that inherits from the superclass is called the *subclass* (or *derived* class).

2. In Java, all classes belong to one big hierarchy derived from the most basic class, called `Object`. This class provides a few features common to all objects; more importantly, it makes sure that any object is an instance of the `Object` class, which is useful for implementing structures that can deal with any type of object. If we start a class from "scratch" the class automatically extends `Object`. For example:

```
public class SeaCreature
{
  ...
}
```

is equivalent to:

```
public class SeaCreature extends Object
{
  ...
}
```

when new classes are derived from `SeaCreature`, a class hierarchy is created. For example:

```
public class Fish extends SeaCreature
{
  ...
}

public class Mermaid extends SeaCreature
{
  ...
}
```

This results in the hierarchy shown below.

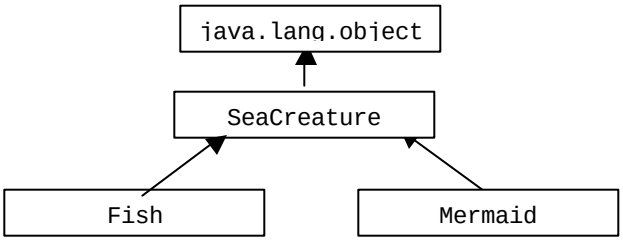


Figure 28-1. `SeaCreature` and two derived classes

B. Abstract Classes

1. The classes that lie closer to the top of the hierarchy are more general and abstract; the classes closer to the bottom are more specialized. Java allows us to formally define an *abstract* class. In an abstract class, some or all methods are declared **`abstract`** and left without code.

2. An **`abstract`** method has only a heading: a declaration that gives the method's name, return type, and arguments. An **`abstract`** method has no code. For example, all of the methods in the definition of the `SeaCreature` class shown below are abstract. `SeaCreature` tells us what methods a sea creature must have, but not how they work.

```
//  A type of creature in the sea
public abstract class SeaCreature
{
  //  Called to move the creature in its environment
  public abstract void swim();

  //  Attempts to breed into neighboring locations
  public abstract void breed();

  //  Removes this creature from the environment
  public abstract void die();

  //  Returns the name of the creature
  public abstract String getName();
}
```

3. In an **`abstract`** class, some methods and constructors may be fully defined and have code supplied for them while other methods are **`abstract`**. A class may be declared abstract for other reasons as well. For example, some of the instance variables in an abstract class may belong to abstract classes.

4. More specialized subclasses of an abstract class have more and more methods defined. Eventually, down the inheritance line, the code is supplied for all methods. A class where all the methods are fully defined and which has no abstract fields is called a *concrete* class. A program can only create objects of concrete classes. An object is called an *instance* of its class. An **`abstract`** class cannot be instantiated.

5. Different concrete classes in the same hierarchy may define the same method in different ways. For example:

```
public class Fish extends SeaCreature
{
  ...

  /**
   *  Returns the name of the creature
   */
  public String getName()
  {
     return "Wanda the Fish";
  }
  ...
}

public class Mermaid extends SeaCreature
{
  ...
```

```
  /**
   *  Returns the name of the creature
   */
  public String getName()
  {
     return "Ariel the Mermaid";
  }
  ...
}
```

C. Polymorphism

1. In addition to facilitating the re-use of code, inheritance provides a common base data type that lets us refer to objects of specific types through more generic types of references; in particular, we can mix objects of different subtypes in the same collection. For example

```
SeaCreature s = new Fish(...);
...
s.swim();
```

The data type of an instance of the `Fish` class is a `Fish`, but it is also a kind of `SeaCreature`. Java provides the ability to refer to a specific type through more generic types of references.

2. There may be situations that require a reference to an object using its more generic supertype rather than its most specific type. One such situation is when different subtypes of objects in the same collection (array, list, etc.) are mixed. For example:

```
SeaCreature creatures = new SeaCreature[2];
creatures[0] = new Fish(...);
creatures[1] = new Mermaid(...);
...
creature[currentCreature].swim();
```

This is possible because both `Fish` and `Mermaid` are `SeaCreatures`.

3. Note that the `Fish` and `Mermaid` classes provide two different implementations of the `swim` method. The correct method that belongs to the class of the actual object is located by the Java virtual machine. That means that one method call

```
String s = x.getname();
```

can call different methods depending on the current reference of `x`.

4. The principle that the actual type of the object determines the method to be called is called *polymorphism* (Greek for "many shapes"). The same computation works for objects of many forms and adapts itself to the nature of the objects. In Java, all instance methods are polymorphic.

5. There is an important difference between polymorphism and overloading. With an overloaded method, the compiler picks the correct method when translating the program, before the program ever runs. This method selection is called *early binding*. With a polymorphic method, selection can only take place when the program runs. This method of selection is called *late binding*.

D. Interfaces

1. In Lesson 14 you saw that Java has a class-like form called an *interface* that can be used to encapsulate only abstract methods and constants. An interface can be thought of as a blueprint or design specification. A class that uses this interface is a class that *implements the interface*.

2. An interface is similar to an abstract class: it lists a few methods, giving their names, return types, and argument lists, but does not give any code. The difference is that an abstract class my have its constructors and some of its methods implemented, while an interface does not give any code for its methods, leaving their implementation to a class that implements the interface.

3. **`interface`** and **`implements`** are Java reserved words. Here is an example of a simple Java interface:

```
public interface Comparable
{
  public int compareTo(Object other);
}
```

   This looks much like a class definition, except that the implementation of the `compareTo()` method is omitted. A class that implements the `Comparable` interface must provide an implementation for this method. The class can also include other methods and variables. For example,

```
class Location implements Comparable
{
  public int compareTo(Object other)
  {
    . . . // do something -- presumably, compare objects
  }
  . . .   // other methods and variables
}
```

   Any class that implements the `Comparable` interface defines a `compareTo()` instance method. Any object created from such a class includes a `compareTo()` method. We say that an object implements an interface if it belongs to a class that implements the interface. For example, any object of type `Location` implements the `Comparable` interface. Note that it is not enough for the object to include a `compareTo()` method. The class that it belongs to must say that it "implements" `Comparable` .

4. A class can implement any number of interfaces. In fact, a class can both extend another class and implement one or more interfaces. So, we can have things like

```
class Fish extends SeaCreature implements Locatable, Eatable
{
  ...
}
```

5. An interface is very much like an abstract class. It is a class that can never be used for constructing objects, but can be used as a basis for making subclasses. Even though you can't construct an object from an interface, you can declare a variable whose type is given by the interface. For example, if `Locatable` is an interface defined as follows:

```
public interface Locatable
{
  Location location();
}
```

then if `Fish` and `Mermaid` are classes that implement `Locatable`, you could say:

```
/**
 * Declare a variable of type Locatable. It can refer to
 * any object that implements the Locatable interface.
 */
Locatable nemo;

nemo = new Fish();       // nemo now refers to an object
                         //   of type Fish
nemo.location();         // Calls location () method from
                         //   class Fish
nemo = new Mermaid();    // Now, nemo refers to an object
                         //   of type Mermaid.
nemo.location();         // Calls location() method from
                         //   class MerMaid
```

A variable of type `Locatable` can refer to any object of any class that implements the `Locatable` interface. A statement like `nemo.location()`, above, is legal because `nemo` is of type `Locatable`, and any `Locatable` object has a `location()` method.

6. You are not likely to need to write your own interfaces until you get to the point of writing fairly complex programs. However, there are a few interfaces that are used in important ways in Java's standard packages. You'll learn about some of these standard interfaces in the next few lessons, and you will see examples of interfaces in the Marine Biology Simulation, which was developed for use in AP Computer Science courses by the College Board™.

SUMMARY/REVIEW: The main goals of OOP are team development, software reusability, and easier program maintenance. The main OOP concepts that serve these goals are abstraction, encapsulation, inheritance, and polymorphism. In this lesson, we reviewed these key concepts and their implementation in Java. This lesson examined how Java uses classes and interfaces, inheritance hierarchies, and polymorphism to achieve the goal of better-engineered programs.

ASSIGNMENT: Lab Exercise, L.A.29.1, *Old MacDonald*

LAB EXERCISE

OldMacDonald

Background:

Old MacDonald had a farm and several types of animals. Every animal shared certain characteristics: they had a type (such as cow, chick or pig) and each made a sound (moo, cluck or oink). An Interface defines those things required to be an animal on the farm.

```
public interface Animal
{
  public String getSound();
  public String getType();
}
```

In this lab, we use Old MacDonald's Farm to learn about Inheritance and Polymorphism.

Notes:
This lab is adapted with gratitude from a lab developed by Roger Frank of Ponderosa HS, Parker CO.

For those unfamiliar with it, a version of the *Old MacDonald* song is found at http://www.scoutsongs.com/lyrics/oldmacdonald.html.

Assignment:

1. Once we know what it takes to be an `Animal`, we can define new classes for the cow, chick and pig that implement the `Animal` interface. Here is a `Cow` class meeting the minimum requirements to be an `Animal`.

```
class Cow implements Animal
{
  private String myType;
  private String mySound;

  Cow(String type, String sound)
  {
    myType = type;
    mySound = sound;
  }

  public String getSound() { return mySound; }
  public String getType() { return myType; }
}
```

2. Implement classes for the chick and the pig. Also complete the test program below to verify your work so far:

```
class OldMacDonald
{
  public static void main(String[] args)
  {
    Cow c = new Cow("cow", "moo");
    System.out.println( c.getType() + " goes " + c.getSound() );

      // < your code here >
  }
}
```

3. Create a complete farm to test all your animals. Here is the *Farm.java* source code.

```
class Farm
{
  private Animal[] a = new Animal[3];
  Farm()
  {
    a[0] = new Cow("cow","moo");
    a[1] = new Chick("chick","cluck");
    a[2] = new Pig("pig","oink");
  }

  public void animalSounds()
  {
    for (int i = 0; i < a.length; i++)
    {
      System.out.println(a[i].getType() + " goes " + a[i].getSound());
    }
  }
}
```

You will need to change your *OldMacDonald.java* code to create an object of type `Farm` and then to invoke its `animalSounds` method.

4. Turns out, the chick is a little confused. Sometimes it makes one sound, when she is feeling childish, and another when she is feeling more grown up. Her two sounds are "cheep" and "cluck". Modify the *Chick.java* code to allow a second constructor allowing two possible sounds and the `getSound()` method to return either sound, with equal probability, if there are two sounds available. You will also have to modify your *Farm.java* code to construct the `Chick` with two possible sounds.

5. Finally, it also came to pass that the cows get a personal name, like Elsie. Create a new class, `NamedCow`, that extends the `Cow` class, adding a constructor, a field for the `Cow`'s name, and a new method: `getName`. The final *Farm.java* code to exercise all your modifications is shown here:

```
class Farm
{
  private Animal[] a = new Animal[3];
  Farm()
  {
    a[0] = new NamedCow("cow","Elsie","moo");
    a[1] = new Chick("chick","cheep","cluck");
    a[2] = new Pig("pig","oink");
  }

  public void animalSounds()
  {
    for (int i = 0; i < a.length; i++)
    {
      System.out.println(a[i].getType() + " goes " + a[i].getSound());
    }
    System.out.println("The cow is known as " +
                       ((NamedCow)a[0]).getName());
  }
}
```

6. Make sure you understand what you just accomplished. Having an array of `Animal` objects and then having the `getSound()` method dynamically decide what sound to make is *polymorphism.* This is also known as *late binding* because it wasn't known until run-time that `a[1]`, for example, really had a `Chick` object.

   You started with an *Interface* for an `Animal` and then used the keyword **`implements`** in making the three types of animals. Then you created a specialized version of the `Cow`, a `NamedCow`, using the keyword **`extends`**. This illustrates the concept of inheritance. The `NamedCow` had all the attributes and methods of the `Cow` and then added some: a new field and a new method to access the cow's name.

Instructions:

1. Develop and test the Old MacDonald Farm classes a described in the Assignment section above.

2. Your lab assignment should consist of the following 7 files:

   Animal.java – interface
   Chick.java, Cow.java, Pig.java – implementations of the Animal interface
   NamedCow.java – subclass of the Cow class
   Farm.java – collection of Animal objects
   OldMacDonald.java – testing class

3. Turn in your source code and run output.