Advanced Relations

Relationships between classes:

- Inheritance

Access modifiers:

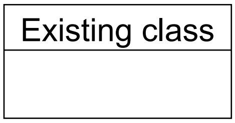
- Public, private, protected

Interfaces: Types Vs. Classes

Abstract classes

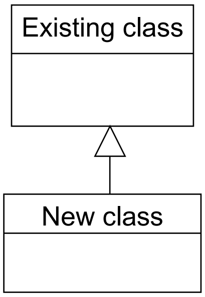
What Is Inheritance?

Creating new classes that are based on existing classes.



What Is Inheritance?

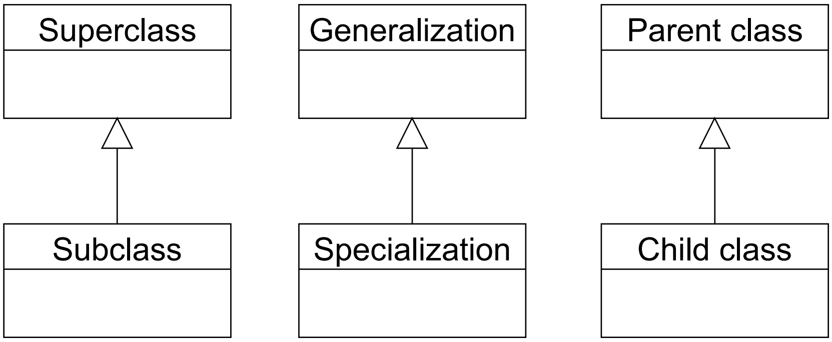
- Creating new classes that are based on existing classes.
- All non-private data and methods are available to the new class (but the reverse is not true).
- The new class is composed of the information and behaviors of the existing class (and more).



Existing class

New class

Inheritance Terminology



Superclass

Subclass

Generalization

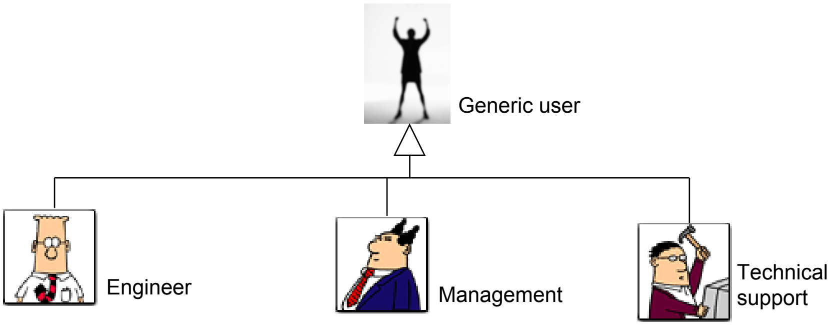
Specialization

Parent class

Child class

When To Employ Inheritance

- If you notice that certain behaviors or data is common among a group of candidate classes
- The commonalities may be defined by a superclass
- What is unique may be defined by particular subclasses



Dilbert © United Features Syndicate

Using Inheritance

Format:

```
public class <Name of Subclass > extends <Name of Superclass>
{
 // Definition of subclass – only what is unique to subclass
}
```

Example:

```
public class Dragon extends Monster
{
   public void displaySpecial ()
   {
      System.out.println("Breath weapon: ");
   }
}
```

The Parent Of All Classes

- You’ve already employed inheritance
- Class Object is at the top of the inheritance hierarchy
- Inheritance from class Object is implicit
- All other classes inherit it’s data and methods
- For more information about this class see the url:
  http://java.sun.com/j2se/1.4.2/docs/api/java/lang/Object.html

Review: Relations Between Classes

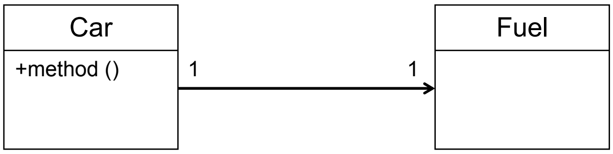
- Association (“knows-a”)
- Aggregation (“has-a”)
- Inheritance (“is-a”)

Association "Knows-A"

A association relation can exist between two classes if within one class' method(s), there exists as a local variable an instance of another class

e.g., A car uses (knows-a) instance of fuel

```
public class Car
{
    public void method ()
    {
        Fuel gas = new Fuel ();
    }
}
```

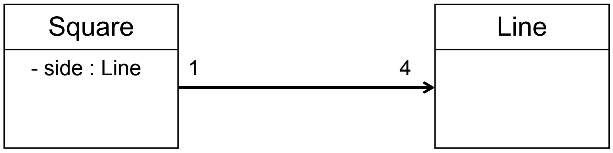


Association "Knows-As" (2)

A association relation can also exist between two classes if an instance of one class is an attribute of another class.

e.g., A square uses (knows-a) line

```
public class Square
{
    private Line side;
}
```



Aggregation "Has-A"

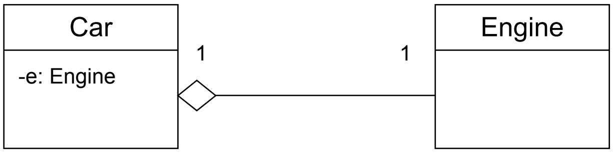
An aggregation relation exists between two classes if one class is an attribute of another class.

And

The first class is part of the second class (or the second class is an aggregate of the first class)

e.g., A car has an (has-a) engine

```
public class Car
{
      private Engine e;
}
```

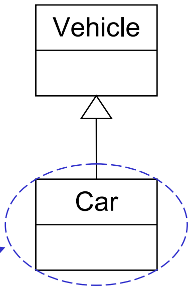


Inheritance "Is-A"

An inheritance relation exists between two classes if one class is one type of another class

e.g., A car is a type of (is-a) vehicle

```
public class Vehicle
{
      :
}

public class Car extends Vehicle
{
      :
}
```



Instances of the subclass can be used in place of instances of the super class

Levels Of Access Permissions

Private "-"

- Can only access the attribute/method in the methods of the class where the attribute is originally defined.

Protected "#"

- Can access the attribute/method in the methods of the class where the attribute is originally defined or the subclasses of that class.

Public "+"

- Can access attribute/method anywhere in the program

Levels Of Access Permissions

Access level	Accessible to		
	Same class	Subclass	Not a subclass
Public	Yes	Yes	Yes
Protected	Yes	Yes	No
Private	Yes	No	No

Levels Of Access Permission: An Example

```
public class P
{
        private int num1;
        protected int num2;
        public int num3;
        // Can access num1, num2 & num3 here.
}

public class C extends P
{
   // Can't access num1 here
}

public class Driver
{
   // Can't access num1 here.
}
```

General Rules Of Thumb

- Variable attributes should not have protected access but instead should be private.
- Most methods should be public
- Methods that are used only by the parent and child classes should be made protected.

Method Overriding

- Different versions of a method can be implemented in different ways by the parent and child class in an inheritance hierarchy.
- Methods have the same name and parameter list (identical signature) but different bodies
  - e.g.,

```
public class Parent                      public class Child extends Parent
{                                        {
        :          :                             :          :
    public void method ()                    public void method ()
    {                                        {
       System.out.println("m1");                  num = 1;
    }                                         }
}                                        }
```

Method Overloading Vs. Method Overriding

Method Overloading

- Multiple method implementations for the same class
- Each method has the same name but the type, number or order of the parameters is different (signatures are not the same)
- The method that is actually called is determined at program *compile time* (early binding).
- i.e., <reference name>.<method name> (parameter list);

Distinguishes overloaded methods

Method Overloading Vs. Method Overriding (2)

Example of method overloading:

```
public class Foo
{
    public void display () { }
    public void display (int i) { }
    public void display (char ch) { }
}



Foo f = new Foo ();
f.display();
f.display(10);
f.display(‘c’);
```

Method Overloading Vs. Method Overriding (3)

Method Overriding

- The method is implemented differently between the parent and child classes
- Each method has the same return value, name and parameter list (identical signatures)
- The method that is actually called is determined at program *run time* (late binding)
- i.e., <reference name>.<method name> (parameter list);

The type of the reference (implicit parameter “this”) distinguishes overridden methods

Method Overloading Vs. Method Overriding (4)

Example of method overriding:

```
public class Foo
{
    public void display () { … }
        :               :
}
public class FooChild extends Foo
{
     public void display () { … }
}

Foo f = new Foo ();
f.display();

FooChild fc = new FooChild ();
fc.display ();
```

Polymorph

The ability to take on different forms

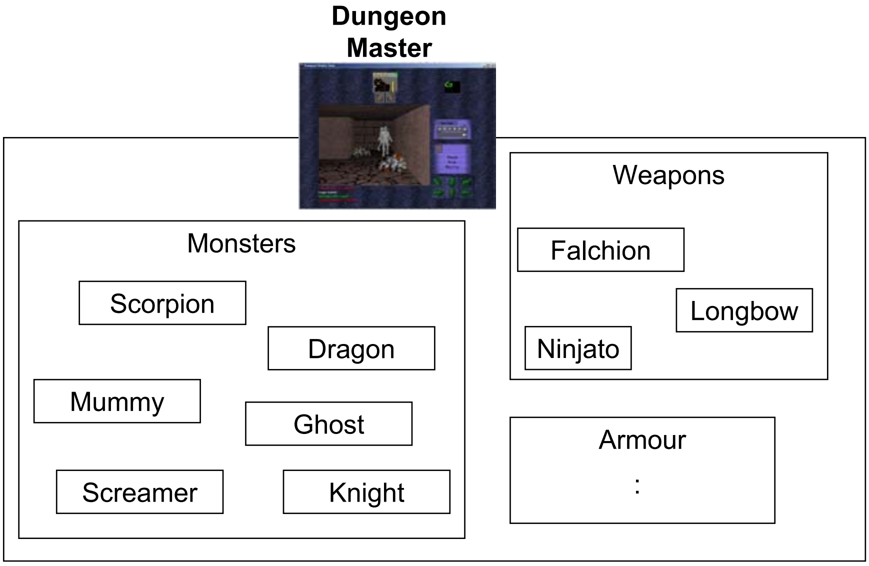
Images from the game Dungeon Master by FTL

Polymorphism In Object-Orientated Theory

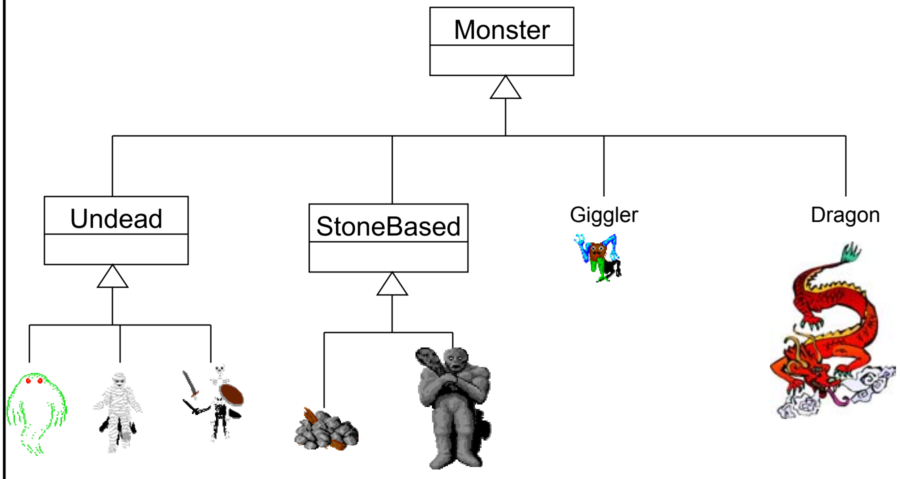
- An overridden method that can take on many forms
- The type of an instance (the implicit parameter) determines at program run-time which method will be executed.

```
public class Foo
{
    public void display () { … }
         :              :
}
public class FooChild extends Foo
{
     public void display () { … }
}
```

A Blast From The Past



The Inheritance Hierarchy For The Monsters



Monster

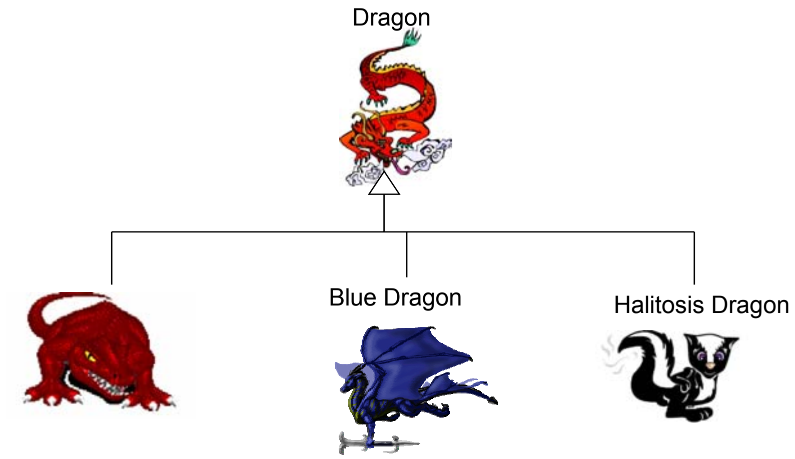
Undead

StoneBased

Giggler

Dragon

The Dragon Sub-Hierarchy

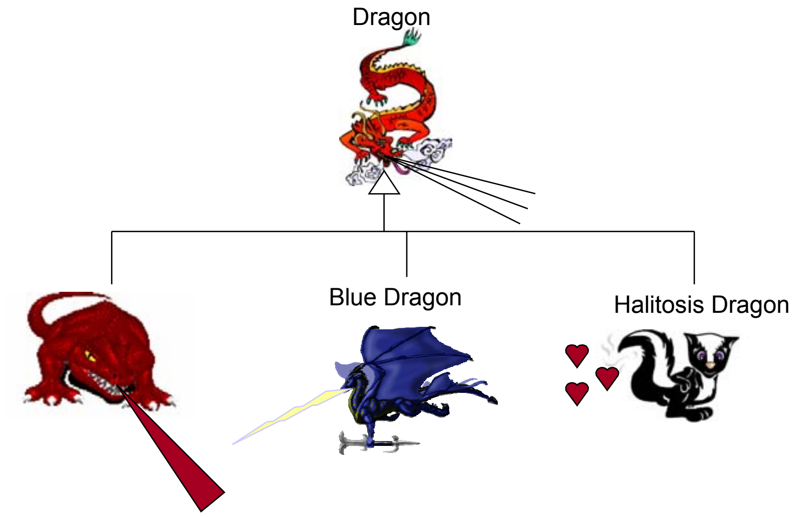


Dragon

Blue Dragon

Halitosis Dragon

The Dragon Sub-Hierarchy



Class DungeonMaster

Example (The complete example can be found in the directory
/home/233/examples/object_programming/DMExample

```
class DungeonMaster
{
   public static void main (String [] args)
   {
      BlueDragon electro = new BlueDragon ();
      RedDragon pinky = new RedDragon ();
      HalitosisDragon stinky = new HalitosisDragon () ;

      electro.displaySpecialAbility ();
      pinky.displaySpecialAbility ();
      stinky.displaySpecialAbility ();
   }
}
```

Class Monster

```
public class Monster
{
   private int protection;
   private int damageReceivable;
   private int damageInflictable;
   private int speed;
   private String name;
   public Monster ()
   {
      protection = 0;
      damageReceivable = 1;
      damageInflictable = 1;
      speed = 1;
      name = "Monster name: ";
   }
```

Class Monster (2)

```
   public int getProtection () {return protection;}
   public void setProtection (int newValue) {protection = newValue;}
   public int getDamageReceivable () {return damageReceivable;}
   public void setDamageReceivable (int newValue) {damageReceivable =
      newValue;}
   public int getDamageInflictable () {return damageInflictable;}
   public void setDamageInflictable (int newValue) {damageInflictable =
      newValue;}
   public int getSpeed () {return speed;}
   public void setSpeed (int newValue) {speed = newValue;}
   public String getName () {return name; }
   public void setName (String newValue) {name = newValue;}
   public void displaySpecialAbility ()
   {
      System.out.println("No special ability");
   }
```

Class Monster (3)

```
 public String toString ()
{
   String s = new String ();
   s = s + "Protection: " + protection + "\n";
   s = s + "Damage receivable: " + damageReceivable + "\n";
   s = s + "Damage inflictable: " + damageInflictable + "\n";
   s = s + "Speed: " + speed + "\n";
   s = s + "Name: " + name + "\n";
   return s;
}
}  // End of definition for class Monster.
```

Class Dragon

```
public class Dragon extends Monster
{
   public void displaySpecialAbility ()
   {
      System.out.print("Breath weapon: ");
   }
}
```

Class BlueDragon

```
public class BlueDragon extends Dragon
{
   public void displaySpecialAbility ()
   {
      super.displaySpecialAbility ();
      System.out.println("Lightening");
   }
}
```

Class HalitosisDragon

```
public class HalitosisDragon extends Dragon
{
   public void displaySpecialAbility ()
   {
      super.displaySpecialAbility();
      System.out.println("Stinky");
   }
}
```

Class RedDragon

```
public class RedDragon extends Dragon
{
   public void displaySpecialAbility ()
   {
      super.displaySpecialAbility();
      System.out.println("Fire");
   }
}
```

Updated Scoping Rules

When referring to an identifier in the method of a class

1. Look in the local memory space for that method
2. Look in the definition of the class
3. Look in the definition of the classes' parent

Updated Scoping Rules (2)

```
public class P
{
     <<< Third >>>
}
public class C extends P
{
     <<< Second >>>
     public void method ()
     {
           <<< First >>>
     }
}
```

Accessing The Unique Attributes And Methods Of The Parent

- All protected or public attributes and methods of the parent class can be accessed directly in the child class

e.g.

```
public class P
{
        protected int num;
 }

 public class C extends P
{
       public void method ()
       {
              this.num = 1;
               // OR
              num = 2;
       }
}
```

Accessing The Non-Unique Attributes And Methods Of The Parent

- An attribute or method exists in both the parent and child class (has the same name in both)
- The method or attribute has public or protected access
- Must prefix the attribute or method with “super” to distinguish it from the child class.
- Format:
  - super.*methodName* ()
  - super.*attributeName* ()

- Note: If you don’t preface the method attribute with the keyword “super” then the by default the attribute or method of the child class will be accessed.

Accessing The Non-Unique Attributes And Methods Of The Parent: An Example

e.g.

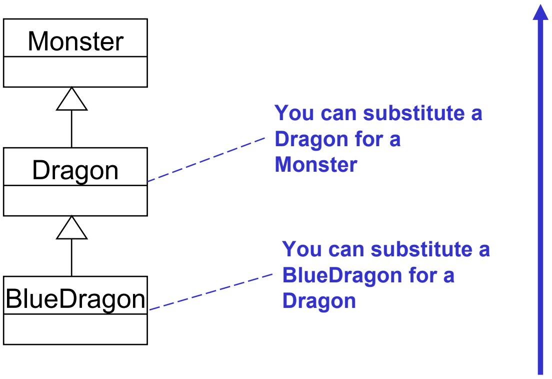
```
public class P
{
   protected int num;
   protected void method ()
   {
      :
   }
}
```

Accessing The Non-Unique Attributes And Methods Of The Parent: An Example (2)

```
public class C extends P
{
   protected int num;
   public void method ()
   {
      num = 2;
      super.num = 3;
      super.method();
}
```

Casting And Inheritance

- Remember: You can substitute instances of a subclass for instances of a superclass.

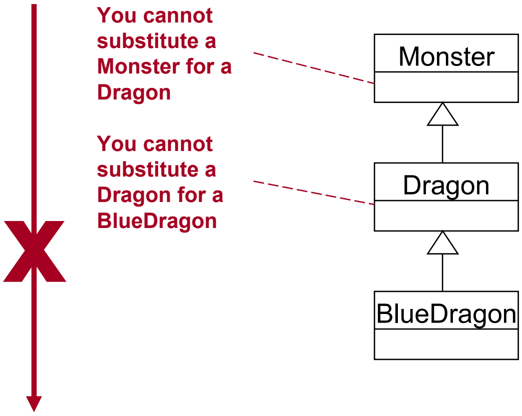


You can substitute a Dragon for a Monster

You can substitute a BlueDragon for a Dragon

Casting And Inheritance (2)

- Remember: You cannot substitute instances of a superclass for instances of a subclass



You cannot substitute a Monster for a Dragon

You cannot substitute a Dragon for a BlueDragon

Casting And Inheritance: A Previous Example

```
public class Monster
{
    private int protection;
    private int damageReceivable;
    private int damageInflictable;
    private int speed;
    private String name;

        :            :         :
    public int getProtection () {return protection;}
        :            :         :
}
```

Casting And Inheritance: An Previous Example

```
public class Dragon extends Monster
{
   public void displaySpecialAbility ()
   {
      System.out.print("Breath weapon: ");
   }

   public void fly ()
   {
      System.out.println("Flying");
   }
}
```

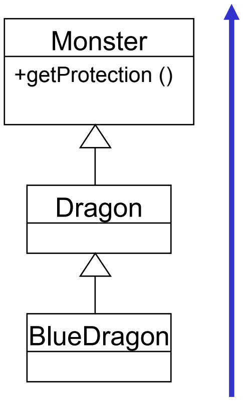
Casting And Inheritance: An Previous Example

```
public class BlueDragon extends Dragon
{
   public void displaySpecialAbility ()
   {
      super.displaySpecialAbility ();
      System.out.println("Lightening");
   }

   public void absorbElectricity ()
   {
      System.out.println("Absorbing electricity.");
   }
}
```

Substituting Sub And Super Classes

- You can substitute an instance of a sub class for an instance of a super class.

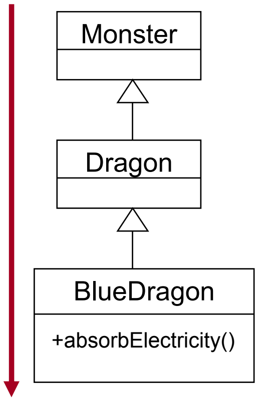
```
BlueDragon electro = new BlueDragon ();
Monster aMonster = new Monster ();

System.out.println(aMonster.getProtection());
System.out.println(electro.getProtection());
```



Substituting Sub And Super Classes

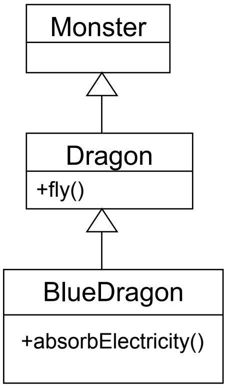
- You cannot substitute an instance of a super class for an instance of a sub class.

```
BlueDragon electro = new BlueDragon ();
Monster aMonster = new Monster ();

electro.absorbElectricity ();
```
~~aMonster.absorbElectricity~~ ();



Casting And Inheritance

```
  BlueDragon electro = new BlueDragon ();
  Monster aMonster;

  aMonster = electro;
X aMonster.fly();
X aMonster.absorbElectricity();

  aMonster = new Monster ();
X electro = aMonster;

X electro = (BlueDragon) aMonster;
X electro.fly();
X electro.absorbElectricity();
```



Casting And Inheritance (2)

- Only use the cast operator if you are sure of the type.

```
BlueDragon electro = new BlueDragon ();
Monster aMonster;
aMonster = electro;

 if (aMonster instanceof BlueDragon)
{
      System.out.println("AMonster is a reference to an instance of a
            BlueDragon");
      electro = (BlueDragon) aMonster;
      electro.fly();
      electro.absorbElectricity();
}
```

Casting And Inheritance (3)

- Only use the cast operator if you are sure of the type.

```
BlueDragon electro = new BlueDragon ();
Monster aMonster;
aMonster = electro;

if (aMonster instanceof BlueDragon)
{
    System.out.println("AMonster is actually a reference to an instance of
         a BlueDragon");
    ((BlueDragon) aMonster).fly();
   ((BlueDragon) aMonster).absorbElectricity();
}
```

Shadowing

- Local variables in a method or parameters to a method have the same name as instance fields
- Attributes of the subclass have the same name as attributes of the superclass

Attributes Of The Subclass Have The Same Name As The SuperClasses' Attributes

```
public class Foo
{
   private int num;
   public Foo () { num = 1; }
   public int getNum () { return num; }
   public void setNum (int newValue) {num = newValue; }
}

public class Bar extends Foo
{
   public Bar ()
   {
      num = 10;
   }
}
```

Attributes Of The Subclass Have The Same Name As The SuperClasses' Attributes

```
public class Foo
{
   private int num;
   public Foo () { num = 1; }
   public int getNum () { return num; }
   public void setNum (int newValue) {num = newValue; }
}

public class Bar extends Foo
{
   public Bar ()
   {
      num = 10;
   }
}
```

Insufficient access permissions: Program won't compile

Attributes Of The Subclass Have The Same Name As The SuperClasses' Attributes (2)

```
public class Foo
{
   private int num;
   public Foo () { num = 1; }
   public int getNum () { return num; }
   public void setNum (int newValue) {num = newValue; }
}

public class Bar extends Foo
{
   private int num;
   public Bar ()
   {
      num = 1;
   }
}
```

Attributes Of The Subclass Have The Same Name As The SuperClasses' Attributes (2)

```
public class Foo
{
   private int num;
   public Foo () { num = 1; }
   public int getNum () { return num; }
   public void setNum (int newValue) {num = newValue; }
}

public class Bar extends Foo
{
   private int num;
   public Bar ()
   {
      num = 1;
   }
}
```

NO!

The Result Of Attribute Shadowing

```
public class Bar extends Foo
{
   private int num;
   public Bar ()
   {
      num = 10;
   }
   public int getSecondNum () { return num; }
}
class Driver
{
   public static void main (String [] arv)
   {
      Bar b = new Bar ();
      System.out.println(b.getNum());
      System.out.println(b.getSecondNum());
   }
}
```

Another Scoping Example

```
class ScopingExample
{
   public static void main (String [] args)
   {
      P p1 = new P ();
      C c1 = new C ();
      GC gc = new GC ();
      gc.method1();
      gc.method2();
      gc.method3();
      gc.method();
   }
}
```

Another Scoping Example (2)

```
public class GC extends C
{
   private int num1;
   public GC ()
   {
      num1 = 1;
   }
   public void method1 ()
   {
      System.out.println("GC's method 1");
      super.method1();
   }
   public void method2 ()
   {
      System.out.println("GC's method 2");
      super.method2();
   }
```

Another Scoping Example (3)

```
    public void method3 ()
   {
      int num0 = 0;
      System.out.println("num0=" + num0);
      System.out.println("num1=" + num1);
      System.out.println("num2=" + num2);
      System.out.println("num3=" + num3);
      System.out.println("ch=" + ch);
   }

   public void method ()
   {
      super.method1();
   }
}  // End of class GC
```

Another Scoping Example (4)

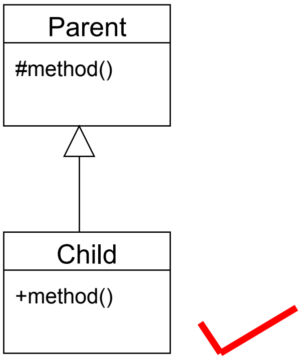
```
public class C extends P
{
   protected int num2;
   protected char ch1;
   public C ()
   {
      ch = 'C';
      num2 = 2;
   }
   public void method1 ()
   {
      System.out.println("C's method 1");
   }
   public void method2 ()
   {
      System.out.println("C's method 2");
      super.method2();
   }
}  // End of class C
```

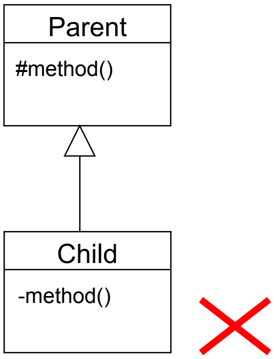
Another Scoping Example (5)

```
public class P
{
   protected int num3;
   protected char ch;
   public P ()
   {
      ch = 'P';
      num3 = 3;
   }
   public void method1 ()
   {
      System.out.println("P's method 1");
   }
   public void method2 ()
   {
      System.out.println("P's method 2");
   }
}  // End of class P
```

Changing Permissions Of Overridden Methods

- The overridden method must have equal or stronger (*less restrictive*) access permissions in the child class.





The Final Modifier (Inheritance)

Methods preceded by the final modifier cannot be overridden

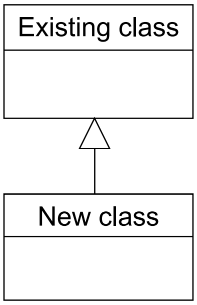
e.g., public ***final*** void displayTwo ()

Classes preceded by the final modifier cannot be extended

- e.g., ***final*** public class ParentFoo

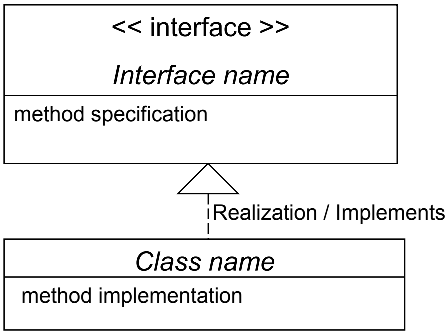
Why Employ Inheritance

- To allow for code reuse
- It may result in more robust code



Java Interfaces (Type)

- Similar to a class
- Provides a design guide rather than implementation details
- Specifies what methods should be implemented but not how
- Cannot be instantiated



Java Interfaces (Type): Lollipop Notation

- Similar to a class
- Provides a design guide rather than implementation details
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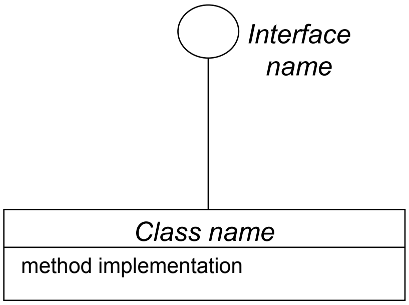
- Cannot be instantiated



Interfaces: Format

Format for defining an interface

public interface <*name of interface*>

{

constants

methods ***to be*** *implemented by the class that realizes this interface*

}

Format for realizing / implementing the interface

public class <*name of class*> implements <*name of interface*>

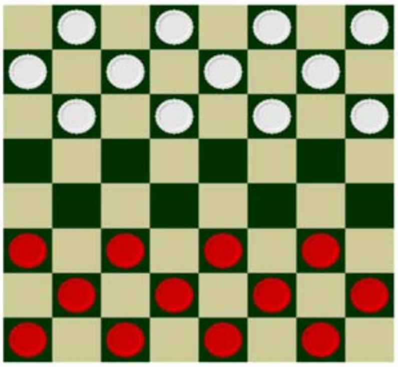
{

attributes

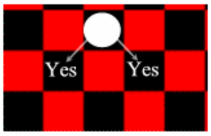
methods ***actually*** *implemented by this class*

}

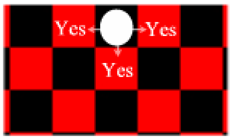
Interfaces: A Checkers Example



Basic board



Regular rules



Variant rules

Interface Board

```
public interface Board
{
    public static final int SIZE = 8;
    public void displayBoard ();
    public void initializeBoard ();
    public void movePiece ();
    boolean moveValid (int xSource, int ySource, int xDestination,
                                  int yDestination);
        :                                   :                                          :
}
```

Class RegularBoard

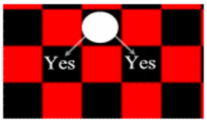
```
public class RegularBoard implements Board
{
   public void displayBoard ()
   {
      :
   }

   public void initializeBoard ()
   {
      :
   }
```

Class RegularBoard (2)

```
   public void movePiece ()
   {
      // Get (x, y) coordinates for the source and destination
      if (moveValid (xS, yS, xD, yD) == true)
            // Actually move the piece
      else
            // Don't move piece and display error message
   }

   public boolean moveValid (int xSource, int ySource, int xDestination,
                                           int yDestination)
   {
      if (moving forward diagonally)
            return true;
      else
            return false;
   }
} // End of class RegularBoard
```



Class VariantBoard

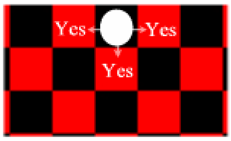
```
public class VariantBoard implements Board
{
   public void displayBoard ()
   {
      :
   }

   public void initializeBoard ()
   {
      :
   }
```

Class VariantBoard (2)

```
   public void movePiece ()
   {
      // Get (x, y) coordinates for the source and destination
      if (moveValid (xS, yS, xD, yD) == true)
            // Actually move the piece
      else
            // Don't move piece and display error message
   }

   public boolean moveValid (int xSource, int ySource, int xDestination,
                                               int yDestination)
   {
      if (moving straight-forward or straight side-ways)
            return true;
      else
            return false;
   }
}  // End of class VariantBoard
```



Interfaces: Recapping The Example

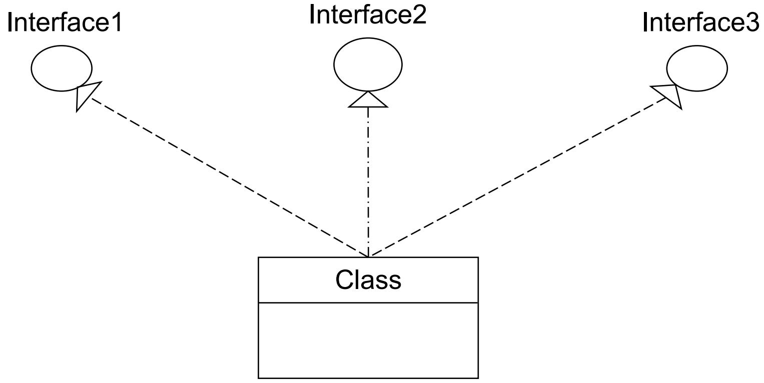
Interface Board

- No state (data) or behavior (body of the method is empty)
- Specifies the behaviors that a board *should* exhibit e.g., clear screen
- This is done by listing the methods that must be implemented by classes that implement the interface.

Class RegularBoard and VariantBoard

- Can have state and methods
- They must implement all the methods specified by interface Board (but can also implement other methods too)

Implementing Multiple Interfaces



Implementing Multiple Interfaces

Format:

public class <*class name*> implements <*interface name 1*>,
    <*interface name 2*>, <*interface name 3*>…
{

}

Multiple Implementations Vs. Multiple Inheritance

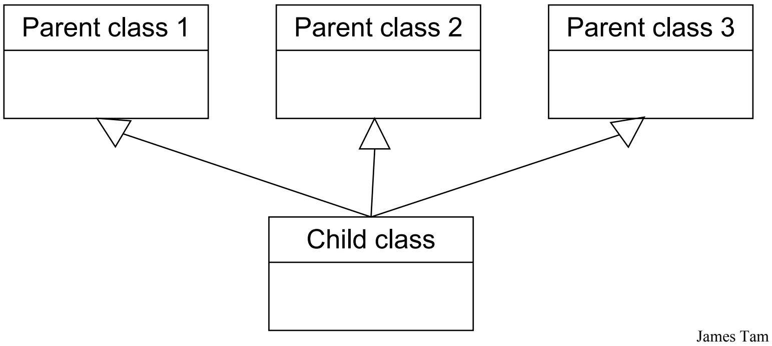
- A class can implement all the methods multiple interfaces
- Classes in Java cannot extend more than one class
- This is not possible in Java but is possible in other languages such as C++:

```
class <class name 1> extends <class
name 2>, <class name 3>…
{


}
```

Multiple Implementations Vs. Multiple Inheritance (2)

- A class can implement all the methods of multiple interfaces
- Classes in Java cannot extend more than one class
- This is not possible in Java but is possible in other languages such as C++:



Abstract Classes

- Classes that cannot be instantiated
- A hybrid between regular classes and interfaces
- Some methods may be implemented while others are only specified
- Used when the parent class cannot define a complete default implementation (implementation must be specified by the child class).

Format:

```
public abstract class <class name>
{
        <public/private/protected> abstract method ();
}
```

Abstract Classes (2)

Example[1]:

```
public abstract class BankAccount
{
   protected float balance;
   public void displayBalance ()
   {
      System.out.println("Balance $" + balance);
   }
   public abstract void deductFees () ;
}
```

[1] From “Big Java” by C. Horstmann pp. 449 – 500.

You Should Now Know

- How the inheritance relationship works
  - When to employ inheritance and when to employ other types of relations
  - What are the benefits of employing inheritance
  - How to create and use an inheritance relation in Java
  - How casting works within an inheritance hierarchy
  - What is the effect of the keyword "final" on inheritance relationships
  - Issues related to methods and attributes when employing inheritance
- What is method overloading?
  - How does it differ from method overriding
  - What is polymorphism

You Should Now Know (2)

- What are interfaces/types
  - How do types differ from classes
  - How to implement and use interfaces in Java
- What are abstract classes in Java and how do they differ from non-abstract classes and interfaces.
- How to read/write UML notations for inheritance and interfaces.