Java - Inheritance/Polymorphism/Interface

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Reusing Classes in Java

- Composition
  - ✦A new class is composed of object instances of existing classes
  - ✦Fields/members of one class contain objects from another.
  - ✦Name class can be made up of three Strings (first, middle, last), Student class can contain a Name object and other Strings.
- Inheritance
  - ✦Creates a new class as a type of an existing class
  - ✦Adds code to it without modifying the existing class
  - ✦All classes inherit from java standard class java.lang.Object

Simple Example of Composition

```
class WaterSource {
  private String s;
  WaterSource() {
    System.out.println("WaterSource()");
    s = new String("Constructed");
  }
}

public class SprinklerSystem {
  private String valve1, valve2, valve3, valve4;
  private WaterSource source;
  SprinklerSystem() {
     System.out.println("SprinklerSystem");
     valve1 = "v1";
     source = new WaterSource();
  }
}
```


Inheritance

- A way to reuse code from existing objects by extending an existing class with new attributes and methods
- Classes can inherit attributes and behavior from pre-existing classes called base classes, superclasses, parent classes or ancestor classes. The resulting classes are known as derived classes, subclasses or child classes.
- The relationships of classes through inheritance gives rise to a hierarchy.
- In Java, each class has exactly one superclass. If none are specified, then java.lang.Object is the superclass.

Simple Example of Inheritance

```
class Cleanser {
  private String s = new String("Cleanser");
  public void append(String a) { s += a; }
  public void dilute() { append(" dilute()"); }
  public void apply() { append(" apply()"); }
  public void scrub() { append(" scrub()"); }
  public String toString() { return s; }

  public static void main(String[] args) {
    Cleanser x = new Cleanser();
    x.dilute(); x.apply(); x.scrub();
    System.out.println(x);
  }
}
```

toString is a method of java.lang.Object

Implicit conversion of x to string
This calls x.toString()

Output:

```
Cleanser dilute() apply() scrub()
```


Simple Example of Inheritance

```
public class Detergent extends Cleanser {
  // Change (override) a method:
  public void scrub() {
    append(" Detergent.scrub()");
    super.scrub(); // Call base-class version
  }
  // Add methods to the interface:
  public void foam() { append(" foam()"); }
  // Test the new class:
  public static void main(String[] args) {
    Detergent x = new Detergent();
    x.dilute();  x.apply();  x.scrub();  x.foam();
    System.out.println(x);
    Cleanser.main(args);
  }
}
```

extends is used to specify the base-class

Output:

```
Cleanser dilute() apply() Detergent.scrub() scrub() foam()
Cleanser dilute() apply() scrub()
```


General convention

- Fields/attributes are private
  - ✦Not even subclasses should access these directly
- Methods are public
  - ✦This is so other classes, including subclasses can access them.
- Overriding a method:
  - ✦Writing a new instance method in the subclass that has the same signature as the one in the superclass.
  - ✦Any instance of the subclass will use the method from the subclass
  - ✦Any instance of the superclass will use the method from the superclass

Some things you can do in a subclass

- The inherited fields can be used directly, just like any other fields (unless they are private).
- You can declare a field in the subclass with the same name as the one in the superclass, thus hiding it (not recommended).
- You can declare new fields in the subclass that are not in the superclass.
- The inherited methods can be used directly as they are.
- You can write a new instance method in the subclass that has the same signature as the one in the superclass, thus overriding it.
- You can write a new static method in the subclass that has the same signature as the one in the superclass, thus hiding it.
- You can declare new methods in the subclass that are not in the superclass.

Initialization

- Java automatically inserts calls to the base-class constructor in the derived-class (subclass) constructor

```
class Art {
  Art() {
    System.out.println("Art constructor");
  }
}
class Drawing extends Art {
  Drawing() {
    System.out.println("Drawing constructor");
  }
}
public class Cartoon extends Drawing {
  public Cartoon() {
    System.out.println("Cartoon constructor");
  }
  public static void main(String[] args) {
    Cartoon x = new Cartoon();
  }
}
```

Output:

```
Art constructor
Drawing constructor
Cartoon constructor
```


Initialization

- If your class doesn't have default constructors, or if you want to call a base-class constructor that has an argument, you must explicitly write the calls to the base-class constructor using the super keyword and the appropriate argument list

```
class Game {
  Game(int i) {
    System.out.println("Game constructor");
  }
}
class BoardGame extends Game {
  BoardGame(int i) {
    super(i);
    System.out.println("BoardGame constructor");
  }
}
public class Chess extends BoardGame {
  Chess() {
    super(11);
    System.out.println("Chess constructor");
  }
}
```


More about inheritance

- "Upcasting"
  - ✦The type of an object is the class that the object is an instance of.
  - ✦Java permits an object of a subclass type to be treated as an object of any superclass type.
  - ✦This is an implicit type conversion called upcasting

  Any method taking a Game as an argument can also take a BoardGame
- When to use composition, when to use inheritance
  - ✦Usually, composition is what you want
  - ✦Use inheritance if you want the interface (public members) of the re-used object to be exposed
  - ✦Use inheritance if you want your new class to be able to be used in methods expecting the re-used class (if you need upcasting).

Packages

- Classes can be grouped into packages

```
package myPackage;

import ....

public class SmallBrain
{ ....
```

  - ✦Declares these classes to belong to a package called "myPackage"
  - ✦package statement must come first in the file.
  - ✦Other classes (outside of myPackage) wanting access to SmallBrain must import myPackage, or fully specify it: `myPackage.SmallBrain`.
  - ✦Anytime you create a package, you implicitly specify a directory structure when you give the package a name: this file should be in a directory named "myPackage"

Packages: example

- To put your classes in a package called xx.myPackage:
  - ✦Declare the package on the first line of each java file

```
package xx.myPackage;

import ....

public class SmallBrain { ....
```

  - ✦Put all the files in package xx.myPackage in the following directory: ...src/xx/myPackage
  - ✦Make src the current directory: `cd ...src`
  - ✦To compile: `javac xx/myPackage/*.java`
  - ✦To run: `java xx.myPackage.ClassA`

Assuming ClassA contains a main method

Access specifiers

- keywords that control access to the definitions they modify
  - ✦**public**: accessible to all other classes
  - ✦**protected**: accessible to classes derived from (subclasses of) the class containing this definition. Note: protected also provides package access.
  - ✦**package** (unspecified, default): accessible only to other classes in the same package
  - ✦**private**: accessible only from within the class in which it is defined

The final keyword

- Java's final keyword has slightly different meanings depending on the context, but in general it says "This cannot be changed."
- Data
  - ✦To create named constants (primitive type):

```
public static final int VAL_THREE = 39;
```

  - ✦Use static so the class does not recreate it for each instance
  - ✦If you create an object that is final, it only means the reference cannot change, but the contents of the object itself could

```
private final Value v2 = new Value(22);
```

  - ✦Cannot assign v2 to something else, but you could change its fields

```
v2.setValue(25);
```


The final keyword

- Methods
  - ✦The final keyword in a method declaration indicates that the method cannot be overridden by subclasses.
  - ✦You might wish to make a method final if it has an implementation that should not be changed and it is critical to the consistent state of the object.

```
final ChessPlayer getFirstPlayer() {
   return ChessPlayer.WHITE;
}
```

The final keyword

- Classes
  - ✦When you say that an entire class is final (by preceding its definition with the final keyword), you state that you don't want to inherit from this class or allow anyone else to do so.

```
class SmallBrain {}

final class Dinosaur {
  int i = 7;
  int j = 1;
  SmallBrain x = new SmallBrain();
  void f() {}
}
```


Polymorphism

- Upcasting:
  - ✦Permitting an object of a subclass type to be treated as an object of any superclass type.
- The ability of objects belonging to different types to respond to method calls of the same name, each one according to an appropriate type-specific behavior.
  - ✦Each subclass of Game defines `bool gameover();` in its own way.
- It allows many types (derived from the same base type) to be treated as if they were one type, and a single piece of code to work on all those different types equally.
  - ✦One piece of code can display a certain dialog when the game is over, regardless of which type of game it is.

Upcasting example

- Wind is an Instrument

```
class Instrument {
  void play(String n) {
    System.out.println("Instrument.play() " + n);
  }
}
class Wind extends Instrument {
  void play(String n) {
    System.out.println("Wind.play() " + n);
  }
}
public class Music {
  public static void tune(Instrument i) {
    i.play("Middle C");
  }
  public static void main(String[] args) {
    Wind flute = new Wind();
    tune(flute); //upcasting
  }
}
```

flute:Wind is upcast to Instrument for tune

Output:

```
Wind.play() Middle C
```


What if we didn't have upcasting?

- Wind, Stringed and Percussion are Instruments

```
class Instrument {
  void play(String n) {
    System.out.println("Instrument.play() " + n);
  }
}
class Wind extends Instrument {
  void play(String n) {
    System.out.println("Wind.play() " + n);
  }
}
class Stringed extends Instrument {
  void play(String n) {
    System.out.println("Stringed.play() " + n);
  }
}
class Percussion extends Instrument {
  void play(String n) {
    System.out.println("Percussion.play() " + n);
  }
}
```

What if we didn't have upcasting? cont.

- We have to overload tune to work for each subclass of Instrument
- If we add a new instrument, we have to add a new tune function

```
public class Music {
  public static void tune(Wind i) {
    i.play("Middle C");
  }
  public static void tune(Stringed i) {
    i.play("Middle C");
  }
  public static void tune(Percussion i) {
    i.play("Middle C");
  }
  public static void main(String[] args) {
    Wind flute = new Wind();
    Stringed violin = new Stringed();
    Percussion snaredrum = new Percussion();
    tune(flute); // No upcasting
    tune(violin);
    tune(snaredrum);  }
}
```

Output:

```
Wind.play() Middle C
Stringed.play() Middle C
Percussion.play() Middle C
```


But we do have upcasting:

- We can get the same effect with just one tune method

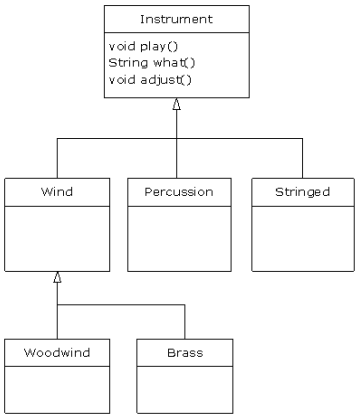
```
public class Music {
  public static void tune(Instrument i) {
    i.play("Middle C");
  }
  public static void main(String[] args) {
    Wind flute = new Wind();
    Stringed violin = new Stringed();
    Percussion snaredrum = new Percussion();
    tune(flute); // upcasting
    tune(violin);
    tune(snaredrum);  }
}
```

Output:

```
Wind.play() Middle C
Stringed.play() Middle C
Percussion.play() Middle C
```


Extensibility

- Lets go back to the polymorphic tune method, AND
- add some more methods and instruments



Extensibility part 1

```
class Instrument {
  void play(String n) {
    System.out.println("Instrument.play() " + n);
  }
  String what() { return "Instrument"; }
  void adjust() {}
}
class Wind extends Instrument {
  void play(String n) {
    System.out.println("Wind.play() " + n);
  }
  String what() { return "Wind"; }
  void adjust() {}
}
class Percussion extends Instrument {
  void play(String n) {
    System.out.println("Percussion.play() " + n);
  }
  String what() { return "Percussion"; }
  void adjust() {}
}
```

Extensibility part 2

```
class Stringed extends Instrument {
  void play(String n) {
    System.out.println("Stringed.play() " + n);
  }
  String what() { return "Stringed"; }
  void adjust() {}
}
class Brass extends Wind {
  void play(String n) {
    System.out.println("Brass.play() " + n);
  }
  String what() { return “Brass”; }
}
class Woodwind extends Wind {
  void play(String n) {
    System.out.println("Woodwind.play() " + n);
  }
  String what() { return "Woodwind"; }
}
```


Extensibility part 3

```
public class Music3 {
  // Doesn't care about type, so new types
  // added to the system still work right:
  public static void tune(Instrument i) {
    i.play("Middle C");
  }
  public static void tuneAll(Instrument[] e) {
    for(int i = 0; i < e.length; i++)
      tune(e[i]);
  }
  public static void main(String[] args) {
    // Upcasting during addition to the array:
    Instrument[] orchestra = {
      new Wind(),
      new Percussion(),
      new Stringed(),
      new Brass(),
      new Woodwind()
    };
    tuneAll(orchestra);
  }
}
```

Output:

```
Wind.play() Middle C
Percussion.play() Middle C
Stringed.play() Middle C
Brass.play() Middle C
Woodwind.play() Middle C
```


Abstract methods and classes

- Purpose of the Instrument class is to create a common interface (public members) for its subclasses
  - ✦No intention of making direct instances of Instrument
- An abstract class is a class that cannot be instantiated, but it can be subclassed
- It may or may not include abstract methods.
- An abstract method is a method that is declared without a method body (without braces, and followed by a semicolon), like this:

```
abstract void f(int x);
```

- If a class contains an abstract method, it must be declared to be an abstract class.

Abstract methods and classes, example

- Any class that inherits from an abstract class must provide method definitions for all the abstract methods in the base class.
  - ✦Unless the derived class is also declared to be abstract
- The Instrument class can be made abstract:
  - ✦No longer need “dummy” definitions for abstract methods
  - ✦Programmer and compiler understand how the class is to be used.

```
abstract class Instrument {
  private int i; // Storage allocated in each subclass
  abstract void play(String n); //subclass must define
  String what() {
    return "Instrument";
  }
  abstract void adjust();      //subclass must define
}
```

Interfaces

- In the Java programming language, an interface is a form or template for a class: it can contain only abstract methods (no method bodies).
- Interfaces cannot be instantiated—they can only be implemented by classes or extended by other interfaces.
- An interface is a “pure” abstract class: no instance-specific items.
- An interface can also contain fields, but these are implicitly static and final

Interfaces

- To create an interface, use the interface keyword instead of the class keyword.
  - ✦ The methods (and fields) are automatically public
- To use an interface, you write a class that implements the interface.
  - ✦A (concrete) class implements the interface by providing a method body for each of the methods declared in the interface.
- An interface can be used as a type (for variables, parameters, etc)
  - ✦Java permits an object instance of a class that implements an interface to be upcast to the interface type

Interfaces, example

```
interface Instrument {
    void play(String n); // Automatically public
    String what();
    void adjust();
}
class Wind implements Instrument {
  public void play(String n) {
    System.out.println("Wind.play() " + n);  }
  public String what() { return "Wind"; }
  public void adjust() {}
}
class Percussion implements Instrument {
  public void play(String n) {
    System.out.println("Percussion.play() " + n);  }
  public String what() { return "Percussion"; }
  public void adjust() {}
}
class Stringed implements Instrument {
  public void play(String n) {
    System.out.println("Stringed.play() " + n);  }
  public String what() { return "Stringed"; }
  public void adjust() {}
}
```

Had to change access of methods to public

Classes MUST define ALL the methods


```
class Brass extends Wind {
  public void play(String n) {
    System.out.println("Brass.play() " + n);
  }
  public String what() { return "Brass"; }
}

class Woodwind extends Wind {
  public void play(String n) {
    System.out.println("Woodwind.play() " + n);
  }
  public String what() { return "Woodwind"; }
}

public class Music5 {
  public static void tune(Instrument i) {  //unchanged
    i.play("Middle C");
  }
  public static void tuneAll(Instrument[] e) {
    for(int i = 0; i < e.length; i++)
      tune(e[i]);
  }
  public static void main(String[] args) {
    Instrument[] orchestra = {
      new Wind(),
      new Percussion(),
      new Stringed(),
      new Brass(),
      new Woodwind()
    };
    tuneAll(orchestra);
  }
}
```

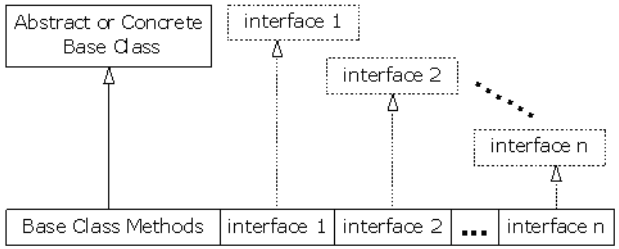
The rest of the code is the same as before

Output:

```
Wind.play() Middle C
Percussion.play() Middle C
Stringed.play() Middle C
Brass.play() Middle C
Woodwind.play() Middle C
```

Multiple Inheritance

- A Class may have only one immediate superclass
  - ✦ But it may have many ancestors
- A Class my implement any number of interfaces.
  - ✦ This allows you to say an x is an A and a B and a C



Multiple Inheritance, example

```
interface CanFight {
  void fight();
}
interface CanSwim {
  void swim();
}
interface CanFly {
  void fly();
}
class ActionCharacter {
    public void fight( ) {System.out.println("fight");}
}
class Hero extends ActionCharacter implements CanFight, CanSwim, CanFly {
  public void swim() {System.out.println("swim");}
  public void fly()  {System.out.println("fly");}
}
public class Adventure {
  public static void t(CanFight x) { x.fight(); }
  public static void u(CanSwim x) { x.swim(); }
  public static void v(CanFly x) { x.fly(); }
  public static void w(ActionCharacter x) { x.fight(); }
  public static void main(String[] args) {
    Hero h = new Hero();
    t(h); // Treat it as a CanFight
    u(h); // Treat it as a CanSwim
    v(h); // Treat it as a CanFly
    w(h); // Treat it as an ActionCharacter
  }
}
```


Interface or Abstract class?

- Interface
  - ✦Pro: can be implemented by any number of classes
  - ✦Con: each class must have its own code for the methods, common method implementations must be duplicated in each class
- Abstract Class
  - ✦Pro: subclasses do not have to repeat common method implementations, common code is in the abstract superclass
  - ✦Con: Cannot be multiply inherited.

Implementing the Comparable Interface

- Assume you want to sort an array (or ArrayList) of custom objects (instances of some class you created).
- The following static methods are available in the Java API:

```
void Collections.sort(List<T> list)    // for ArrayLists
void Arrays.sort(Object [] a)          // for static arrays
```

- All elements in the list/array must implement the java.lang.Comparable interface:

```
int compareTo(T o);     //T is your custom class
```

Compares this object with the specified object for order.
Returns a negative integer, zero, or a positive integer as this object is less than, equal to, or greater than the specified object.

Sorting with Comparable, example

```
import java.util.*;

public class Student implements Comparable {
    String name;
    String major;
    int idNumber;
    float gpa;
    public Student(String name, String major,
                   int idNumber, float gpa) {
        this.name = name;  this.major = major;
        this.idNumber = idNumber; this.gpa = gpa;
    }
    public String toString() {
        return "Student: " + name + " " +major + " "
                           + idNumber + " " + gpa;
    }
    public int compareTo(Object rhs) {
        String rhsName = ((Student)rhs).name;
        return name.compareTo(rhsName);
    }
```


Sorting with Comparable, example (p2)

```
  public static void main(String[] args) {
      Student[] a = new Student[3];
      a[0] = new Student("Doe, J","Math",1234,3.6F);
      a[1] = new Student("Carr, M","CS",1000,2.7F);
      a[2] = new Student("Ames, D","Business",2233,3.7F);
      System.out.println("Before: ");
      for (int i=0; i<a.length; i++)
          System.out.println(a[i]);
    Arrays.sort(a);
      System.out.println("After: ");
      for (int i=0; i<a.length; i++)
          System.out.println(a[i]);
  }
}
```

Output:

```
Before:
Student: Doe, J Math 1234 3.6
Student: Carr, M CS 1000 2.7
Student: Ames, D Business 2233 3.7
After:
Student: Ames, D Business 2233 3.7
Student: Carr, M CS 1000 2.7
Student: Doe, J Math 1234 3.6
```


Sorting with Comparable, sort by gpa

- To sort by gpa, redefine compareTo as follows:

```
    public int compareTo(Object rhs) {
        float rhsGpa = ((Student)rhs).gpa;
        return (gpa < rhsGpa ? -1 : (gpa == rhsGpa ? 0 : 1));
    }
```

Output:

```
Before:
Student: Doe, J Math 1234 3.6
Student: Carr, M CS 1000 2.7
Student: Ames, D Business 2233 3.7
After:
Student: Carr, M CS 1000 2.7
Student: Doe, J Math 1234 3.6
Student: Ames, D Business 2233 3.7
```


Extending an Interface

```
public interface DoIt {
   void doSomething(int i, double x);
   int doSomethingElse(String s);
}
```

- Suppose that later you want to add a third method to DoIt:

```
public interface DoIt {
   void doSomething(int i, double x);
   int doSomethingElse(String s);
   boolean didItWork(int i, double x, String s);
}
```

- If you make this change, all classes that implement the old DoIt interface will break because they don't implement the interface

Extending an Interface

- Solution: you could create a DoItPlus interface that extends DoIt.

```
public interface DoItPlus extends DoIt {
   boolean didItWork(int i, double x, String s);
}
```

- Now users of your code can choose to continue to use the old interface or to upgrade to the new interface.