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 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 an extension to an existing class.
  - ✦New class adds code to the existing class the without modifying it, resulting in two classes (the original class and the extension).
  - ✦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 classes by extending an existing class with new fields and methods
- Classes can inherit attributes and behavior from pre-existing classes called base classes, superclasses, or parent 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.
- Note: In Java, constructors are NOT inherited.

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

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 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
  - ✦The subclass can call the superclass method using “super.method()”

Some things you can do in a subclass

- The inherited fields (from the superclass) 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 (from the superclass) can be used directly (unless they are private).
- 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 declare new methods in the subclass that are not in the superclass.

Initialization

- Java automatically inserts calls to the (default) superclass constructor at the beginning of the 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
```

So constructors are not inherited, they are called from the constructors of the subclass.

Initialization

- If your class doesn't have default (no arg) constructors, or if you want to call a superclass constructor that has an argument, you must explicitly write the calls to the superclass 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 (superclass) object to be exposed in the new class
  - ✦Use inheritance if you want your new class objects to be able to be passed to methods expecting the re-used class (if you need upcasting).

Access specifiers (reminder)

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

Polymorphism

- Upcasting:
  - ✦Permitting an object of a subclass type to be treated as an object of any superclass type.

```
Cleanser x = new Detergent();
```

- Polymorphism:
  - ✦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.
  - ✦It allows many types (derived from the same superclass) to be treated as if they were one type, and a single piece of code to work on all those different types equally, yet getting type-specific behavior for each one.

Example:

- 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);
  }
}
```


Example continued

```
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();
    tune(flute);  //upcasting to Instrument
    tune(violin); //upcasting to Instrument
  }
}
```

What is output?

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

or

```
Instrument.play() Middle C
Instrument.play() Middle C
```

Polymorphism:
in tune, i is an Instrument, but it calls the play method based on the specific type of the object it receives.

What if we didn't have polymorphism?

- 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();
    tune(flute); // No upcasting necessary
    tune(violin);
  }
}
```

Output:

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

But we do have upcasting and polymorphism:

- 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: polymorphism

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

- What would the output be if we did not have polymorphism?
- Note: C++ requires “virtual” keyword (on play()) to get polymorphism.

Dynamic (run-time) binding

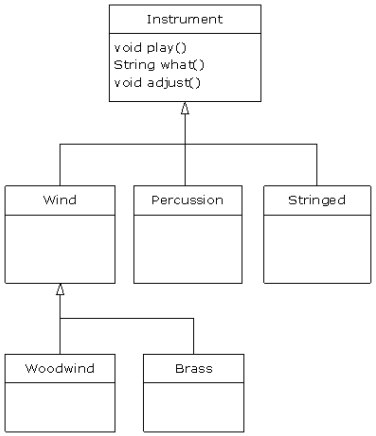
- Given the definition of tune, how does the **compiler** know which definition of the play method to call? Instrument? Wind? Stringed?

```
public static void tune(Instrument i) {
    i.play("Middle C");
  }
```

  - ✦It will differ depending on the specific type of each argument passed to i.
  - ✦This cannot be determined at compile time.
- Binding: connecting the method call to a method definition.
  - ✦Static binding: done at compile time (play binds to Instrument.play)
  - ✦Dynamic binding: at run-time, the JVM determines the actual type of i and uses its play() definition. It can vary for each invocation of tune.
  - ✦If the actual type of i does not define “play()”, the JVM looks for the nearest definition in its superclass hierarchy.

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 {
 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
```

- We extended our system by adding methods and new subclasses,
- But we did NOT need to change (or add to) the tune function.

Abstract methods and classes

- Purpose of the Instrument class is to create a common interface (public methods) 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";        //when would this be called?
  }
  abstract void adjust();       //subclass must define
}
```

Interfaces

- In the Java programming language, an interface is a form or template for a class: all of its methods must be abstract (no method bodies).
- Interfaces cannot be instantiated—they can only be implemented by classes or extended by other interfaces.
- Interfaces cannot have constructors (there are no fields to initialize).
- An interface is a "pure" abstract class: no instance-specific items.
- An interface may contain fields, but these are implicitly static and final (named constants)

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();       // and abstract
    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 (they were package)

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);
  }
}
```

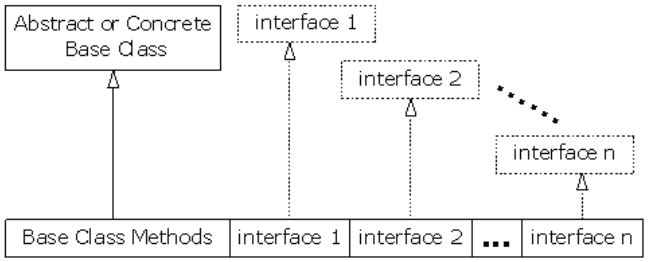
The rest of the code is the same as before

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 in the hierarchy
- 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
  }
}
```


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 (DoIt) or to “upgrade” to the new interface (DoItPlus).

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 Java 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<T> interface:

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

Compares this object with the specified object (o) for order.
Returns a negative integer, zero, or a positive integer when this object is less than, equal to, or greater than (respectively) the specified object.

Sorting with Comparable, example

```
import java.util.*;

public class Student implements Comparable<Student> {
    private String name;
    private String major;
    private int idNumber;
    private 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(Student rhs) {
       return name.compareTo(rhs.name);
    }
```

This will sort by name

compareTo is already defined in String, so we can reuse it.

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(Student rhs) {
    float rhsGpa = rhs.gpa;
    if (gpa < rhsGpa) return -1;
    if (gpa == rhsGpa) return 0;
    return 1;
}   // or return Math.round(gpa - rhsGpa);
    // or return (new Float(gpa)).compareTo(rhsGpa);
```

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
```

Note: compareTo is already defined in the primitive-type wrapper classes