

CHAPTER 5

Inheritance



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Inheritance: Key Definitions

- ◆ A class that is derived from another class is called a *subclass* (also a *derived class*, *extended class*, or *child class*).
- ◆ The class from which the subclass is derived is called a *superclass* (also a *base class* or a *parent class*).
- ◆ Every class has one and only one direct superclass (single inheritance).
- ◆ Only *java.lang.Object* has no superclass.
- ◆ Every class is implicitly a subclass of *Object*.

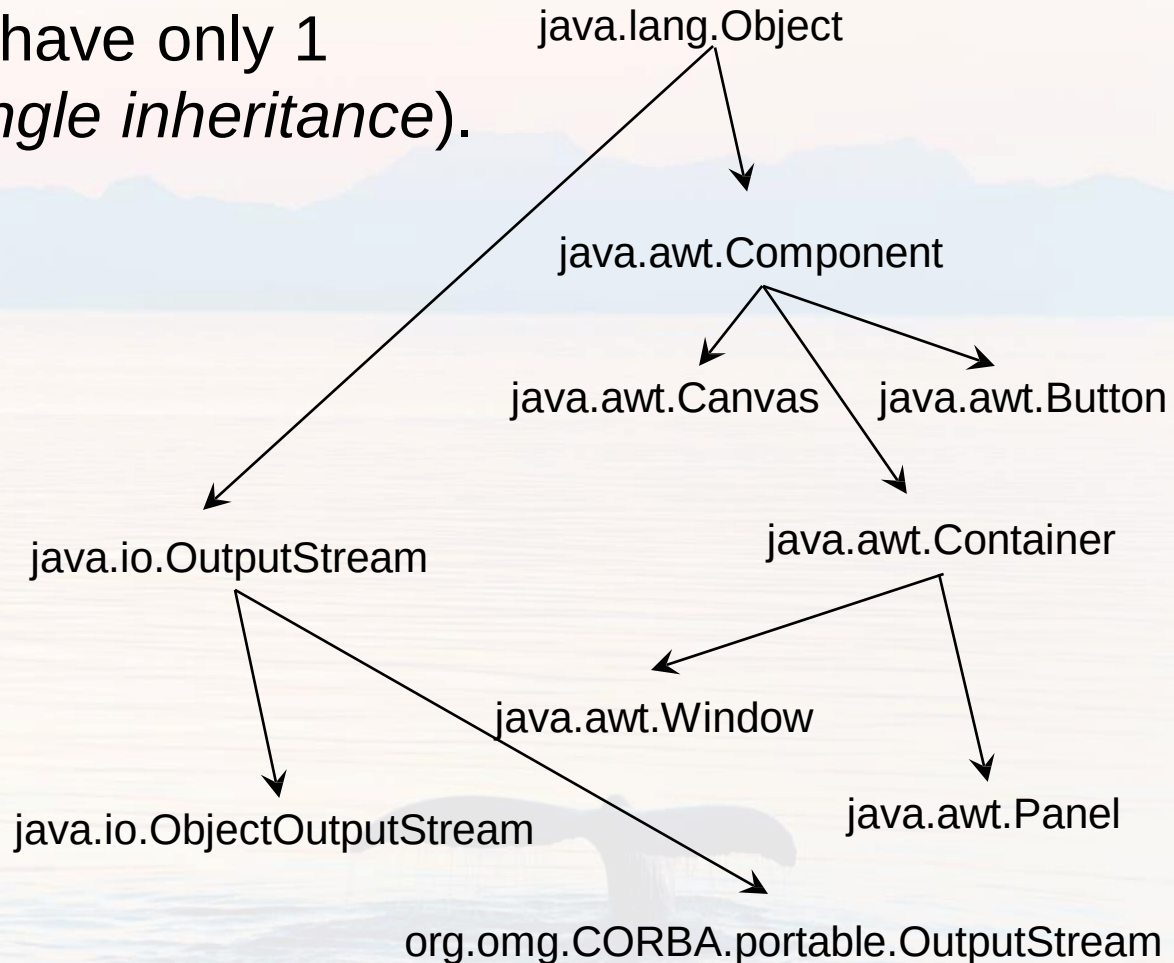
The Purpose of Inheritance

- ◆ The idea of inheritance is simple but powerful:
 - When you want to create a new class and there is already a class that includes some of the code that you want, you can derive your new class from the existing class.
 - In doing this, you can reuse the fields and methods of the existing class without having to write (and debug!) them yourself.

Single Inheritance

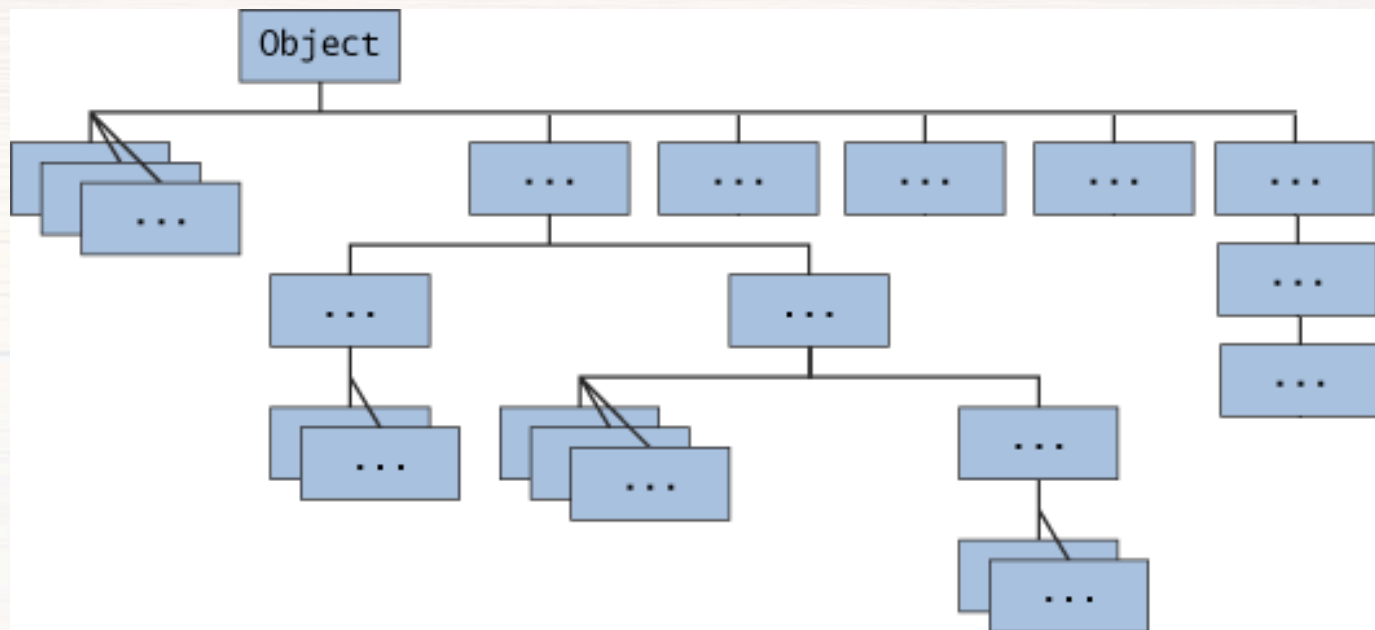
- ◆ In Java, a class can have only 1 direct superclass (*single inheritance*).

- ◆ A class that is the superclass to another class, may also have a superclass.
- ◆ A hierarchy of classes can be formed, and they all *descend* from all the superclasses.



The Java Platform Class Hierarchy

- ◆ The Object class, defined in the java.lang package, defines and implements behavior common to all classes—including the ones that you write.
- ◆ In the Java platform, many classes derive directly from Object, other classes derive from some of those classes, and so on, forming a hierarchy of classes.

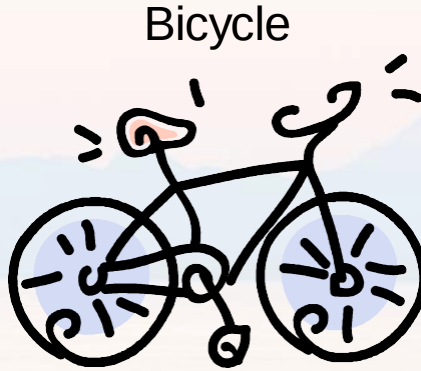


Inheritance: A Closer Look

- ◆ A subclass inherits all the *public* and *protected members* (fields, methods) from its superclass.
 - When a subclass inherits a member, it is as if the subclass defined the member itself.
- ◆ Constructors are not members, so they are not inherited by subclasses.
- ◆ The constructor of the superclass can be invoked from the subclass by using the keyword *super*.

A Hierarchy of Bicycle Classes

Bicycle (superclass):
more general features



RoadBike



MountainBike



TandemBike

RoadBike, MountainBike, TandemBike (subclasses): more specific features

Comments on the Previous Slide

- ◆ In chapter 2, you considered an example of the bicycle class.
- ◆ Different kinds of objects often have a certain amount in common with each other.
 - Bicycle is superclass (more general features).
 - Mountain bikes, road bikes, and tandem bikes share the characteristics of bicycles:
 - current speed,
 - current pedal cadence,
 - current gear.
 - MountainBike, RoadBike, and TandemBike are subclasses of Bicycle (more specific features).

An Example of Inheritance

```
public class Bicycle {           // the Bicycle class has three fields
    protected int cadence;
    protected int gear;
    protected int speed;        // the Bicycle class has one constructor
    public Bicycle(int startCadence, int startSpeed, int startGear) {
        gear = startGear;
        cadence = startCadence;
        speed = startSpeed;
    }                            // the Bicycle class has four methods
    public void setCadence(int newValue) {
        cadence = newValue;
    }
    public void setGear(int newValue) {
        gear = newValue;
    }
    public void applyBrake(int decrement) {
        speed -= decrement;
    }
    public void speedUp(int increment) {
        speed += increment;
    }
}
```

An Example of Inheritance

- ◆ A class declaration for a MountainBike class that is a subclass of Bicycle might look like this:

```
public class MountainBike extends Bicycle {  
    // the MountainBike subclass adds one field  
    protected int seatHeight;  
    // the MountainBike subclass has one constructor  
    public MountainBike(int startHeight, int startCadence, int  
        startSpeed, int startGear){  
        super(startCadence, startSpeed, startGear);  
        seatHeight = startHeight;  
    }  
    // the MountainBike subclass adds one method  
    public void setHeight(int newValue){  
        seatHeight = newValue;  
    }  
}
```

- ◆ MountainBike inherits all the fields and methods of Bicycle and adds the field *seatHeight* and a method to set it. A new MountainBike class has four fields and five methods.

What You Can Do in a Subclass

- ◆ You can use the inherited members as is, replace them, hide them, or supplement them with new members:
 - The inherited fields can be used directly, just like any other fields.
 - 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.
 - You can write a subclass constructor that invokes the constructor of the superclass, either implicitly or by using the keyword `super`.

Private Members in a Superclass

- ◆ A subclass has no access to a private field or method of its superclass.
- ◆ If the superclass has public or protected methods for accessing its private fields, these can also be used by the subclass.

```
class AA {  
    private int aak;  
    protected float aaf;  
    public setAAK(int aak) {  
        this.aak = aak;  
    }  
}  
  
class BB extends AA {  
    private int bbk;  
    BB() {  
        aak = 5;           // error  
        setAAK(5);         // correct  
        aaf = 0F;  
        bbk = 4;  
    }  
}
```

```
class AA {  
    public AA(int i) { ... }  
    private AA(float f) { ... }  
  
    private void m1() { ... }  
    public void m2() { ... }  
}  
  
class BB extends AA {  
    BB(){  
        super(5.0F);       // error  
    }  
    BB(int i, float f){  
        super(i);          // correct  
        m1();              // error  
        m2();              // correct  
    }  
}
```


Casting Objects

- ◆ We have seen that an object is of the data type of the class from which it was instantiated:

```
MountainBike myBike = new MountainBike();
```

- ◆ myBike is of type MountainBike in the example.
- ◆ MountainBike is descended from Bicycle and Object. Therefore, a MountainBike is a Bicycle and is also an Object, and it can be used wherever Bicycle or Object objects are called for.
- ◆ The reverse is not necessarily true: a Bicycle *may be* a MountainBike, but it isn't necessarily. Similarly, an Object *may be* a Bicycle or a MountainBike, but it isn't necessarily.

Casting Objects

- ◆ *Casting* shows the use of an object of one type in place of another type, among the objects permitted by inheritance and implementations.

```
Object obj = new MountainBike();
```

- ◆ *obj* is both an *Object* and a *Mountainbike* (until such time as *obj* is assigned another object that is *not a Mountainbike*). This is called *implicit casting*.
- ◆ If, on the other hand, we write:

```
MountainBike myBike = obj; // error
```

- ◆ we would get a compile-time error because *obj* is not known to the compiler to be a *MountainBike*.

Casting Objects

- ◆ We can *tell* the compiler that we promise to assign a `MountainBike` to `obj` by *explicit casting*:

```
MountainBike myBike = (MountainBike)obj;
```

- ◆ This cast inserts a runtime check that *obj* is assigned a *MountainBike* so that the compiler can safely assume that *obj* is a *MountainBike*. If *obj* is not a *Mountainbike* at runtime, an exception will be thrown.

- ◆ To avoid run-time errors, use the *instanceof*:

```
if(obj instanceof MountainBike) {  
    MountainBike myBike = (MountainBike)obj;  
}
```

- This code verifies that *obj* refers to a *MountainBike* so that we can make the cast with knowledge that there will be no runtime exception thrown.

Overriding Instance Methods

- ◆ *Overriding* means that a subclass redefines a method from a superclass when:

- Both methods have the same signature;
- Both methods have the same return type.

- ◆ A *covariant* return type – an overriding method can also return a subtype of the type returned by the overridden method.

- ◆ By using the keyword *super*, the overridden method can be invoked.

```
class AA {  
    Object method(int i) {  
        Object oo;  
        ...  
        return oo;  
    } // end of the method  
} // end of the AA class
```

```
class BB extends AA {  
    String method(int k) {  
        String os;  
        Object oo = super.method(5);  
        ...  
        return os;  
    } // end of the method  
} // end of the BB class
```

```
String os = new BB().method(4);
```

Overriding Class Methods

- ◆ If a subclass defines a class method with the same signature as its superclass, the subclass' method *hides* the superclass' method.
- ◆ The distinction between hiding and overriding is important when invoking:
 - The subclass version of an overridden method gets invoked.
 - The version that gets invoked depends on the namespace from which it is invoked.

Example: Overriding and Hiding Methods

```
public class Animal {
    public static void testClassMethod() {
        System.out.println("The class method in Animal.");
    }
    public void testInstanceMethod() {
        System.out.println("The instance method in Animal.");
    }
} // end of the Animal class

public class Cat extends Animal {
    public static void testClassMethod() {
        System.out.println("The class method in Cat.");
    }
    public void testInstanceMethod() {
        System.out.println("The instance method in Cat.");
    }
    public static void main(String[] args) {
        Cat myCat = new Cat();
        Animal myAnimal = myCat;
        Animal.testClassMethod();
        myAnimal.testInstanceMethod();
    }
} // end of the Cat class
```

◆ Compile and run:

- Save the text to the file: [Cat.java](#)
- Compile the program typing: [javac Cat.java](#)
- Run the program typing: [java Cat](#)
- Output of the program:

[The class method in Animal.](#)

[The instance method in Cat.](#)

Comments on the Previous Slide

- ◆ The Cat class overrides the instance method in Animal and hides the class method in Animal.
- ◆ The main method in this class creates an instance of Cat and calls `testClassMethod()` on the class and `testInstanceMethod()` on the instance.
- ◆ The version of the hidden method that gets invoked is the one in the superclass, and the version of the overridden method that gets invoked is the one in the subclass.

Example: Overriding Methods

```
class AA {  
    void insMethod() { ... }  
}
```

```
class BB extends AA {  
    void insMethod() { ... }  
}
```

```
AA oa = new AA();  
oa.insMethod();           // AA
```

```
BB ob = new BB();  
ob.insMethod();           // BB
```

```
oa = ob;  
oa.insMethod()             // BB
```

```
class AA {  
    static void stcMethod() { ... }  
}
```

```
class BB extends AA {  
    static void stcMethod() { ... }  
}
```

```
AA.stcMethod();  
BB.stcMethod();
```

```
AA oa = new AA();  
oa.stcMethod();           // AA
```

```
oa = new BB();  
oa.stcMethod();           // AA
```

Overriding Methods: Summary

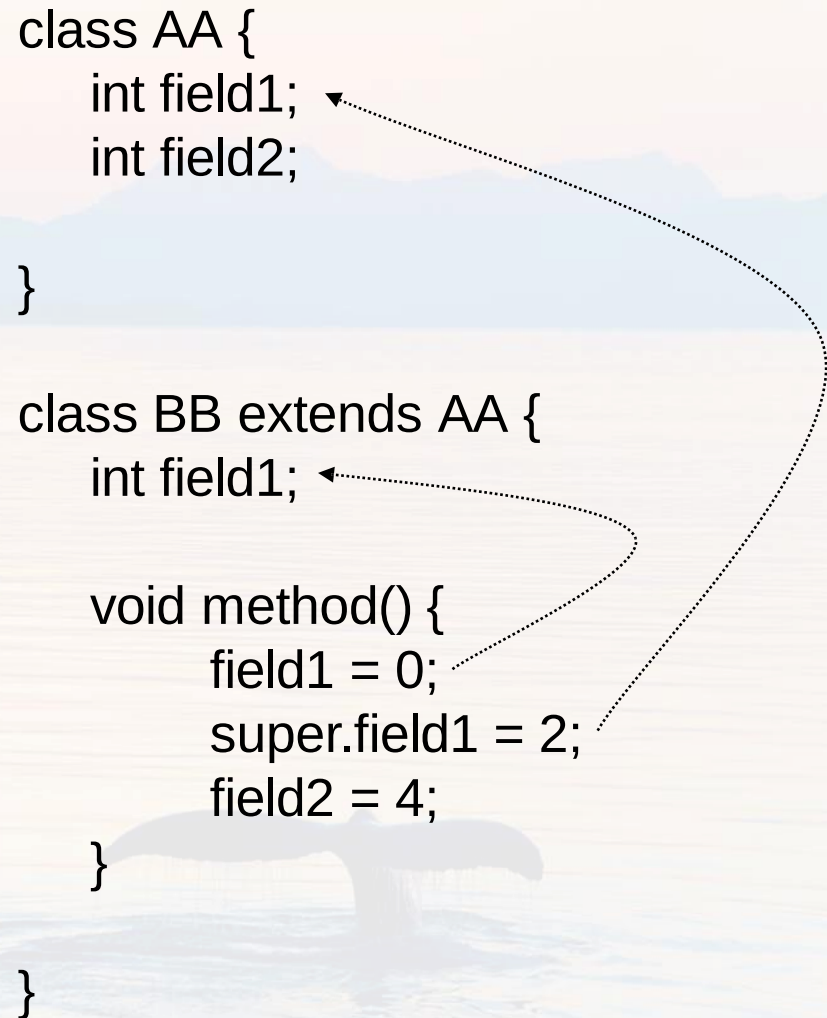
- ◆ A subclass can redefine the methods it inherits from its superclass:
 - Overriding instance methods
 - Hiding class methods
- ◆ Defining a method with the same signature:

	Superclass instance methods	Superclass static methods
Subclass instance methods	Overrides	Generates a compile-time error
Subclass static methods	Generates a compile-time error	Hides

Hiding Fields

- ◆ A subclass field that has the same name as a superclass field *hides* the superclass' field.
- ◆ Use the keyword *super* to access a hidden field of the superclass.
- ◆ Avoid hiding fields: It makes code difficult to read.

```
class AA {  
    int field1;  
    int field2;  
}  
  
class BB extends AA {  
    int field1;  
  
    void method() {  
        field1 = 0;  
        super.field1 = 2;  
        field2 = 4;  
    }  
}
```



Accessing Superclass Members

```
public class Father {  
    public void printMethod() {  
        System.out.println("Printed in Father class.");  
    }  
} // end of the Father class  
public class Son extends Father {  
    //overrides printMethod in Father class  
    public void printMethod() {  
        super.printMethod();  
        System.out.println("Printed in Son class");  
    }  
    public static void main(String[] args) {  
        Son s = new Son();  
        s.printMethod();  
    }  
} // end of the Son class
```

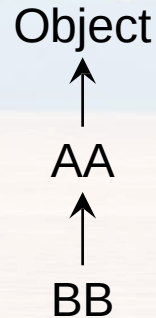
◆ Compile and run:

- Save the text to the file:
`Son.java`
- Compile the program typing:
`javac Son.java`
- Run the program typing:
`java Son`
- Output of the program:
?

If your method overrides one of its superclass's methods, you can invoke the overridden method through the use of the keyword `super`.

Example: *super* and Members

```
public class AA {  
    private int field1;  
    protected int field2;  
}
```



```
public class BB extends AA {  
    private int field1;  
  
    void method() {  
        field1 = 0;  
        super.field1 ≠ 2;    // error  
        field2 = 4;  
    }  
}
```

```
class AA extends Object {  
  
    public String toString() {  
        String s = super.toString();  
  
        return "AA:" + s;  
    }  
}
```

```
class BB extends AA {  
  
    public String toString() {  
        String s = super.toString();  
  
        return "BB:" + s;  
    }  
}
```

super and Constructors

- ◆ MountainBike is a subclass of Bicycle. Here is the MountainBike (subclass) constructor that calls the superclass constructor and then adds initialization code of its own:

```
public MountainBike(int startHeight, int startCadence, int  
    startSpeed, int startGear) {  
    super(startCadence, startSpeed, startGear);  
    seatHeight = startHeight;  
}
```

- ◆ Invocation of a superclass constructor must be the first line in the subclass constructor:

```
super();           // the superclass no-argument constructor is called  
--or --  
super(parameter list); // the superclass constructor with a matching  
                        // parameter list is called.
```

super and Constructors

- ◆ If a constructor does not explicitly invoke a superclass constructor, the Java compiler automatically inserts a call to the no-argument constructor of the superclass.
- ◆ If the super class does not have a no-argument constructor, you will get a compile-time error.
- ◆ Object *does* have such a constructor, so if Object is the only superclass, there is no problem.
- ◆ If a subclass constructor invokes a constructor of its superclass, either explicitly or implicitly, you might think that there will be a whole chain of constructors called, all the way back to the constructor of Object.
 - It is called *constructor chaining*, and you need to be aware of it when there is a long line of class descent.

Constructor Chaining

// File: Cartoon.java

```
class Art {
    Art() {
        System.out.println("Art constructor");
    }
} // end of Art class

class Drawing extends Art {
    Drawing() {
        System.out.println("Drawing constructor");
    }
} // end of the Drawing class

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

◆ Compile and run:

- Save the text to the file: [Cartoon.java](#)
- Compile the program typing:
[javac Cartoon.java](#)
- Run the program typing:
[java Cartoon.](#)
- Output of the program:

[Art constructor](#)

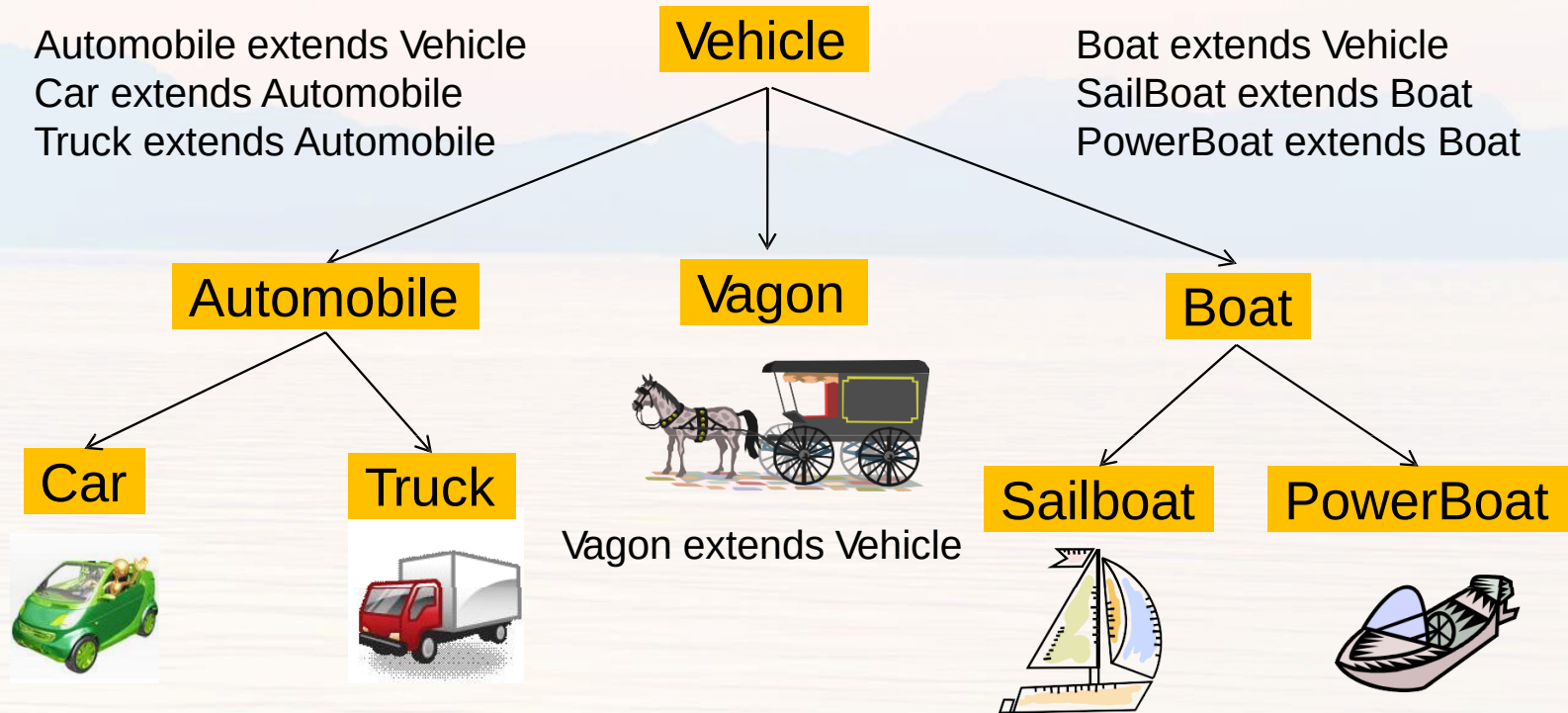
[Drawing constructor](#)

[Cartoon constructor](#)

Summary

- ◆ Object is the root (or top) of any class hierarchy in Java.
- ◆ All other classes are inherited from Object, either directly or indirectly.
- ◆ A class inherits fields and methods from all its superclasses.
- ◆ A subclass may:
 - Override accessible inherited methods
 - Hide accessible fields or methods

Hierarchy of Classes: IS-A Relationship



```
Boat b = new Sailboat();  
Vehicle v = new Boat();  
Vehicle v = new Sailboat();  
Boat b1 = new Vehicle(); //error  
// Vehicle IS NOT ALWAYS a Boat
```



Reusing Classes

- ◆ Inheritance: A new class is created as a *type* of an existing class. You take the form of the existing class and add code to it without modifying the existing class. The compiler does most of the work.
 - IS-A relationship between classes.
- ◆ Composition: A new class is composed of objects of existing classes. You reuse the functionality of the code, not its form.
 - HAS-A relationship between classes.

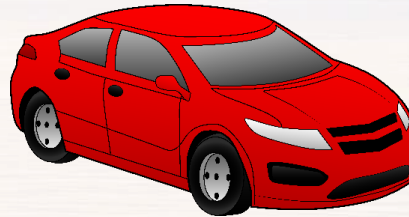
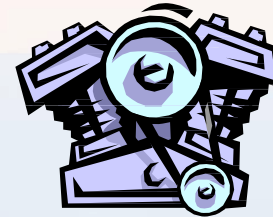
Example: Composition (HAS-A Relationship)

```
class Engine {  
    public void start() {}  
    public void rev() {}  
    public void stop() {}  
} // end of the Engine class  
class Wheel {  
    public void inflate(int psi) {}  
} // end of the Wheel class  
class Window {  
    public void rollup() {}  
    public void rolldown() {}  
} // end of the Window class  
class Door {  
    public Window window = new Window();  
    public void open() {}  
    public void close() {}  
} // end of the Door class
```

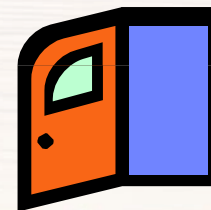
```
public class Car {  
    public Engine engine = new Engine();  
    public Wheel[] wheel = new Wheel[4];  
    public Door  
        left = new Door(),    // first door  
        right = new Door();   // 2-door  
    public Car() { // constructor  
        for(int i = 0; i < 4; i++)  
            wheel[i] = new Wheel();  
    } // end of the constructor  
    public static void main(String[] args) {  
        Car car = new Car();  
        car.left.window.rollup();  
        car.wheel[0].inflate(72);  
    } // end of the main method  
} // end of the Car class
```

Comments on the Previous slide

- ◆ We have classes:
Engine, Wheel,
Window, Door, and
Car.
- ◆ The Door class is
composed of the
object of class
Window.
- ◆ The Car class is
composed of the
objects of classes
Engine, four Wheels,
two Doors.



Car HAS-A Engine
Car HAS-A Wheel
Car HAS-A Door



Door HAS-A Window

The Object Class as a Superclass

- ◆ The Object class, in the java.lang package, is the root of the class hierarchy tree.
- ◆ Every class inherits the instance methods of Object.
- ◆ The methods defined by Object are:
 - clone – creates and returns a copy of itself;
 - equals – checks whether another object is equal to this one;
 - getClass – returns the runtime class of an object;
 - toString – returns a string representation of the object.

The *equals* Method

- ◆ This method compares 2 objects for equality and returns true if they are equal.
- ◆ The implementation by Object tests whether the references are equal, i.e., if it is the same object:

```
public boolean equals(final Object obj) {  
    return obj == this;  
}
```

The *equals* Method: Example 1

```
class Book { private int
    price;
    private String ISBN;
    public Book(int price, String
        ISBN) {
        this.price = price;
        this.ISBN = ISBN;
    }
    public int getPrice() {
        return price;
    }
    public getISBN() {
        return ISBN;
    }
}
```

```
Book firstBook = new Book(1250, "0201914670");
Book secondBook = new Book(1250, "0201914670");
Book thirdBook = secondBook;
if (firstBook.equals(secondBook)) {
    System.out.println("objects 1 and 2 are equal");
} else {
    System.out.println("objects 1 and 2 are not equal");
}
if (thirdBook.equals(secondBook)) {
    System.out.println("objects 2 and 3 are equal");
} else {
    System.out.println("objects 2 and 3 are not equal");
}
```

OUTPUT:

objects 1 and 2 are not equal
objects 2 and 3 are equal

- ◆ secondBook and thirdBook are two names for the same object
- ◆ Values of firstBook and secondBook are different references.

The *equals* Method

- ◆ To test in the sense of equivalency (containing the same information) each class must override the `equal()` method.



The *equals* Method: Example 2

```
class Book {  
    private int price;  
    private String ISBN;  
    public Book(int price, String ISBN) {  
        this.price = price;  
        this.ISBN = ISBN;  
    }  
    public int getPrice() {  
        return price;  
    }  
    public getISBN() {  
        return ISBN;  
    }  
    public boolean equals(Object obj) {  
        if (obj == null)  
            return false;  
        else if (super.equals(obj))  
            return true;  
        else if (getClass() == obj.getClass()) { // equivalent objects  
            Book oa = (Book)obj;  
            return oa.getPrice() == price && oa.getISBN().equals(ISBN);  
        }  
        else return false;  
    }  
} // end of the equals method  
} // end of the Book class
```

The *equals* Method: Example 2

```
Book firstBook = new Book(1250, "0201914670");
Book secondBook = new Book(1250, "0201914670");
if (firstBook.equals(secondBook)) {
    System.out.println("objects are equal");
} else {
    System.out.println("objects are not equal");
}
```

- ◆ This program displays objects are equal even though firstBook and secondBook reference two distinct objects. They are considered equal because the objects compared contain the same ISBN number and the same price.

The *getClass* Method

- ◆ `getClass` returns a *Class* object which stores information about the class.
- ◆ `getClass` is a final method.
- ◆ *java.lang.Class* defines these methods:
 - `getName` – returns the (class) name
 - `getFields` – returns all the public fields
 - `getMethods` – returns all the public methods
 - `getPackage` – returns the class' package
 - `getSuperclass` – returns the class' superclass
 - `getConstructors` – returns all the public constructors

Example: getClass

```
class AA {  
    public int aak;  
  
    public AA(int k) {  
        aak = k;  
    }  
}
```

```
final AA oa = new AA(5);  
Class oc = oa.getClass();  
String ocname = oc.getName();
```

// → "AA"

```
final Class sc = oa.getSuperclass();  
String scname = sc.getName();
```

// → "Object"

The *final* Keyword

- ◆ A final method cannot be overridden by a subclass, for example:
 - `final void method() { ... }`
- ◆ Final methods protect the behavior that is critical to the consistent state of the object
- ◆ An entire class can be declared final to prevent the class from being subclassed:
 - `public final class String { ... }`
 - `public final class Class { ... }`

Example: *final* Method and Class

```
public class AA {  
    private int aak;  
  
    final void method() {  
        ...  
    }  
}  
  
class BB extends AA {  
    void method() { ... }  
}
```

```
public final class AA {  
    private int aak;  
  
    void method() {  
        ...  
    }  
}  
  
class BB extends AA {  
}
```

Example: *final* Fields

```
public class AA {  
    final int fi = 0; // initialized  
  
    AA() {  
        fi = 3;      // error  
    }  
  
    void method() {  
        fi = 3;      // error  
    }  
}
```

```
public class AA {  
    final int fi; // not initialized  
  
    AA() {  
        fi = 3; // initialized  
    }  
  
    void method() {  
        fi = 5;      // error  
    }  
}
```


Example: *final* Variables

```
public class AA {  
  
    void method() {  
        final int k;  
  
        k = 3;  
        k = 5; // error  
    }  
}
```

```
public class AA {  
  
    void method() {  
        final int k = 3;  
  
        k = 5; // error  
    }  
}
```

Example: *final* Parameters

```
public class AA {  
  
    Object aao;  
  
    void mt(Object arg) {  
        aao = arg;  
  
        arg = null;  
    }  
}
```

```
public class AA {  
  
    Object aao;  
  
    void mt(final Object arg) {  
        aao = arg;  
  
        arg = null;    // error  
    }  
}
```

Summary

- ◆ IS-A and HAS-A are different relations between classes.
- ◆ The Object class is the top of the class hierarchy.
 - Useful methods inherited from Object include `toString()`, `equals()`, and `getClass()`.
- ◆ A final class cannot be extended.
- ◆ A final method cannot be overridden.
- ◆ A final field or variable, once initialized, cannot change its value.