Inheritance

- Reuse
- Extension and intension
- Class specialization and class extension
- Inheritance
- Inheritance and methods
- Method redefinition
- The **`final`** keyword
- An widely used inheritance example the *composite design pattern*

How to Reuse Code?

- Write the class completely from scratch (one extreme).
  - What some programmers always want to do!
- Find an existing class that exactly match your requirements (another extreme).
  - The easiest for the programmer!
- Built it from well-tested, well-documented existing classes.
  - A very typical reuse, called composition reuse!
- Reuse an existing class with inheritance
  - Requires more knowledge than composition reuse.
  - Today's main topic.

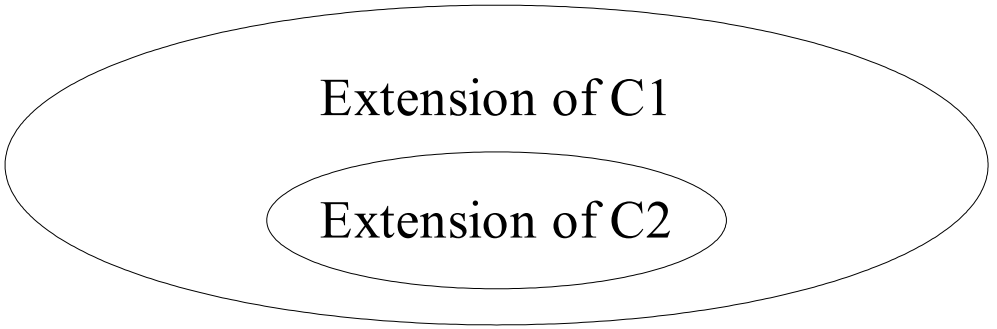
Class Specialization

- In *specialization* a class is considered an *Abstract Data Type* (ADT).
- The ADT is defined as a set of coherent values on which a set of operations are defined.

- A specialization of a class C1 is a new class C2 where
  - The instances of C2 are a subset of the instances of C1.
  - Operations defined of C1 are also defined on C2.
  - Operations defined on C1 can be *redefined* in C2.

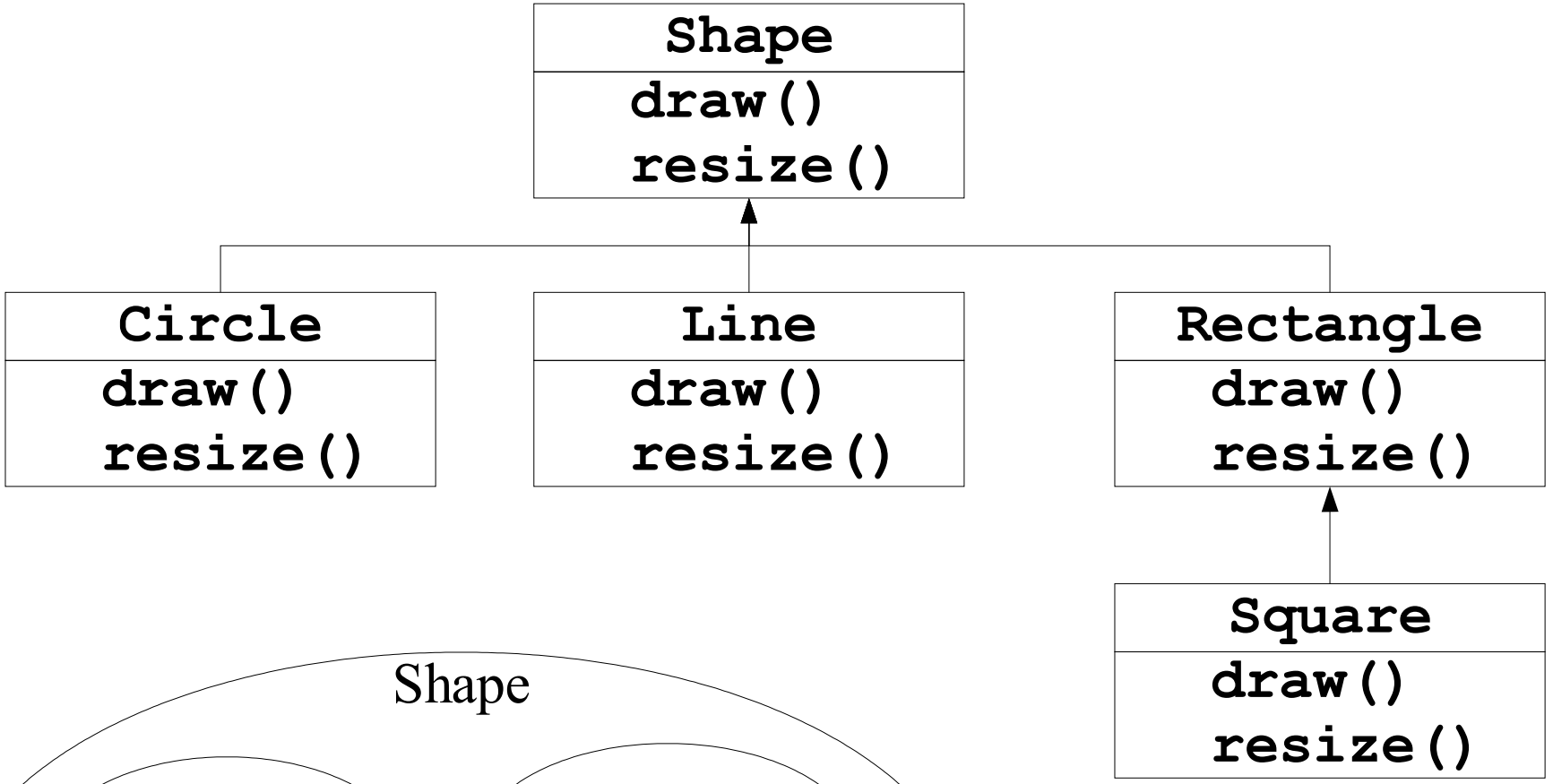
Extension

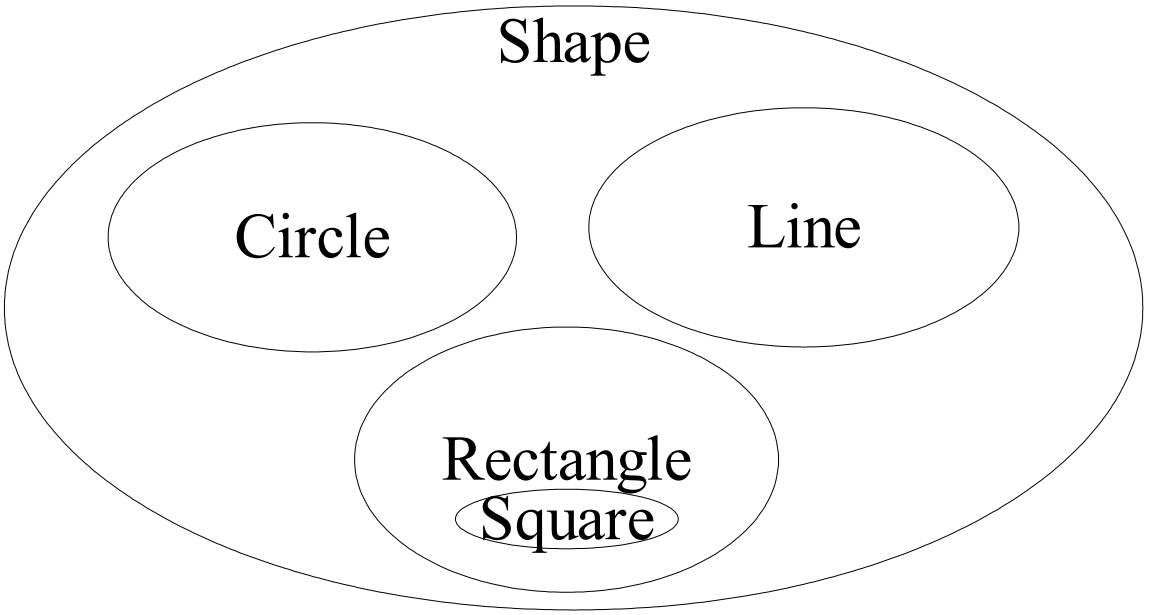
- The *extension* of a specialized class C2 is a subset of the extension of the general class C1.



- "is-a" Relationship
  - A C2 object is a C1 object (but not vice-versa).
  - There is an "is-a" relationship between C1 and C2.
  - We will later discuss a has-a relationship

Class Specialization, Example





Should the extensions be overlapping?

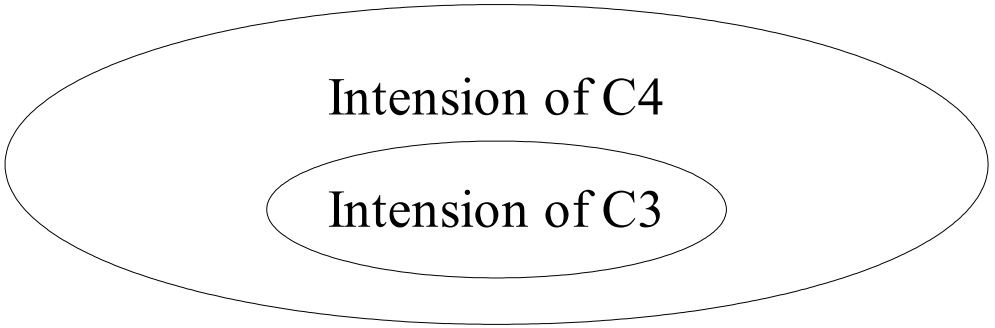
Class Extension

- In *class extension* a class is considered a *module*.
- A module is a syntactical frame where a number of variables and method are defined, found in, e.g., Modula-2 and PL/SQL.
- Class extension is important in the context of *reuse*. Class extension makes it possible for several modules to share code, i.e., avoid to have to copy code between modules.

- A class extension of a class C3 is a new class C4
  - In C4 new properties (variables and methods) are added.
  - The properties of C3 are also properties of C4.

Intension

- The *intension* of an extended class C4 is a superset of the intension of C3.



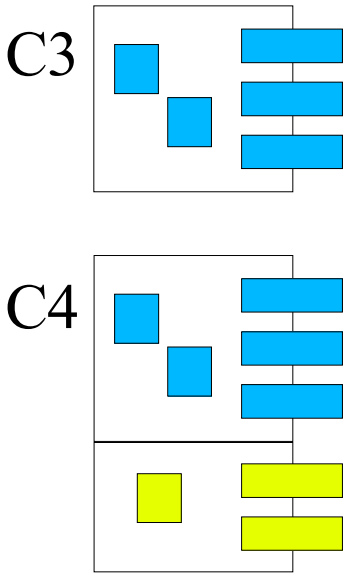
Inheritance

- Inheritance is a way to derive a new class from an existing class.

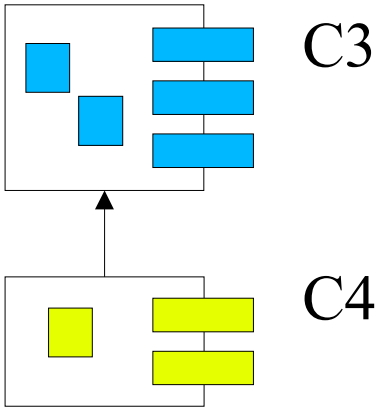
- Inheritance can be used for
  - Specializing an ADT (i.e., class specialization).
  - Extending an existing class (i.e., class extension).
  - Often both class specialization and class extension takes place when a class inherits from an existing class.

Module Based vs. Object Oriented

Module based



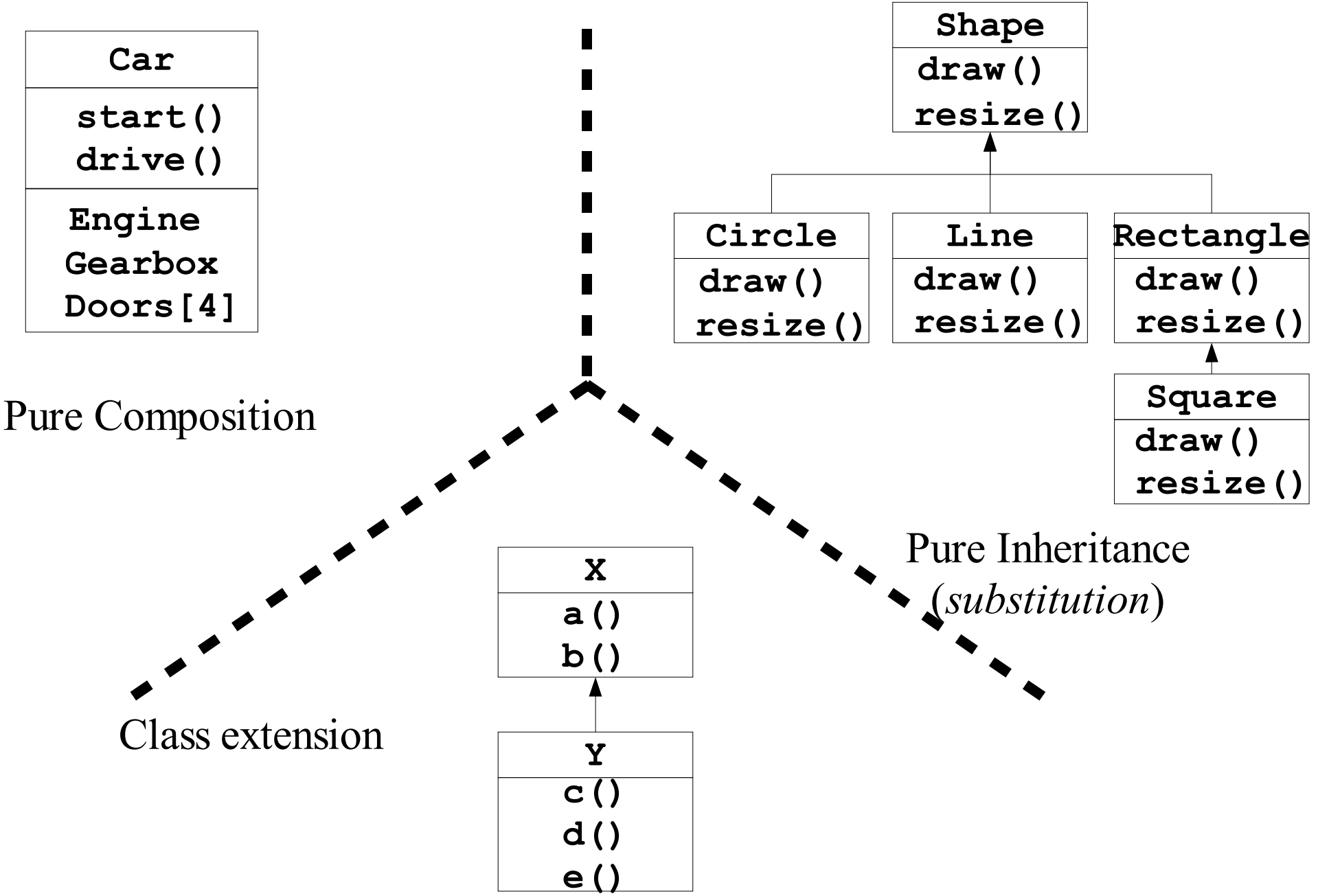
Object oriented



- Class C4 is created by *copying* C3.
- There are C3 and C4 instances.
- Instance of C4 have all C3 properties.
- C3 and C4 are totally separated.
- Maintenance of C3 properties must be done *two* places
- Languages, e.g., Ada, Modula2, PL/SQL

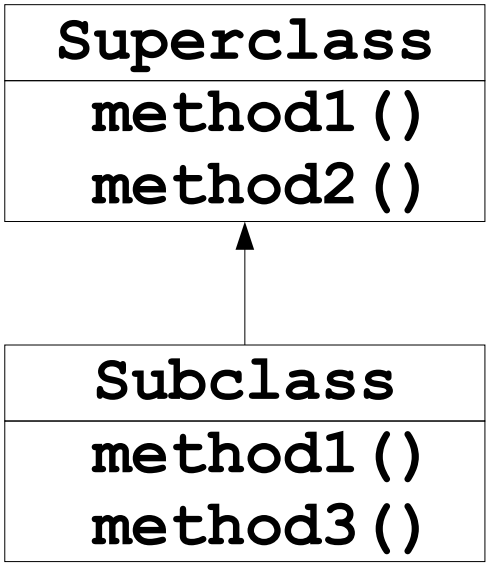
- Class C4 *inherits* from C3.
- There are C3 and C4 instances.
- Instance of C4 have all C3 properties.
- C3 and C4 are closely related.
- Maintenance of C3 properties must be done in *one* place.
- Languages, C++, C#, Java, Smalltalk

Composition vs. Inheritance



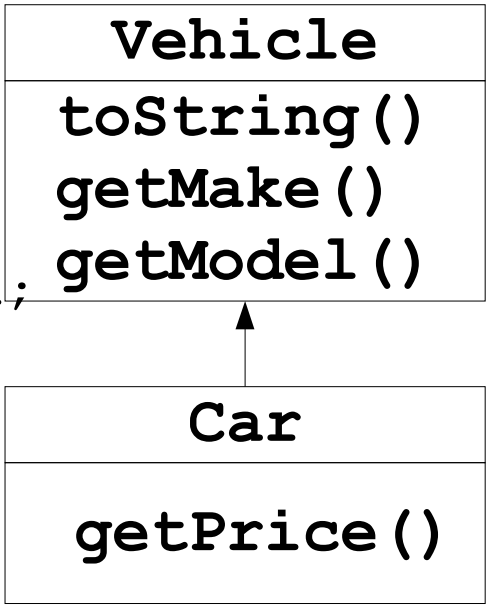
Inheritance in Java

```
class Subclass extends Superclass {
   // <class body>
}
```



Inheritance Example

```
public class Vehicle {
    private String make;
    private String model;
    public Vehicle() { make = ""; model = "";}
     public String toString() {
          return "Make: " + make + " Model: " + model;
     }
    public String getMake(){ return make; }
    public String getModel() { return model; }
}
public class Car extends Vehicle {
    private double price;
    public Car() {
        super(); // called implicitly can be left outs
        price = 0.0;
    }
    public String toString() { // method overwrites
        return "Make: " + getMake() + " Model: " + getModel()
                        + " Price: " + price;
    }
    public double getPrice(){ return price; }
}
```



Class Specialization and Class Extension

- The **`Car`** type with respect to extension and intension

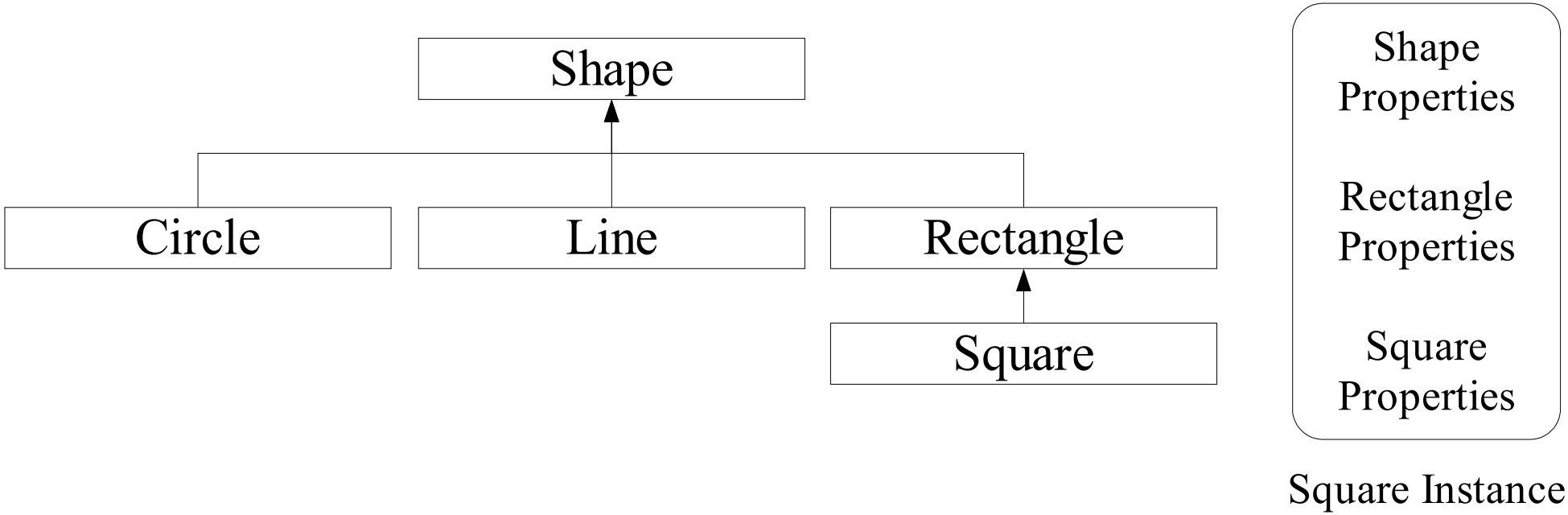
Class Extension

- **`Car`** is a class extension of **`Vehicle`**.
- The intension of **`Car`** is increased with the variable **`price`**.

Class Specialization

- **`Car`** is a class specialization of **`Vehicle`**.
- The extension of **`Car`** is decreased compared to the class **`Vehicle`**.

Instatianting and Initialization



- The Square, that inherits from Rectangle, that inherits from Shape is instantiated as a single object, with properties from the three classes Square, Rectangle, and Shape.

Inheritance and Constructors

- Constructors are not inherited.
- A constructor in a subclass must initialize variables in the class and variables in the superclass.
  - What about **`private`** fields in the superclass?
- It is possible to call the superclass' constructor in a subclass.
  - Default superclass constructor called if exists

```
public class Vehicle{
    private String make, model;
    public Vehicle(String ma, String mo) {
        make = ma; model = mo;
    }
}
public class Car extends Vehicle{
    private double price;
    public Car() {
        // System.out.println("Start");  // not allowed
        super("", "");                   // must be called
        price = 0.0;
    }
}
```

Order of Instantiation and Initialization

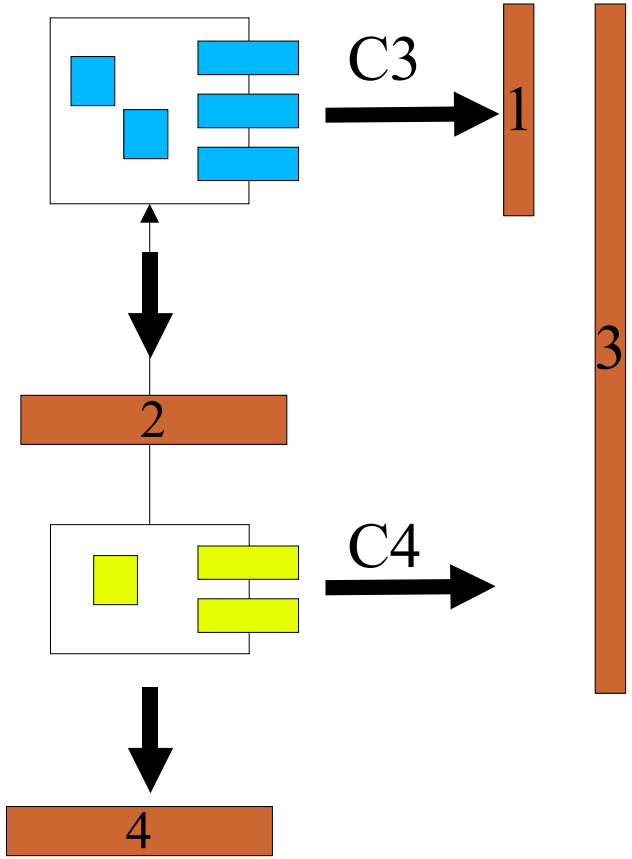
- The storage allocated for the object is initialized to binary zero before anything else happens.
- Static initialization in the base class then the derived classes.
- The base-class constructor is called. (all the way up to **`Object`**).
- Member initializers are called in the order of declaration.
- The body of the derived-class constructor is called.

Inheritance and Constructors, cont.

```
class A {
    public A(){
        System.out.println("A()");
        // when called from B the B.doStuff() is called
        doStuff();
    }
    public void doStuff(){System.out.println("A.doStuff()"); }
}
class B extends A{
    int i = 7;
    public B(){System.out.println("B()");}
    public void doStuff(){System.out.println("B.doStuff() " + i);
    }

}

public class Base{
    public static void main(String[] args){
        B b = new B();
        b.doStuff();
    }
}
```

```
//prints
A()
B.doStuff() 0
B()
B.doStuff() 7
```

Interface to Subclasses and Clients

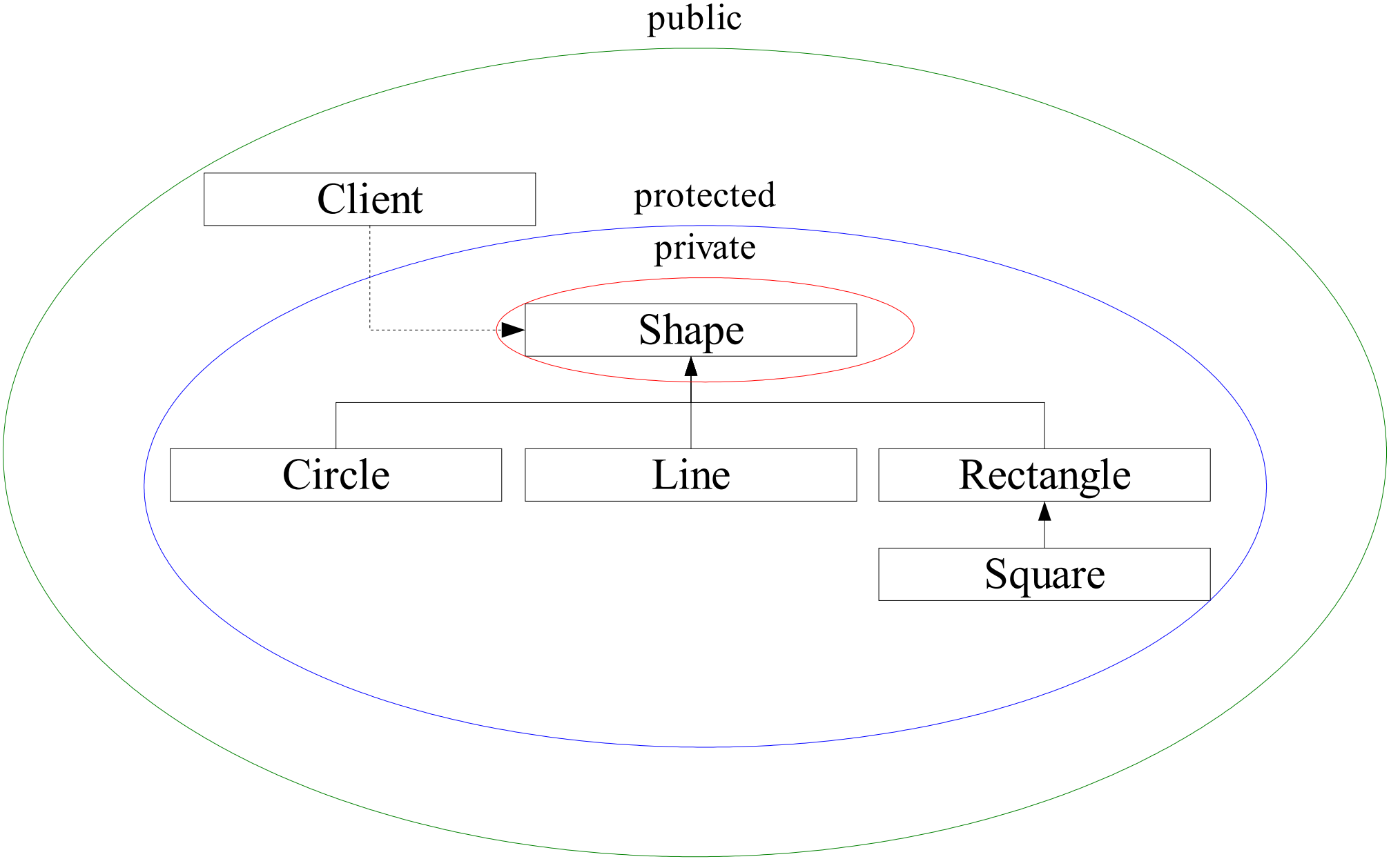


1. The properties of C3 that clients can use.
2. The properties of C3 that C4 can use.
3. The properties of C4 that clients can use.
4. The properties of C4 that subclasses of C4 can use.

`protected`, Revisited

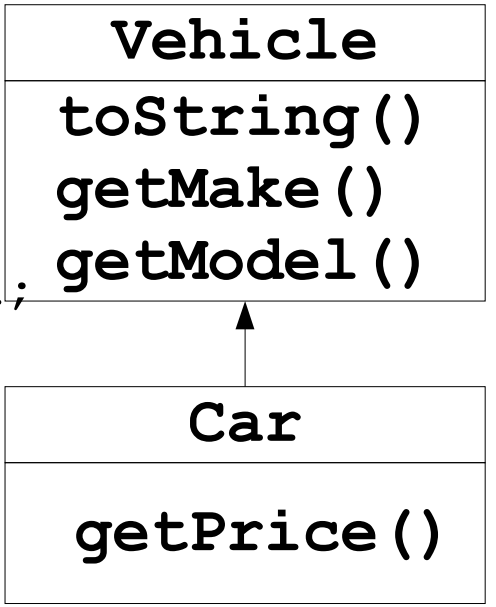
- It must be possible for a subclass to access properties in a superclass.
  - **`private`** will not do, it is to restrictive
  - **`public`** will not do, it is to generous
- A *protected* variable or method in a class can be accessed by subclasses but not by clients.
- Which is more restrictive **`protected`** or package access?
- Change access modifiers when inheriting
  - Properties can be made “more public”.
  - Properties cannot be made “more private”.

`protected`, Revisited



`protected`, Example

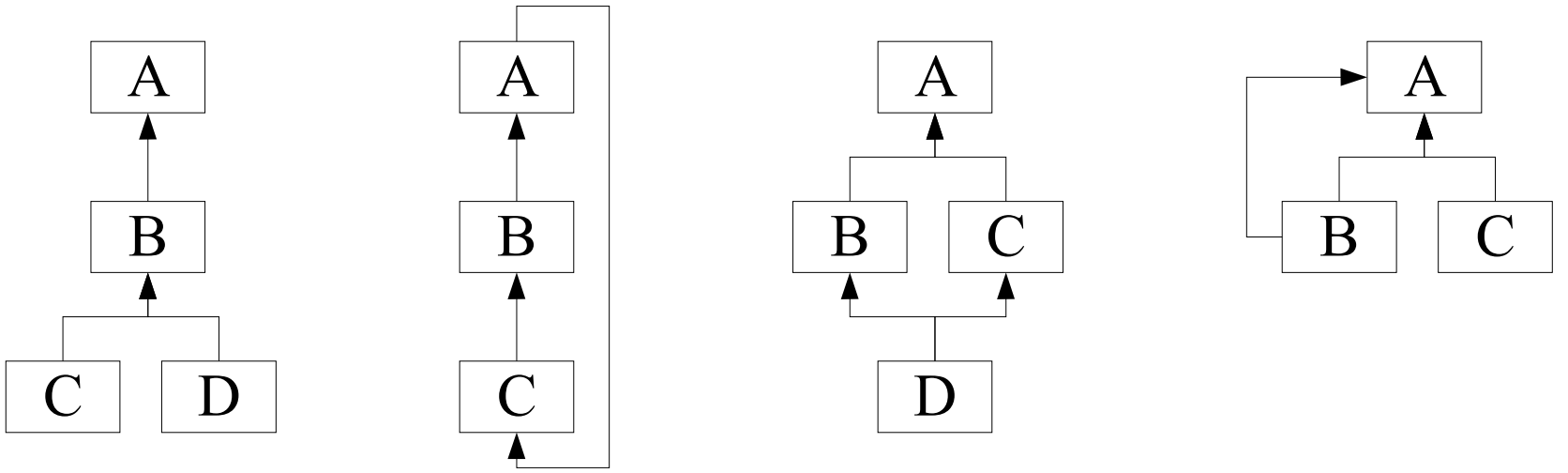
```
public class Vehicle1 {
    protected String make;
    protected String model;
    public Vehicle1() {   make = ""; model = "";}
     public String toString() {
         return "Make: " + make + " Model: " + model;
     }
    public String getMake(){ return make;}
    public String getModel() { return model;}
}

public class Car1 extends Vehicle1 {
    private double price;
    public Car1() {
       price = 0.0;
    }
    public String toString() {
       return "Make: " + make + " Model: " + model
                    + " Price: " + price;
    }
    public double getPrice(){ return price; }
}
```



Class Hierarchies in General

- Class hierarchy: a set of classes related by inheritance.

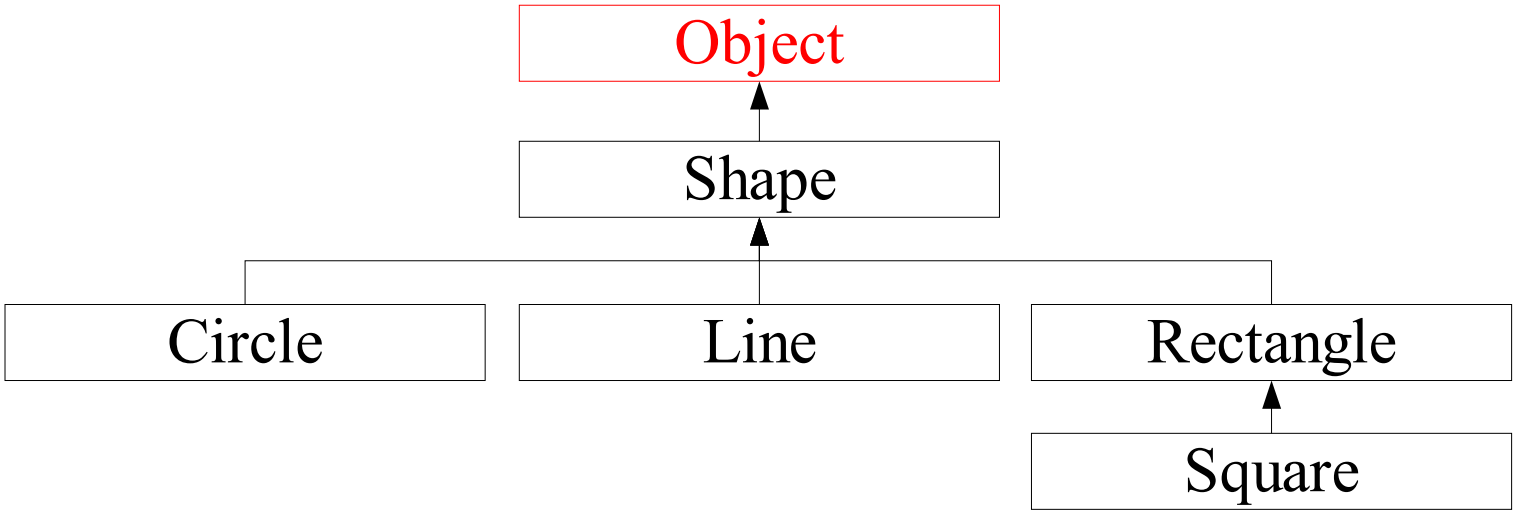
- Possibilities with inheritance
  - Cycles in the inheritance hierarchy is not allowed.
  - Inheritance from multiple superclass may be allowed.
  - Inheritance from the same superclass more than once may be allowed.



- "Multiple and repeated inheritance is a basic feature of Eiffel." [Meyer pp. 62].

Class Hierarchies in Java

- Class **`Object`** is the root of the inheritance hierarchy in Java.
- If no superclass is specified a class inherits *implicitly* from **`Object`**.
- If a superclass is specified *explicitly* the subclass will inherit **`Object`**.



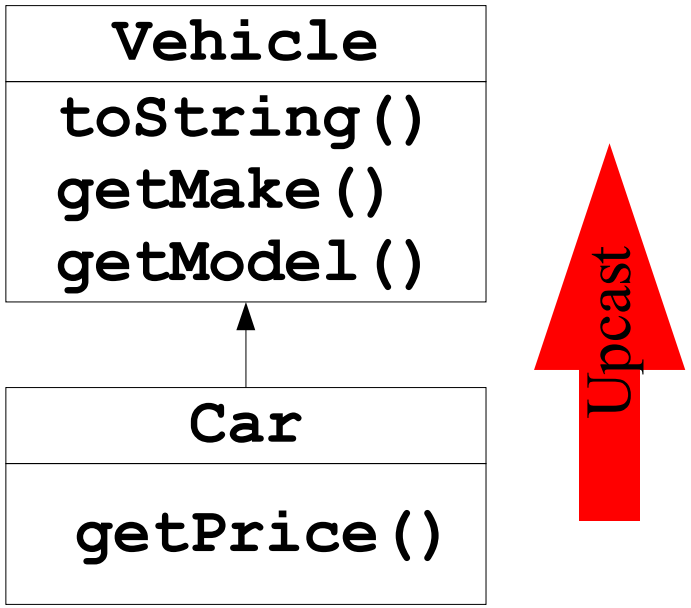
Method/Variable Redefinition

- *Redefinition*: A method/variable in a subclass has the same as a method/variable in the superclass.
- Redefinition should change the *implementation* of a method, not its *semantics*.
- Redefinition in Java class B inherits from class A if
  - Method: Both versions of the method is available in instances of B. Can be accessed in B via **`super`**.
  - Variable: Both versions of the variable is available in instances of B. Can be accessed in B via **`super`**.

- "There are no language support in Java that checks that a method redefinition does not change the semantics of the method. In the programming language Eiffel assertions (pre- and post conditions) and invariants are inherited." [Meyer pp. 228].

Upcasting

- Treat a subclass as its superclass



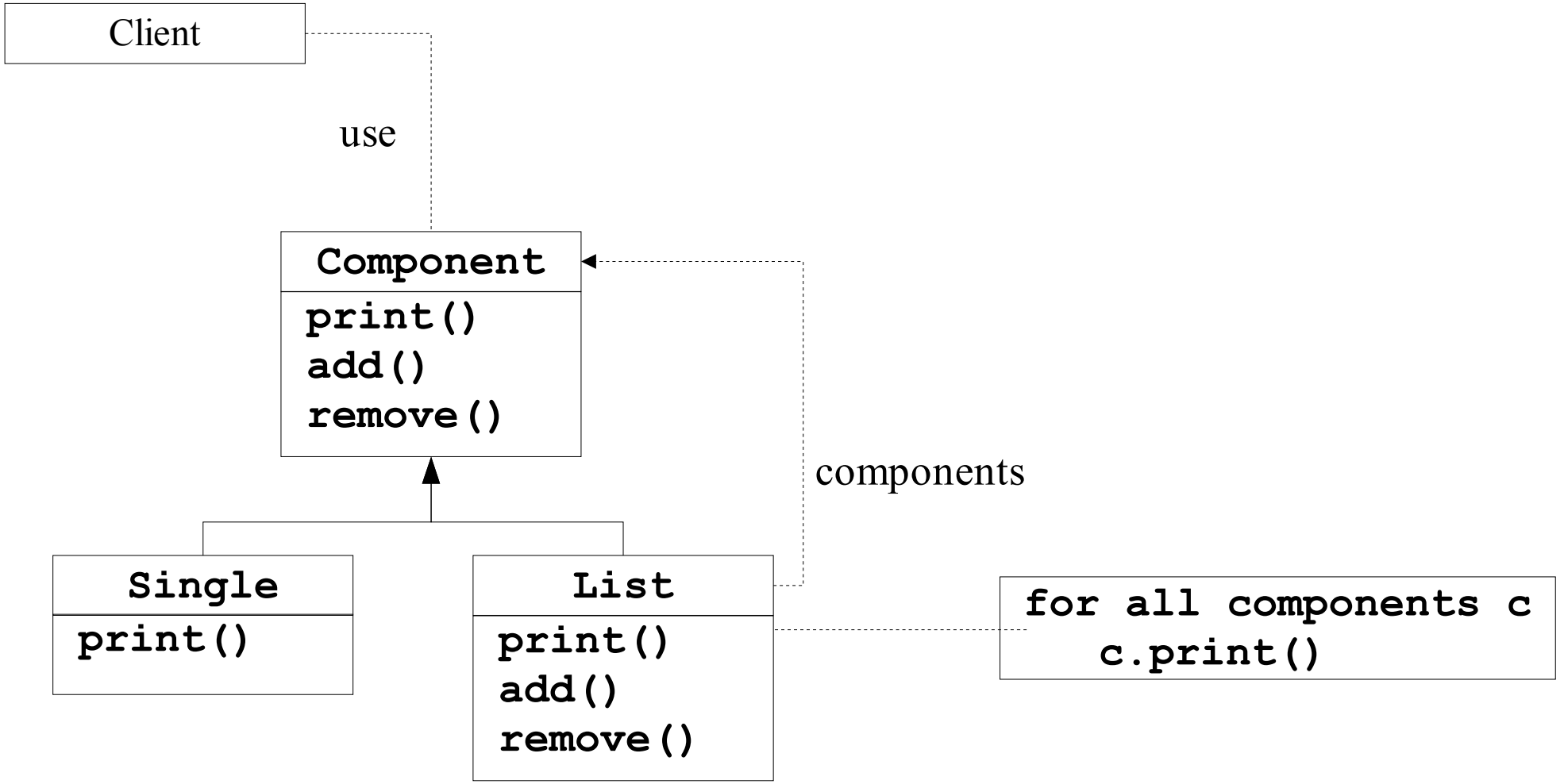

```
// example
Car c = new Car();
Vehicle v;
v = c;              // upcast

v.toString();   // okay
v.getMake();    // okay
//v.getPrice(); // not okay
```

- Central feature in object-oriented program (covered in next lecture)
- Should be obvious that a method/field cannot be made more "private" in a subclass when redefining method/field.
  - However it can be made more public.

The Ikea Component List Problem

- A part can be just the part itself (a brick).
- A part can consists of part that can consists of parts and so on. As an example a garden house consists of the following parts
  - Garden house
    - walls
    - door
      - knob
      - window
        - frame
        - glass
    - window
      - frame
      - glass
    - floor
- Regardless whether it is a simple or composite part we just want to print the list.

Design of The Ikea Component List



- The *composite design pattern*
  - Used extensively when buidling Java GUIs (AWT/Swing)

Implementation of The Ikea Component List

```
public class Component{
    public void print(){
        System.out.println("Do not call print on me!");}
    public void add(Component c){
        System.out.println("Do not call add on me!");}
}

public class Single extends Component{
    private String name;
    public Single(String n){ name = n; }
    public void print(){System.out.println(name);}
}

public class List extends Component{
    private Component[] comp; private int count;// uses parent class
    public List(){ comp = new Component[100]; count = 0; }
    public void print(){ for(int i = 0; i <= count - 1; i++){
            comp[i].print();
        }
    }
    public void add(Component c){ comp[count++] = c;}
}
```

Implementation of The Ikea Component List

```
public class ComponentClient{ // Ikea
  public Component makeWindow(){ // helper function
   Component win = new List();
   win.add(new Single("frame")); win.add(new Single("glass"));
   return win;
  }
  public Component makeDoor(){ // helper function
      Component door = new List();
      door.add(new Single("knob")); door.add(makeWindow());
      return door;
  }
  public Component makeGardenHouse(){ // helper function
   Component h = new List();
   h.add(makeDoor());   h.add(makeWindow()); // etc
   return h;
 }
 public static void main(String[] args){
   ComponentClient c = new ComponentClient();
   Component brick = new Single("brick");
   Component myHouse = c.makeGardenHouse();
   brick.print();
   myHouse.print();
```

Evaluation of The Ikea Component List

- Made **`List`** and **`Single`** classes look alike when printing from the client's point of view.
  - The main objective!
- Can make instances of **`Component`** class, not the intension
  - Can call dummy add/remove methods on these instances
- Can call add/remove method of **`Single`** objects, not the intension.
- Fixed length, not the intension.
- Nice design!

The `final` Keyword

- Fields
  - Compile time constant (very useful)

```
final static double PI = 3.14
```

  - Run-time constant (useful)

```
final int RAND = (int) Math.random * 10
```

- Arguments (not very useful)

```
double foo (final int i)
```

- Methods
  - Prevents overwriting in a subclass (use this very carefully)
  - Private methods are *implicitly* final
- Final class (use this very carefully)
  - Cannot inherit from the class

- Many details on the impacts of **`final`**, see the book.

Summary

- Reuse
  - Use composition when ever possible more flexible and easier to understand than inheritance.
- Java supports specialization and extension via inheritance
  - Specialization and extension can be combined.
- A subclass automatically gets the fields and method from the superclass.
  - They can be redefined in the subclass
- Java supports single inheritance, all have **`Object`** as superclass
- Designing good reusable classes is (very) hard!
  - **`while(!goodDesign()){ reiterateTheDesign(); }`**

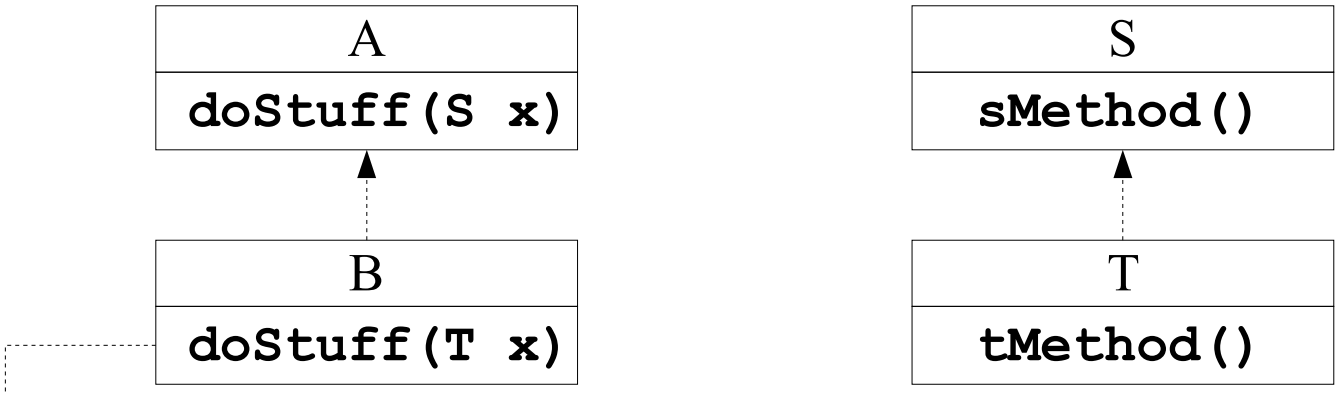
Method Combination

Different method combination

- It is programmatically controlled
  - Method doStuff on A controls the activation of doStuff on B
  - Method doStuff on B controls the activation of doStuff on A
  - *Imperative method combination*
- There is an overall framework in the run-time environment that controls the activation of doStuff on A and B.
  - doStuff on A should not activate doStuff on B, and vice versa
  - Declarative method combination

- Java support imperative method combination.

Changing Parameter and Return Types




```
class B extends A {
   void doStuff (T x){
      x.tMethod();
   }
}

A a1 = new A();
B b1 = new B();
S s1 = new S();

a1 = b1;
a1.doStuff (s1);  // can we use an S object here?
```

Covarians and Contravarians

- *Covarians*: The type of the parameters to a method varies in the same way as the classes on which the method is defined.
- *Constravarians*: The type of the parameters to a method varies in the opposite way as the classes on which the method is defined.