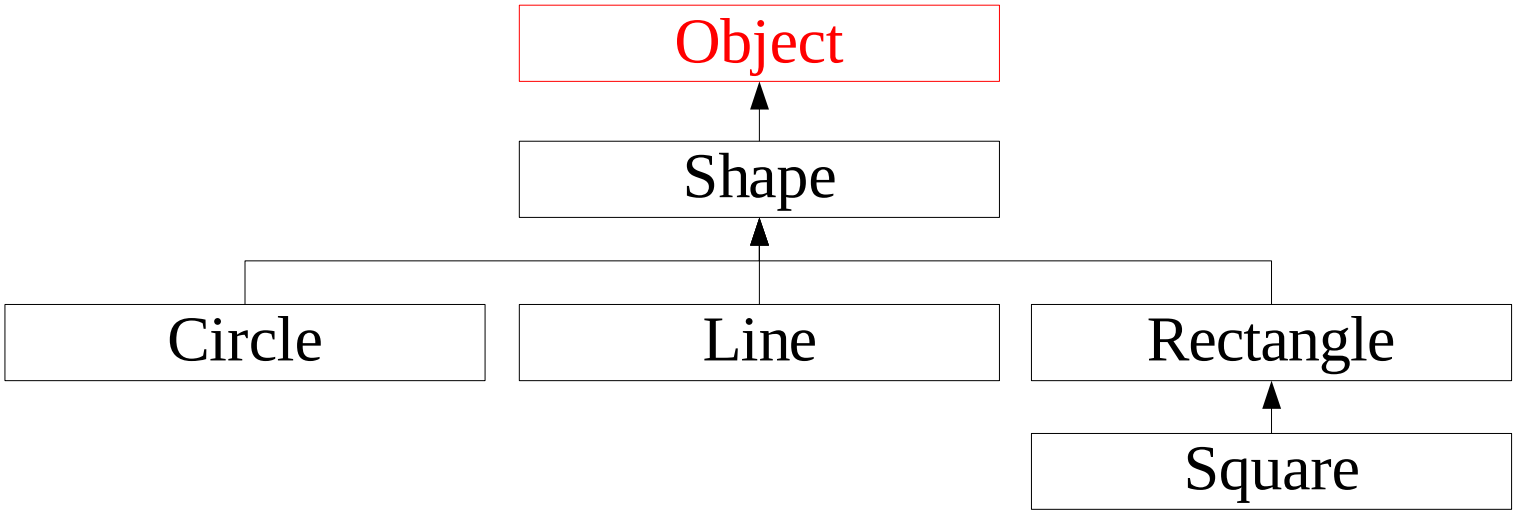
Polymorphism

- Why use polymorphism
- Upcast revisited (and downcast)
- Static and dynamic type
- Dynamic binding
- Polymorphism
  - A polymorphic field (the *state design pattern*)

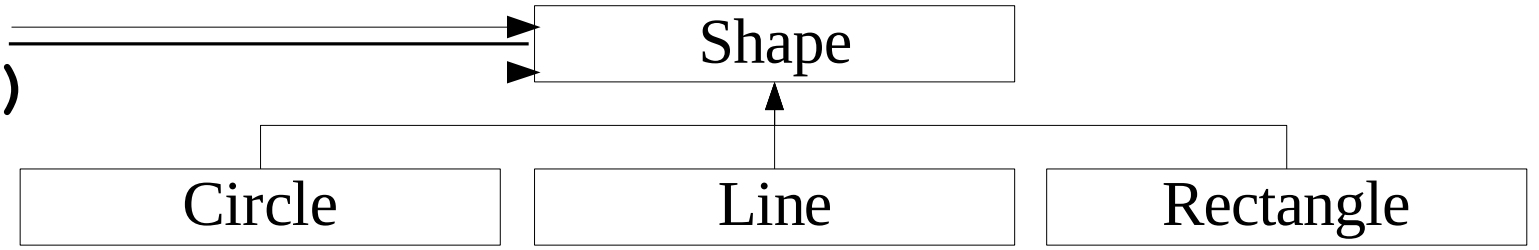
Class Hierarchies in Java, Revisited

- 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 indirectly from **`Object`**.

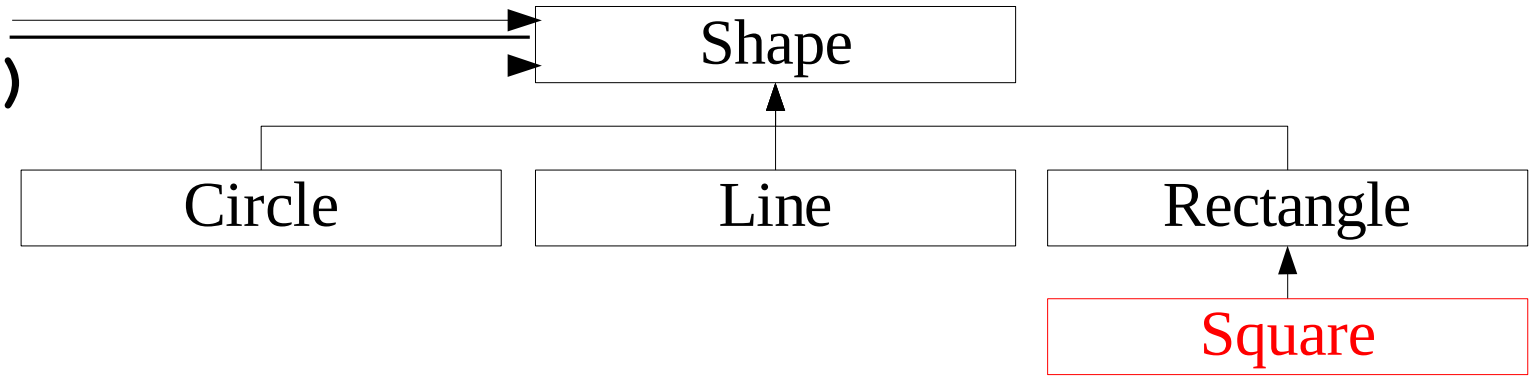


Why Polymorphism?

```
// substitutability
Shape s;
s.draw()
s.resize()
```

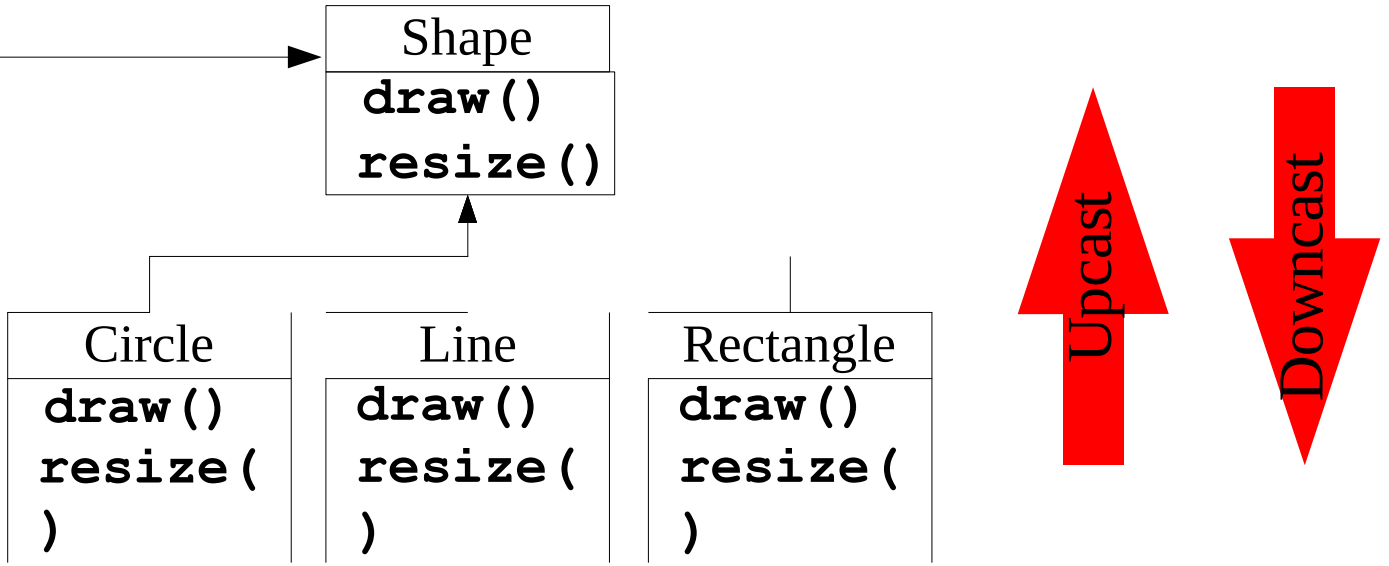



```
// extensibility
Shape s;
s.draw()
s.resize()
```



Why Polymorphism?

```
// common interface
Shape s;
s.draw()
s.resize()
```




```
// upcasting
Shape s = new Line();
s.draw()
s.resize()
```

Advantages/Disadvantages of Upcast

- Advantages
  - Code is simpler to write (and read)
  - Uniform interface for clients, i.e., type specific details only in class code, not in the client code
  - Change in types in the class does not effect the clients
    - If type change within the inheritance hierarchy

- Used extensively in object-oriented programs
  - Many upcast to **`Object`** in the standard library

- Disadvantages
  - Must explictely *downcast* if type details needed in client after object has been handled by the standard library (very annoing sometimes).

```
Shape s = new Line();
Line l = (Line) s; // downcast
```

Static and Dynamic Declaration

- The *static type* of a variable/argument is the declaration type.
- The *dynamic type* of a variable/argument is the type of the object the variable/argument refers to.

```
class A{
  // body
  Public static x;        // static type A
  Public static y;        // static type B
}
class B extends A{
  // body
}
public static void main(String args[]){


   x = new A();           // dynamic type A
   y = new B();           // dynamic type B
   x = y;                 // dynamic type B
}
```

They get created when the CLASS created

They get created when the OBJECT created

Polymorphism, informal

- In a bar you say “I want a beer!”
  - What ever beer you get is okay because your request was very generic
- In a bar you say “I want a Samuel Adams Cherry Flavored beer!”
  - If you do not exactly get this type of beer you are allowed to complain

- In chemistry they talk about polymorph materials as an example H_20 is polymorph (ice, water, and steam).

Polymorphism

- *Polymorphism:* "The ability of a variable or argument to refer at run-time to instances of various classes"

```
Shape s = new Shape();
Circle c = new Circle();
Line l = new Line();
Rectangle r = new Rectangle();

s = l;          // is this legal?
l = s;          // is this legal?
l  = (Line)s    // is this legal?
```

- The assignment **`s = l`** is legal if the static type of **`l`** is **`Shape`** or a subclass of **`Shape`**.
- This is *static type checking* where the type comparison rules can be done at compile-time.
- Polymorphism is constrained by the inheritance hierarchy.

Dynamic Binding

```
class A {
   void doSomething(){
      ...
   }
}
```

```
class B extends A {
   void doSomething (){
      ...
   }
}
```

```
A x = new A();
B y = new B();
x = y;
x.doSomething(); // on class A or class B?
```

- *Binding*: Connecting a method call to a method body.
- *Dynamic binding*: The dynamic type of **x** determines which method is called (also called *late binding*).
  - Dynamic binding is not possible without polymorphism.
- *Static binding*: The static type of **x** determines which method is called (also called *early binding*).

Dynamic Binding, Example

```
class Shape {
   void draw() { System.out.println ("Shape"); }
}
class Circle extends Shape {
   void draw() { System.out.println ("Circle"); }
}
class Line extends Shape {
   void draw() { System.out.println ("Line"); }
}
class Rectangle extends Shape {
   void draw() {System.out.println ("Rectangle"); }
}
public static void main(String args[]){
   Shape[] s = new Shape[3];
   s[0] = new Circle();
   s[1] = new Line();
   s[2] = new Rectangle();
   for (int i = 0; i < s.length; i++){
      s[i].draw(); // prints Circle, Line, Rectangle
   }
}
```

Array of different shapes

Polymorphish and Constructors

```
class A { // example from inheritance lecture
    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()
 0  B()
B.doStuff() 7
```

Polymorphish and **`private`** Methods

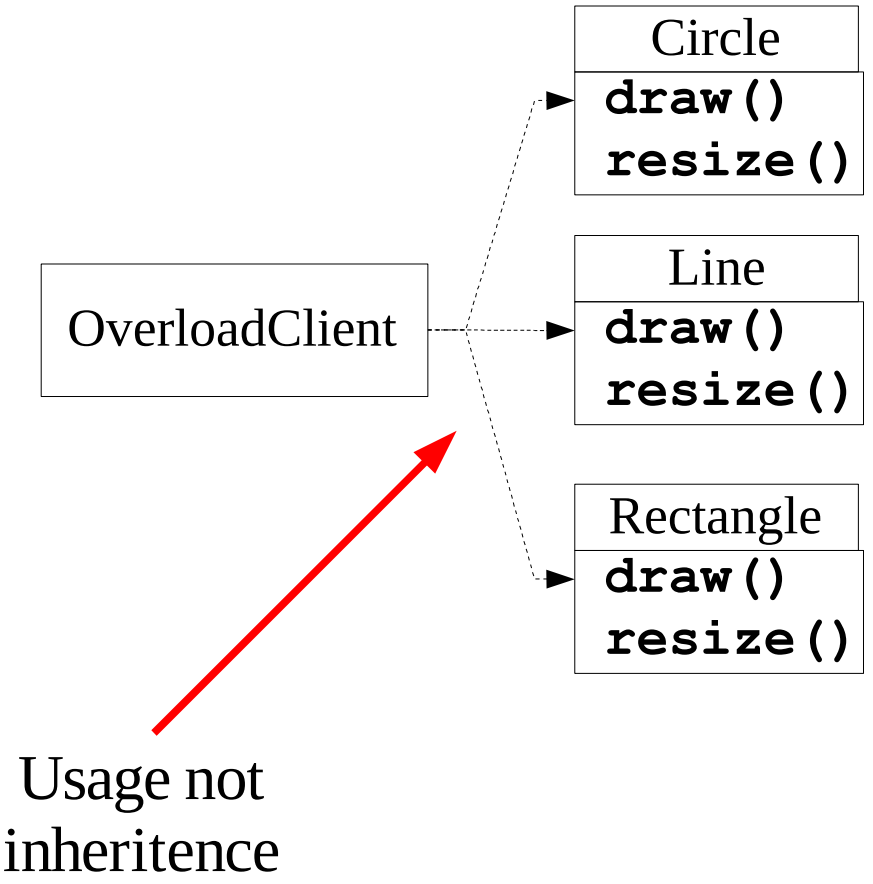
```
class Shape {
   void draw() { System.out.println ("Shape"); }
   private void doStuff() {
      System.out.println("Shape.doStuff()");
   }
}
class Rectangle extends Shape {
   void draw() {System.out.println ("Rectangle"); }
   public void doStuff() {
      System.out.println("Rectangle.doStuff()");
    }
}

public class PolymorphShape {
   public static void polymorphismPrivate(){
      Rectangle r = new Rectangle();
      r.doStuff();   // okay part of Rectangle interface
      Shape s = r;   // up cast
      s.doStuff();   // not allowed, compiler error
   }                 (different types)
}
```

Why Polymorphism and Dynamic Binding?

- Separate interface from implementation.
  - What we are trying to achieve in object-oriented programming!
- Allows programmers to isolate type specific details from the main part of the code.
  - Client programs only use the method provided by the **`Shape`** class in the shape hierarchy example.
- Code is simpler to write and to read.
- Can change types (and add new types) with this propagates to existing code.

Overloading vs. Polymorphism (1)

- Has not yet discovered that the Circle, Line and Rectangle classes are related. (not very realisitic but just to show the idea).

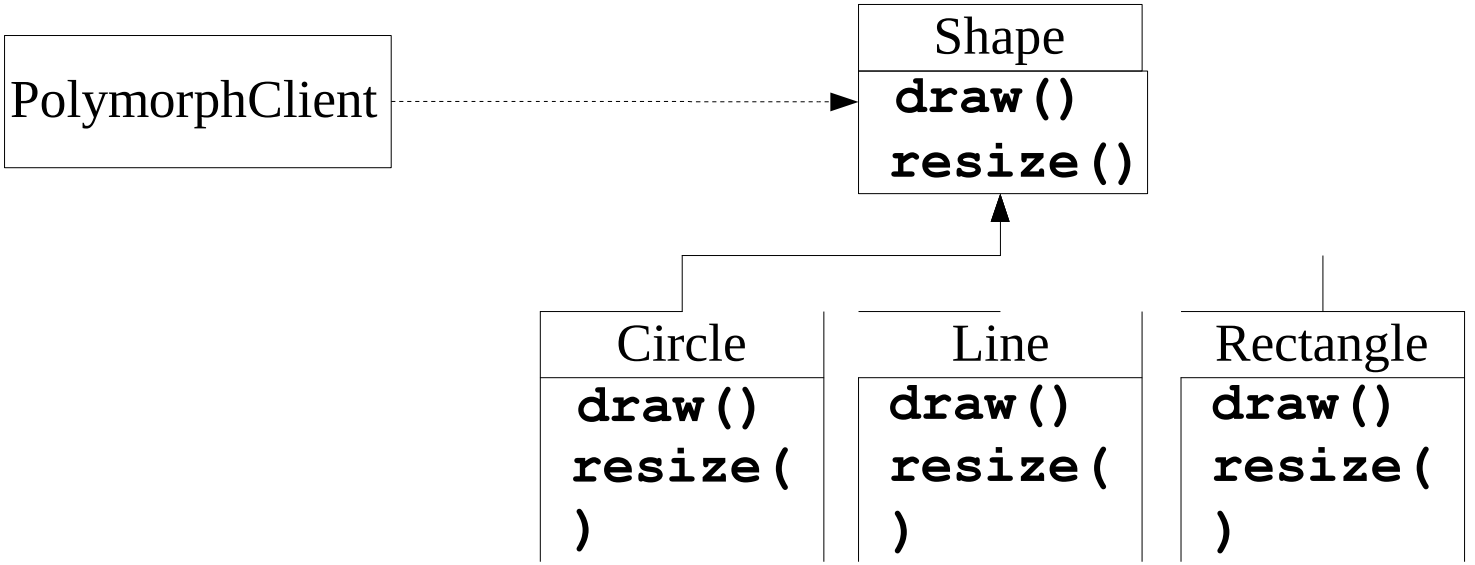


Overloading vs. Polymorphism (2)

```
class Circle {
    void draw() { System.out.println("Circle"); }}
class Line {
    void draw() { System.out.println("Line"); }}
class Rectangle {
    void draw() { System.out.println("Rectangle"); }}

public class OverloadClient{
    // make a flexible interface by overload and hard work
    public void doStuff(Circle c){ c.draw(); }
    public void doStuff(Line l){ l.draw(); }
    public void doStuff(Rectangle r){ r.draw(); }

    public static void main(String[] args){
        OverloadClient oc = new OverloadClient();
        Circle ci = new Circle();
        Line li = new Line();
        Rectangle re = new Rectangle();
        // nice encapsulation from client
        oc.doStuff(ci); oc.doStuff(li); oc.doStuff(re);
    }
}
```

Overloading vs. Polymorphism (3)

- Discovered that the Circle, Line and Rectangle class are related via the general concept Shape
- Client only needs access to base class methods.

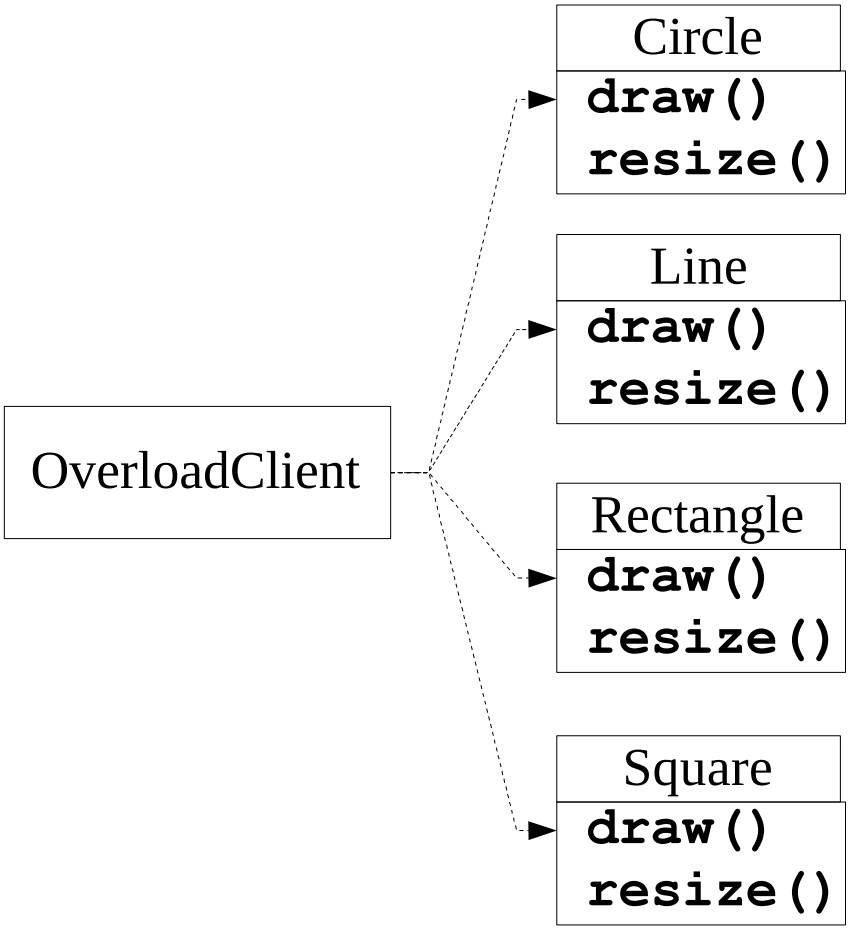


Overloading vs. Polymorphism (4)

```
class Shape {
   void draw() { System.out.println("Shape"); }}
class Circle extends Shape {
    void draw() { System.out.println("Circle"); }}
class Line extends Shape {
    void draw() { System.out.println("Line"); }}
class Rectangle extends Shape {
    void draw() { System.out.println("Rectangle"); }}

public class PolymorphClient{
    // make a really flexible interface by using polymorphism
    public void doStuff(Shape s){ s.draw(); }

    public static void main(String[] args){
        PolymorphClient pc = new PolymorphClient();
        Circle ci = new Circle();
        Line li = new Line();
        Rectangle re = new Rectangle();
        // still nice encapsulation from client
        pc.doStuff(ci); pc.doStuff(li); pc.doStuff(re);
    }
}
```

Overloading vs. Polymorphism (5)

- Must extend with a new class Square and the client has still not discovered that the Circle, Line, Rectangle, and Square classes are related.

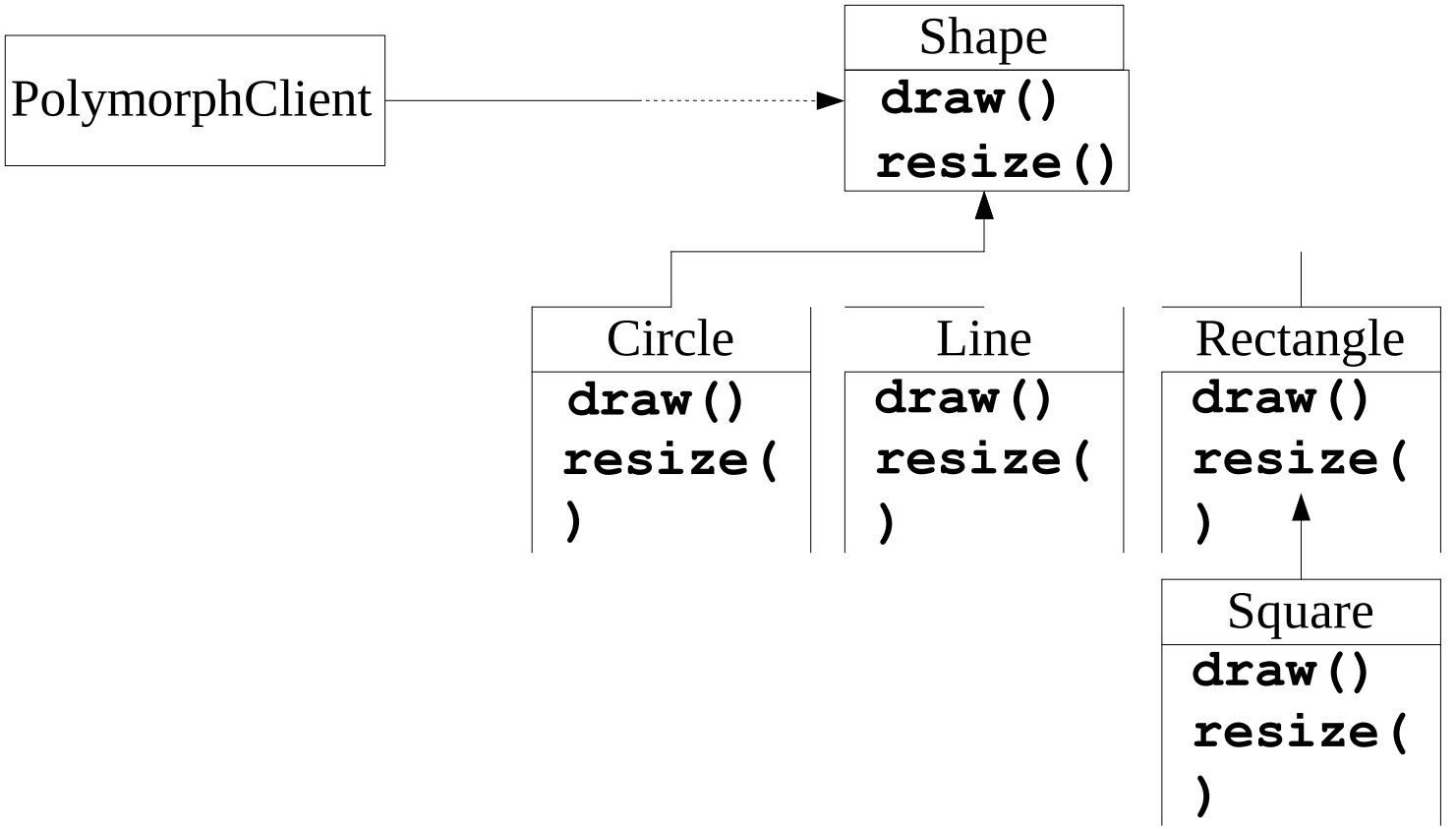


Overloading vs. Polymorphism (6)

```
class Circle {
    void draw() { System.out.println("Circle"); }}
class Line {
    void draw() { System.out.println("Line"); }}
class Rectangle {
    void draw() { System.out.println("Rectangle"); }}
class Square {
    void draw() { System.out.println("Square"); }}

public class OverloadClient{
    // make a flexible interface by overload and hard work
    public void doStuff(Circle c){ c.draw(); }
    public void doStuff(Line l){ l.draw(); }
    public void doStuff(Rectangle r){ r.draw(); }
    public void doStuff(Square s){ s.draw(); }

    public static void main(String[] args){
        <snip>
        // nice encapsulation from client
        oc.doStuff(ci); oc.doStuff(li); oc.doStuff(re);
    }
}
```

Overloading vs. Polymorphism (7)

- Must extend with a new class Square that is a subclassto Rectangle.



Overloading vs. Polymorphism (8)

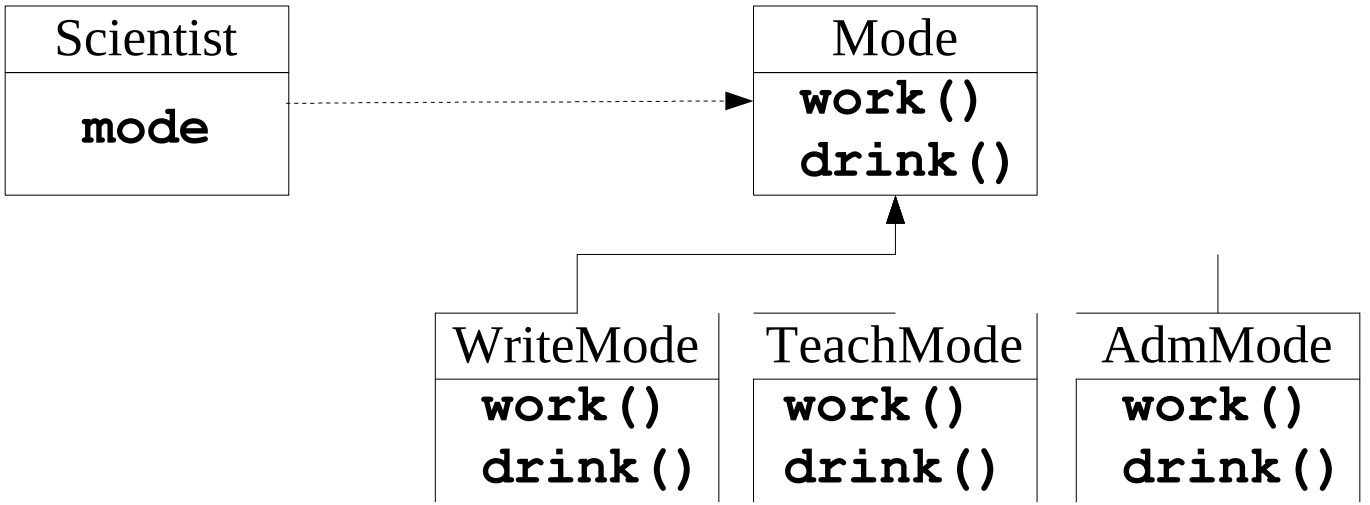
```
class Shape {
   void draw() { System.out.println("Shape"); }}
class Circle extends Shape {
    void draw() { System.out.println("Circle"); }}
class Line extends Shape {
    void draw() { System.out.println("Line"); }}
class Rectangle extends Shape {
    void draw() { System.out.println("Rectangle"); }}
class Square extends Rectangle {
    void draw() { System.out.println("Square"); }}

public class PolymorphClient{
    // make a really flexible interface by using polymorphism
    public void doStuff(Shape s){ s.draw(); }

    public static void main (String[] args){
        <snip>
        // still nice encapsulation from client
        pc.doStuff(ci); pc.doStuff(li); pc.doStuff(re);
    }
}
```

The Opened/Closed Principle

- Open
  - The class hierarchy can be extended with new specialized classes.
- Closed
  - The new classes added do not affect old clients.
  - The superclass interface of the new classes can be used by old clients.
- This is made possible via
  - Polymorphism
  - Dynamic binding
    - Try to do this in C or Pascals!

A Polymorph Field

- A scientist does three very different things
  - Writes paper (and drinking coffee)
  - Teaches classes (and drinking water)
  - Administration (and drinking tea)
- The implementation of each is assumed very complex
- Must be able to change dynamically between these modes



Summary

- Polymorphism an object-oriented “switch” statement.
- Polymorphism should strongly be prefered over overloading
  - Must simpler for the class programmer
  - Identical (almost) to the client programmer
- Polymorphism is a prerequest for dynamic binding and central to the object-oriented programming paradigm.
  - Sometimes polymorphism and dynamic binding are described as the same concept (this is inaccurate).
-