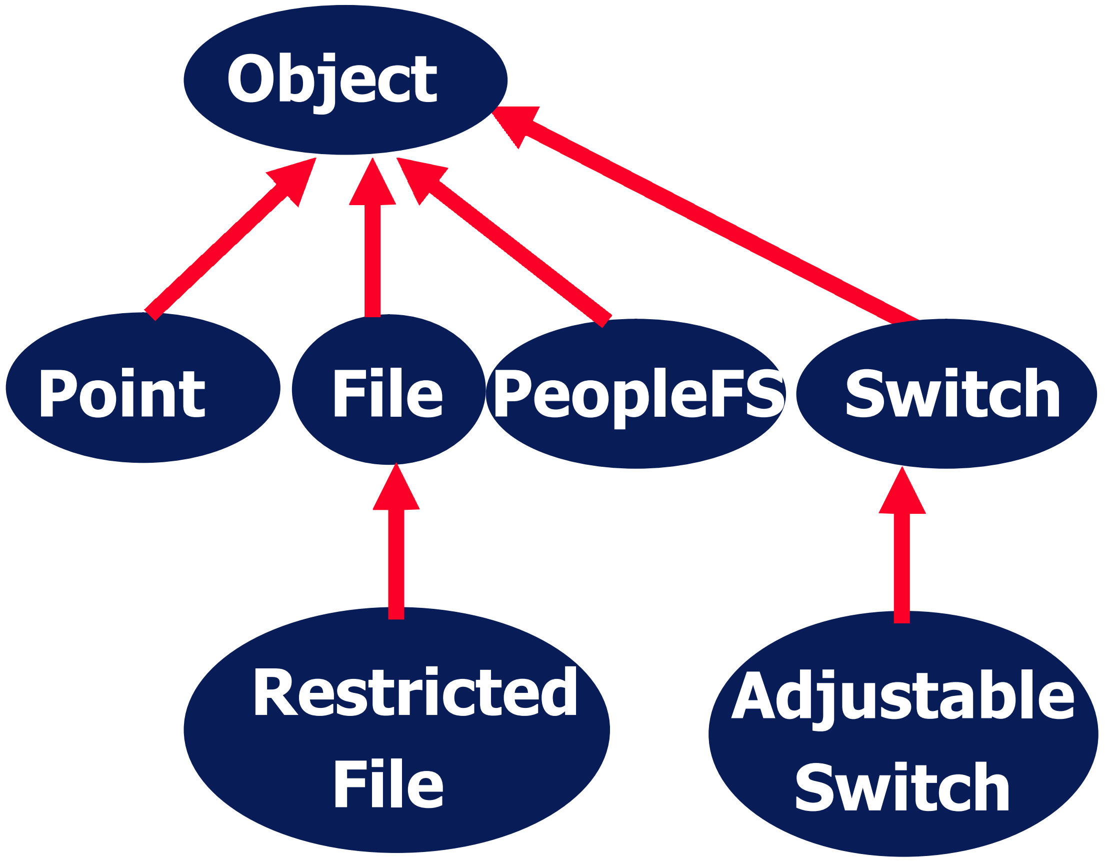
Java Object and Wrapper Classes and Understanding Polymorphism

The Object Class

- Java defines the class `java.lang.Object` that is defined as a superclass for all classes!
- If a class doesn't specify explicitly which class it is derived from, then it will be implicitly derived from class `Object` Object
  - ◆The `Object` class is therefore the ultimate root of all class hierarchies
  - ◆Any object is-a(n) Object



All Classes Extend `Object`

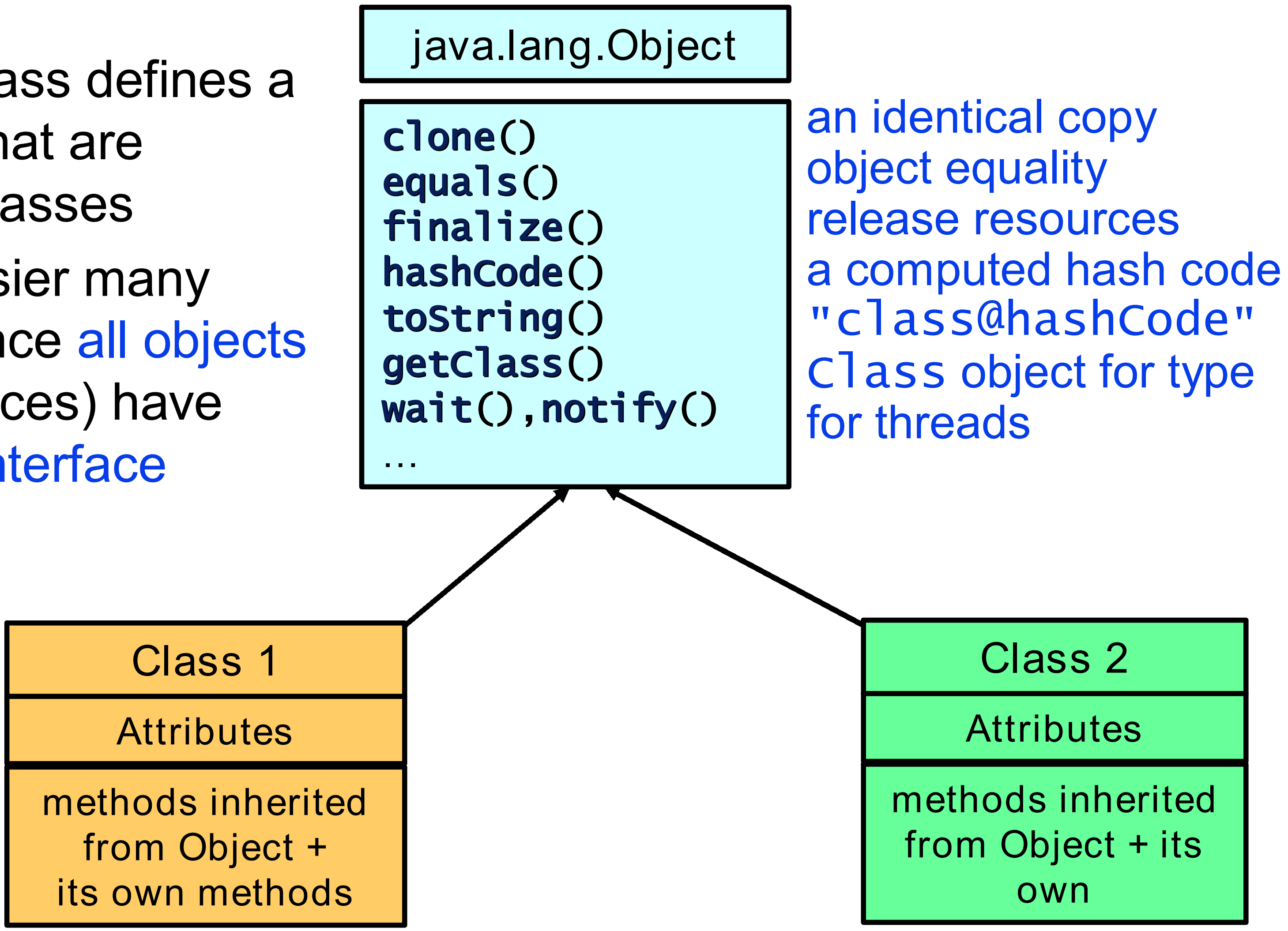
- The following two class definitions are equivalent:

```
class SomeClass

{

// some code

}
```

```
class SomeClass extends Object

{

// some code

}
```

The `Object` Class Methods

- The **`Object`** class defines a set of methods that are inherited by all classes
- This makes easier many functionalities since all objects (i.e., class instances) have some common interface



The `clone()` Method

- The `clone()` method has no parameters an returns an `Object` type
  - returns a new object whose initial state is a copy of the current state of the object
- Note that what is actually returned by each class does not match the return type on the method header verses
  - Since all classes are derived from `Object`, every class "is an" `Object`
- In many classes, the default implementation of (protected) `clone()` will be wrong because it duplicates a reference to an object that shouldn't be shared
  - A shallow copy, by default
  - A deep copy is often preferable

example

Forget this for the moment

```
class Car implements Cloneable {
    String color = "white";
    private int serialNum = 0;
    public void setSerialNum (int sn){serialNum =sn;}
    public int  getSerialNum (){return serialNum;}
    public Car(int sn) {serialNum = sn;}
    public String toString() {
            return "Color="+color+" serialNum="+serialNum;}
    public Car clone() throws CloneNotSupportedException  {
      //System.out.println("cloning");
      return (Car)super.clone();
    }
}
```

example (cont.)

```
class TestCloning {
 static public  void main (String[] a) {
   try {
      Car c1 = new Car(11);
      Car c2 = c1.clone(); //also try Car c2 = c1
                           //you will not get what you wanted
      c1.setSerialNum(20);
      System.out.println(c1.toString()+ "\n" + c2.toString());
   } catch (Exception e) {}
 }
}
```

You will get at the console:

```
Color=white serialNum=20
Color=white serialNum=11
```

An alternative way (without using clone()) using a static newInstance() method

```
class Car implements Cloneable {
    String color = "white";
    ...
    public String toString() {
            return "Color="+color+" serialNum="+serialNum;}
    public static Car newInstance(Car a) {
          return new Car(a.getSerialNum());
    }
}
```

Instead of

```
Car c2 = c1.clone();
```

now we have to use:

```
Car c2 = Car.newInstance(c1);
```

Assignment for you:

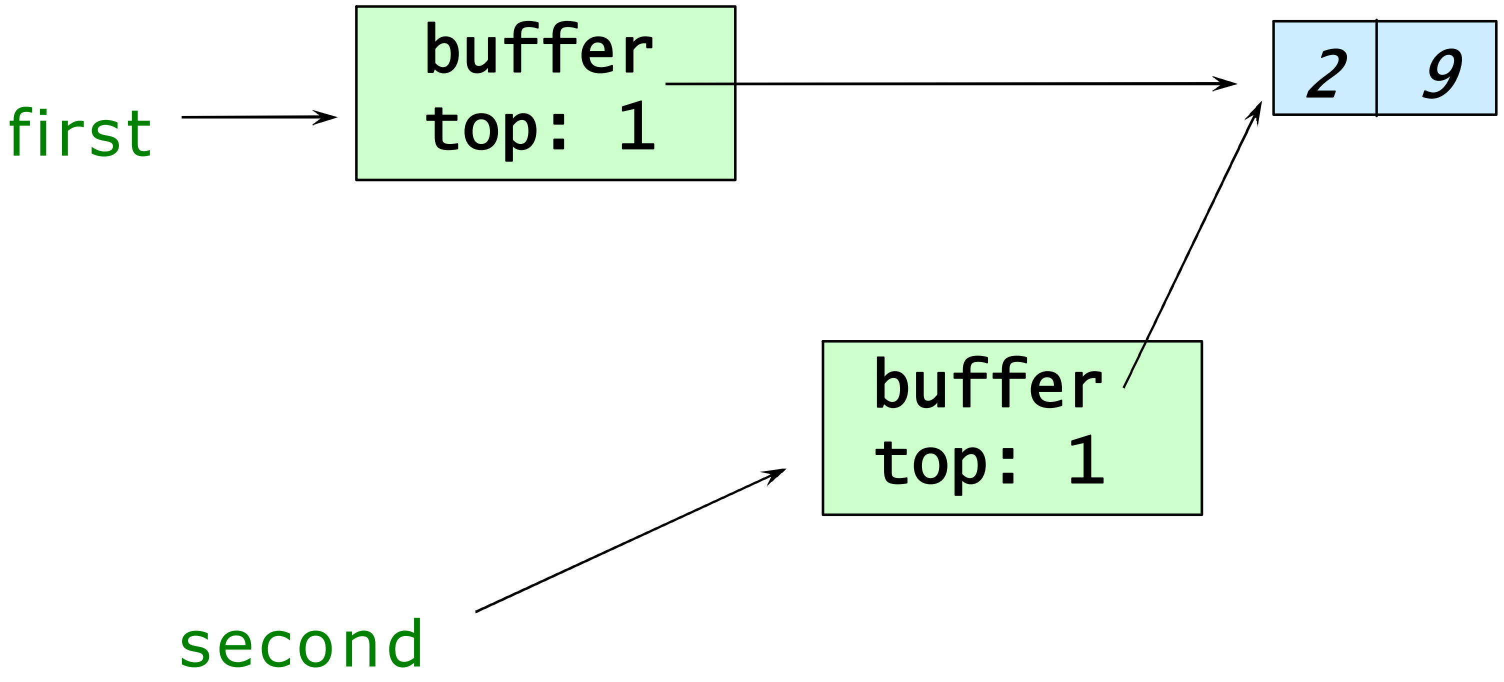
Achieve the same functionality by a defining an appropriate constructor

Creating a Shallow Copy of an Object

```
Public class IntegerStack {
      private int[] buffer;
      private int top;
      public IntegerStack(int maxContents){
        buffer = new int[maxContents];
        top = -1;
      }
      public void push(int val)
        buffer[++top] = val;
      }
      public int pop(){
        return buffer[top--];
      }
}
```

```
IntegerStack first =
      new IntegerStack(2);
first.push(2);
first.push(9);
IntegerStack second =
   (IntegerStack)first.clone();
```

Creating a Shallow Copy of an Object

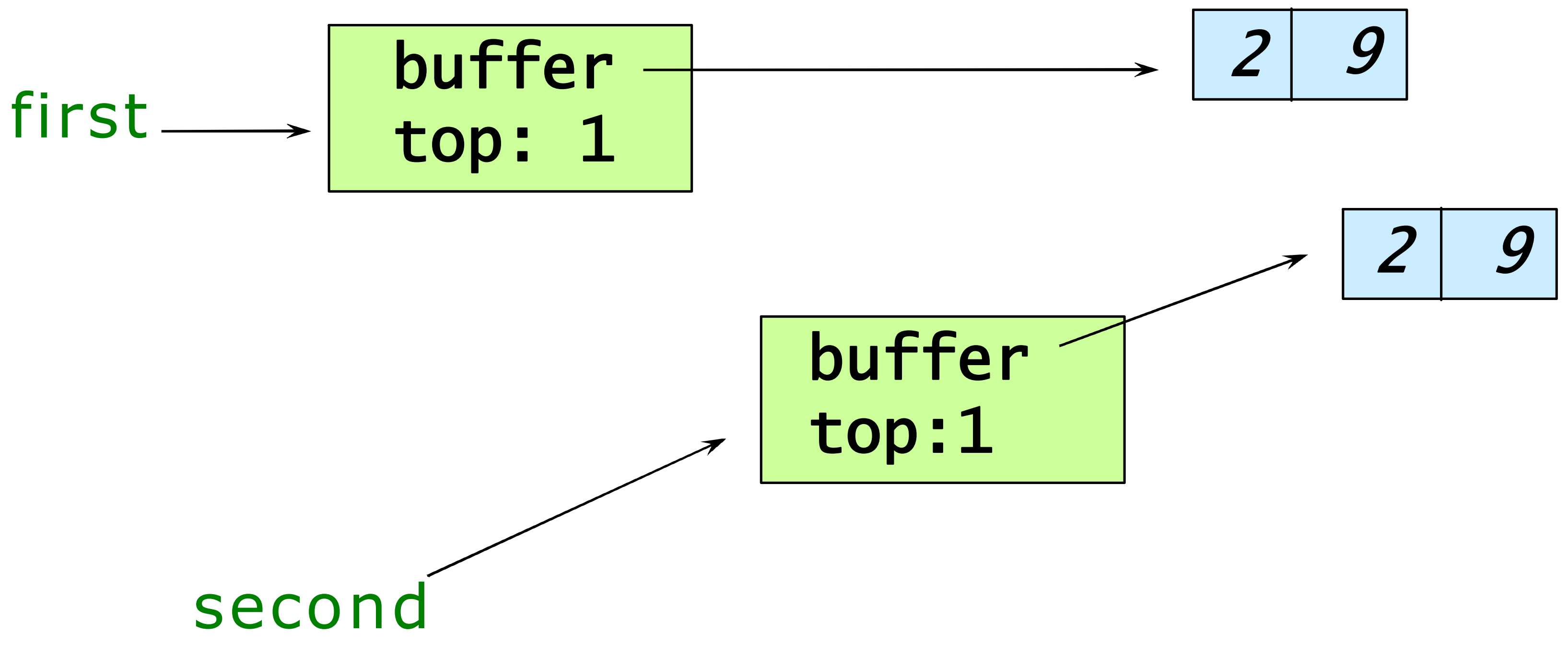


Creating a Deep Copy of an Object

Object clone method is used

```
public Object clone() {
   try {
    IntegerStack nObj = (IntegerStack)super.clone();
    nObj.buffer = (int[])buffer.clone();
   }catch (CloneNotSupportedException e){
     throw new InternalError(e.toString());
   }
}
```

Creating a Deep Copy of an Object



The `equals()` Method

- The **`equals()`** method receives an **`Object`** as a parameter
  - Since all classes are derived from **`Object`**, every class “is an” **`Object`**
- The default implementation just checks if the two references are the same
  - We can override this method in order to test object state equality

```
public class Box{
    …
    public boolean equals(Object o){
        if (o instanceof Box){
            Box b = (Box) o;
            return ((length == b.getLength()) &&
           (width == b.getWidth()) &&
           (height == b.getHeight()));
        }
    }
```

possible *ClassCastException* avoided by checking

The `instanceof` Operator

- You can restore the narrow point of view for objects, by using casting
- However at runtime you must know the true type of object referenced by some wider (base) reference (why?)
- The `instanceof` operator can be used to query about the true type of the `Object` you are referencing
  - E.g., Is this particular `Object` an instance of Class `Box`?
- Question: If Java can determine that a given `Object` is or is not a `Box` (via `instanceof`), then:
  - Why the need to cast it to a `Box` object before Java can recognize that it can `getWidth()` or `getHeight()`?
  - Why can't Java do it for us?

The instanceof Operator and Casting

```
if (o instanceof Box){
     Box b = (Box) o;
     return ((length == b.getLength()) &&
              (width == b.getWidth()) &&
              (height == b.getHeight()));
```

- 1st statement is legal
- 2nd statement isn't (unless o is Box)
- We can see that 1st line guarantees 2nd and 3rd are legal

- Compiler cannot see inter-statement dependencies… unless compiler runs whole program with all possible data sets!
- Runtime system could tell easily
  - We want most checking at compile-time for performance and correctness

The `instanceof` Operator and Casting

- Here, legality of each line of code can be evaluated at compile time
- Legality of each line discernable without worrying about inter-statement dependencies, i.e., each line can stand by itself
- Can be sure that code is legal (not sometimes-legal)
- A Good Use for Casting:
  - Resolving polymorphic ambiguities for the compiler

The finalize() Method

- The **finalize()** method is useful to release system resources
- Who runs it?
  - The garbage collector
- Unlike constructors, you can only have one **finalize** method
- A finalizer receives no parameters and return no value (e.g., its return type is void)
- Example:

```
public Class Box
    private static int count;
    ...
    protected void finalize(){
       --count
    }
```

However we cannot be sure that it will be called before JVM shutdown

however you could use:
System.runFinalizersOnExit(true);

The hashCode() Method

- `hashCode()` returns distinct integers for distinct objects
  - If two objects are equal according to the `equals()` method, then the `hashCode()` method on each of the two objects must produce the same integer result
  - When `hashCode()` is invoked on the same object more than once, it must return the same integer, provided no information used in equals comparisons has been modified
  - It is not required that if two objects are unequal according to `equals()` that `hashCode()` must return distinct integer values

The `toString()` Method

- The **`toString`**`()` method is used whenever we want to get a String representation of an object
- When you define a new class, you can override the **`toString`**`()` method in order to have a suitable representation of the new type of objects as Strings
- Example:

```
System.out.println (new Random() );
```

printed

```
Java.util.Random@fd78d6b6
```

shortcut for

```
System.out.println (new Random().toString() );
```

The Class Class

- We can navigate the type system in a program
  - instance of the class `Class` represents each class or interface in a running Java application
- Provide a tool to manipulate classes (`defineClass()` in `Classloader`)
  - creating objects of types specified in strings
  - loading classes using specialized techniques, such as across the network
- Two way to get a `Class` object
  - use `this.getClass` method of `Object`
  - fully qualified name using the static method `Class.forName(clsname)`
- The `Class` Class Methods
  - `getName()` -> a string class/interface name
  - `getSuperclass()` -> a `Class` object
  - `getInterfaces()` -> an array of objects representing all interfaces implemented/extended by the class/interface

Printing the Type Hierarchy of a `Class` Object

```
public class ClassInfo {
    // We expect class names as command line arguments
    public static void main(String[] args) {
    ClassInfo info = new ClassInfo();
        for(int i = 0; i < args.length; i++) {
            try {
                info.printInfo(Class.forName(args[i]), 0);
            } catch(ClassNotFoundException e) {
                System.err.println(e); // report the error
            }
   }
   // by default print on standard output
   private java.io.PrintStream out = System.out;
   // used in printInfo() for labeling type names
   private static String[]
             basic    = {“class”,   “interface”},
             extended = {“extends”, “implements”};
```

Printing the Type Hierarchy of a Class Object

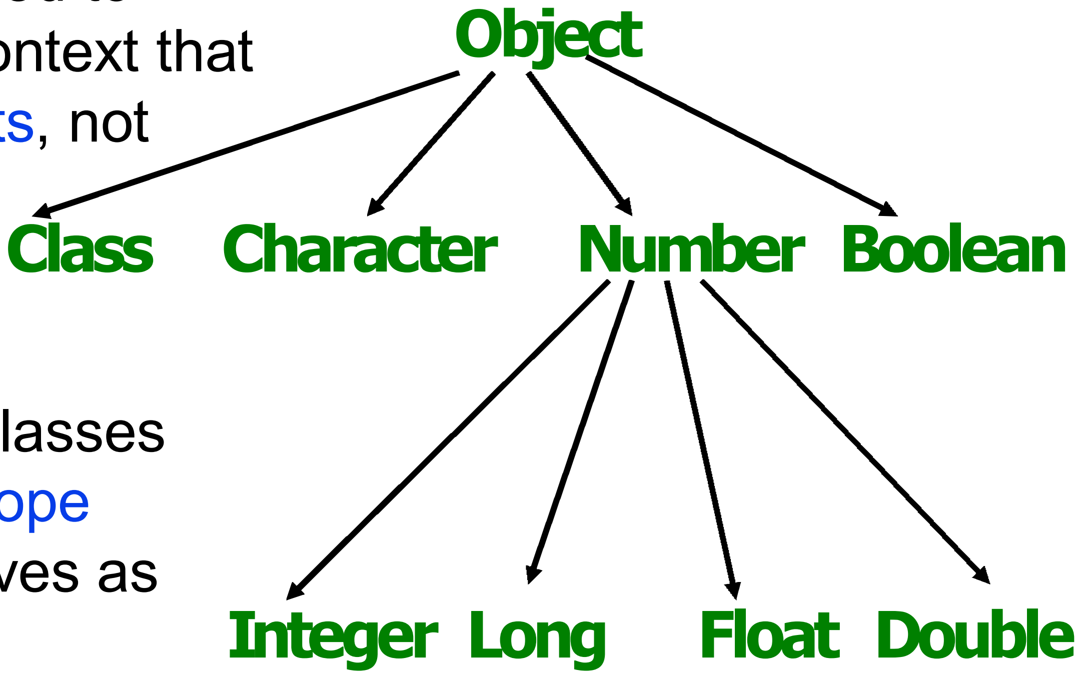
```
  public void printInfo(Class type, int depth) {
    // Object’s supertype is null
    if(type == null)
       return;
    // print out this type
    for(int i=0; i < depth; i++)
       out.print(“ “);
    String[] labels = (depth == 0 ? basic : extended);
    out.print(labels[type.isInterface() ? 1 : 0] + “ “);
    out.println(type.getName());
    // print out all interface this class implements
    Class[] initerfaces = type.getInterfaces();
    for(int i = 0; i < interfaces.length ; i++)
        printInfo(interfaces[i], depth + 1);
    // recurse on the superclass
    printInfo(type.getSuperClass(), depth + 1);
  }
}
```

If args[] = {"java.lang.Object", "reflection.ClassInfo", "java.util.Vector", "java.io.Serializable", "java.lang.Cloneable"}, the we will get:

```
===============================
class java.lang.Object
===============================
class reflection.ClassInfo
          extends java.lang.Object
===============================
class java.util.Vector
          implements java.util.List
                    implements java.util.Collection
                              implements java.lang.Iterable
          implements java.util.RandomAccess
          implements java.lang.Cloneable
          implements java.io.Serializable
          extends java.util.AbstractList
                    implements java.util.List
                              implements java.util.Collection
                                        implements java.lang.Iterable
                    extends java.util.AbstractCollection
                              implements java.util.Collection
                                        implements java.lang.Iterable
                              extends java.lang.Object
===============================
interface java.io.Serializable
===============================
interface java.lang.Cloneable
```

Wrapper Classes

- Primitive types (e.g., int) are not classes
- But sometimes, we may have need to make use of primitive types in a context that requires that we manipulate objects, not primitives
  - e.g., many collection classes are collections of Objects
- Java provides a set of wrapper classes (a.k.a. type wrappers, a.k.a. envelope classes) to support treating primitives as objects
- It does this by providing a specific class that corresponds to each primitive data type
- They are in `java.lang`, so the names are universally available



Wrapper Classes

Class	corresponds to	Primitive
Boolean		boolean
Character		char
Byte		byte
Short		short
Integer		int
Long		long
Float		float
Double		double

- Each one:
- allows us to manipulate primitives as objects
- contains useful conversion methods
  - E.g. Integer contains
  - `static Integer valueOf(String s)`
  - `Integer.valueOf("27")`
  - is the object corresponding to int 27
- contains useful utility methods (e.g. for hashing)

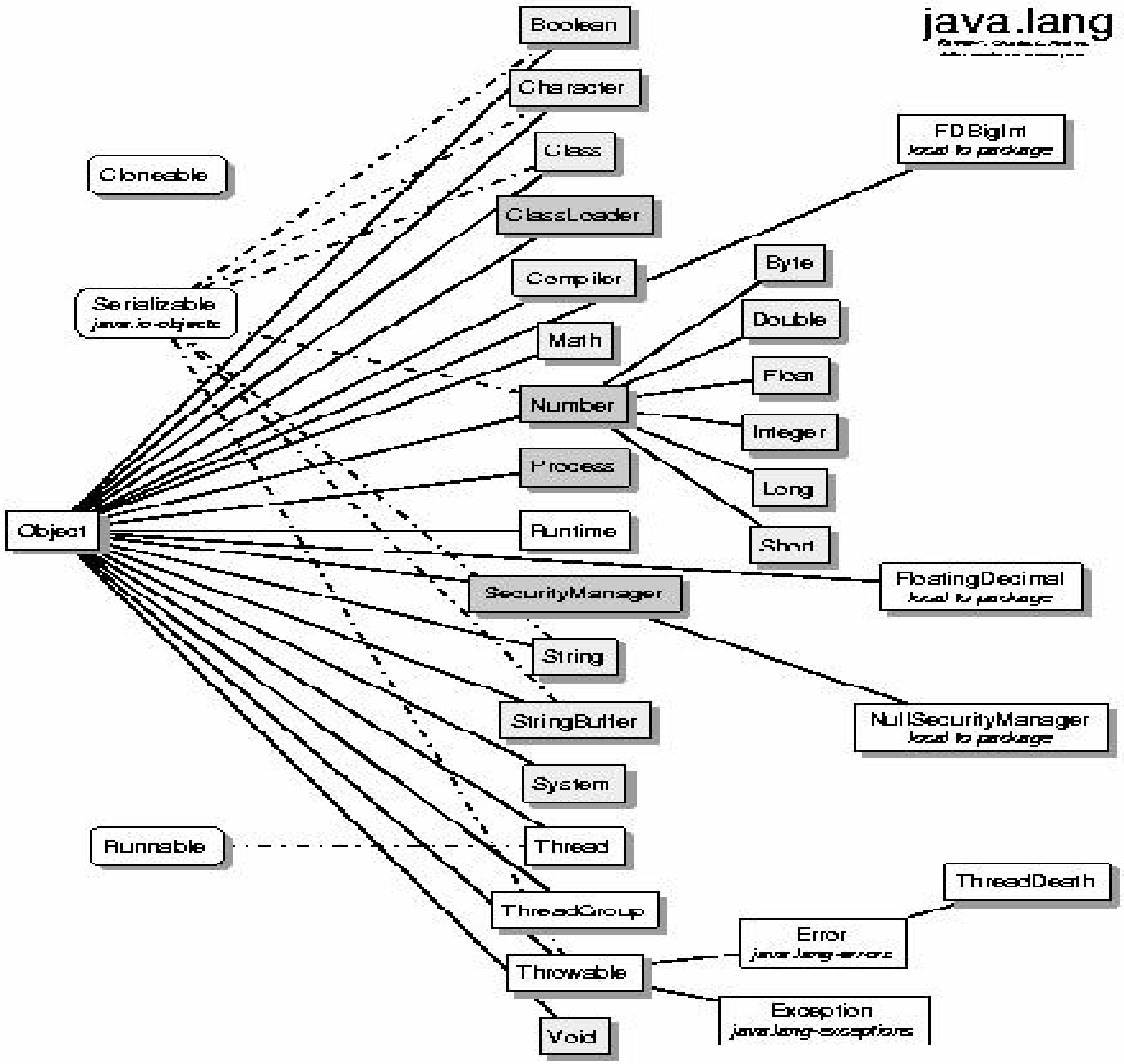
Wrapper Classes

- Using wrappers to bridge between objects and primitives:

```
// create and initialize an int
   int i = 7;

// create an Integer object and convert the int to it
   Integer intObject = new Integer( i );

// retrieve the int by unwrapping it from the object
   System.out.println( intObject.intValue );

// convert a string into an Integer object
   String strS = "27";
   Integer intObject
   intObject = new Integer (Integer.valueOf(strS) );
// then to an int
   i = intObject.intValue;
```

A class method

The Java.Lang Hierarchy



Understanding Polymorphism

The Notion of Polymorphism

- The Webster definition:
  - pol-y-mor-phism n. : a genetic variation that produces differing characteristics in individuals of the same population or species
  - pol-y-mor-phous adj. : having, assuming, or passing through many or various forms, stages, or the like
- The basic principle and aims of the generality and abstraction are:
  - Reuse
  - Interoperability
- The basic idea:
  - A programmer uses a single, general interface, Java selects the correct method

Principle of Substitutability

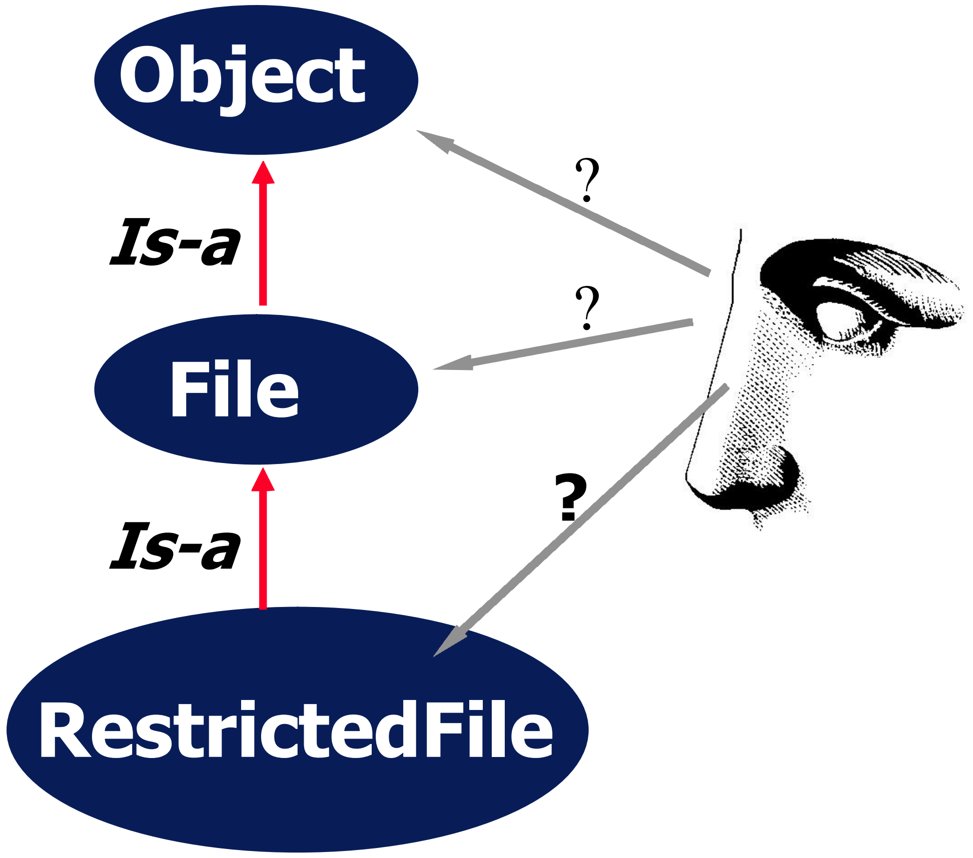
- If B is a subclass of A, then we can replace any instance of A with an instance of B in any situation with no observable effect
- If A responds to message m, then B responds to m
  - ◆All Numbers respond to + aNumber
- Strongly typed languages require this property in many more situations than just adhering to a protocol
  - ◆E.g., in Java, we may insist on parameters of a certain type – subtypes may be used here.
- Strongly typed languages require casts to adhere to typing rules

Subclass, Subtype, Substitutability

- Substitutability: type of a variable does not have to match the type of the actual value, subclasses are OK, too
- A subclass is usually substitutable, because:
  - Subclass instances have all parent fields
  - Subclasses implement all parent methods
  - Thus, subclasses support parent protocol
- But: not always true (see later)
- Interfaces can also be used for subtyping
- Subtype <> subclass, “stronger notion”

The Principle of Substitutability: Example

- Recall the is-a relationship induced by inheritance:
  - A `RestrictedFile` is a `File`, which is an `Object`
- `RestrictedFile` can be used by any code designed to work with `File` objects
- If a method expects a `File` object you can hand it a `RestrictedFile` object and it will work (think why?)
- This means that `RestrictedFile` object can be used as both a `File` object and a `RestrictedFile` object (and an `Object`)



The object can have many forms!

3 Views of `RestrictedFile`

- We can view a `RestrictedFile` object from 3 different points of views:
  - As a `RestrictedFile`
    - This is the most narrow point of view (the most specific)
    - This point of view ‘sees’ the full functionality of the object
  - As a `File`
    - This is a wider point of view (a less specific one)
    - We forget about the special characteristics the object has as a `RestrictedFile` (we can only open and close the file)
  - As a plain `Object`
    - What can we do with it?

Referencing a Subclass

- We “view” and use an object by holding and referring to the object’s reference

- A variable of type ‘reference to `File`’ can only refer to an object which is a `File`

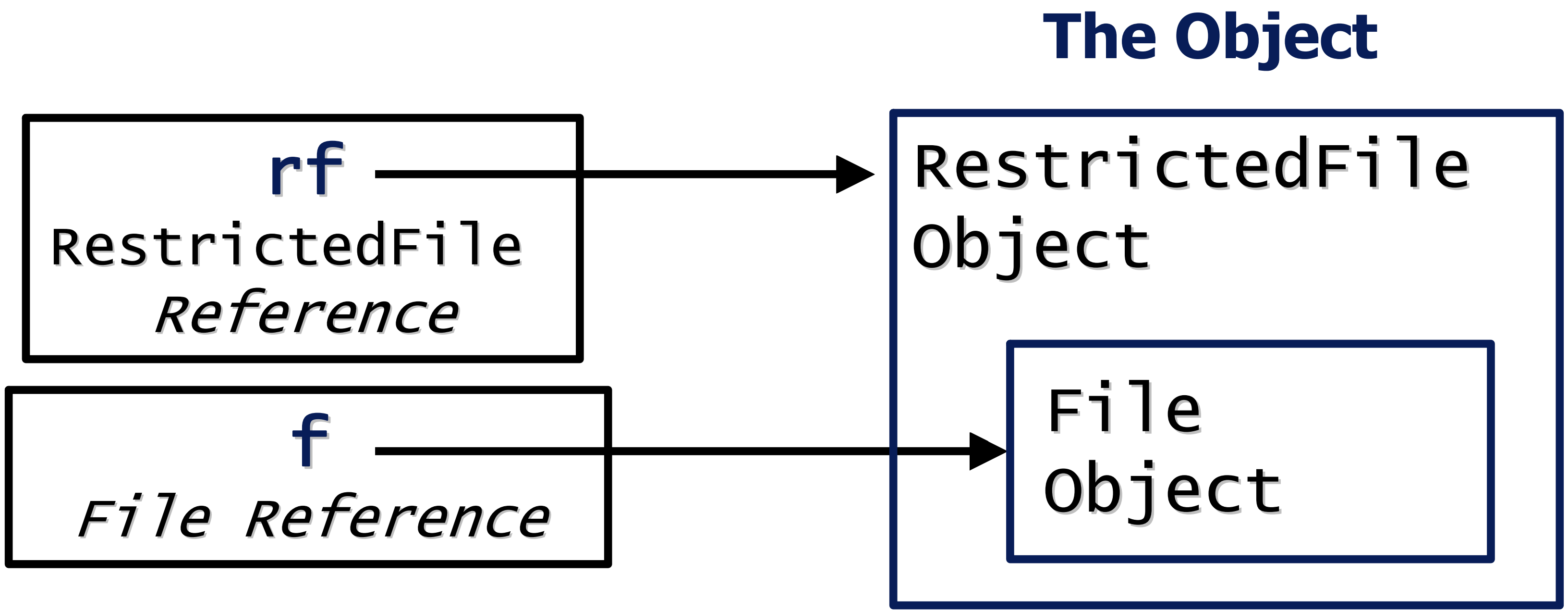
```
File f = new File(“story.txt”);
```

- But a `RestrictedFile` is also a `File`, so `f` can also refer to a `RestrictedFile` object

```
File f = new RestrictedFile(“mydoc.txt”);
```

The Reference Determines the View

- The type of the reference we use determines the point of view we will have on the object



View 1

- If we refer to a `RestrictedFile` object using a `RestrictedFile` reference we have the RestrictedFile point of view - we see all the methods that are defined in RestrictedFile and up the hierarchy tree

```
RestrictedFile rf = new
  RestrictedFile(
  “visa.dat”, 12345);
✓rf.lock();
✓rf.unlock(12345);
✓rf.close();
✓String s =
  rf.toString();
```

View 2

- If we refer to a `RestrictedFile` object using a `File` reference we have the File point of view - which lets us use only methods that are defined in class File and up the hierarchy tree.

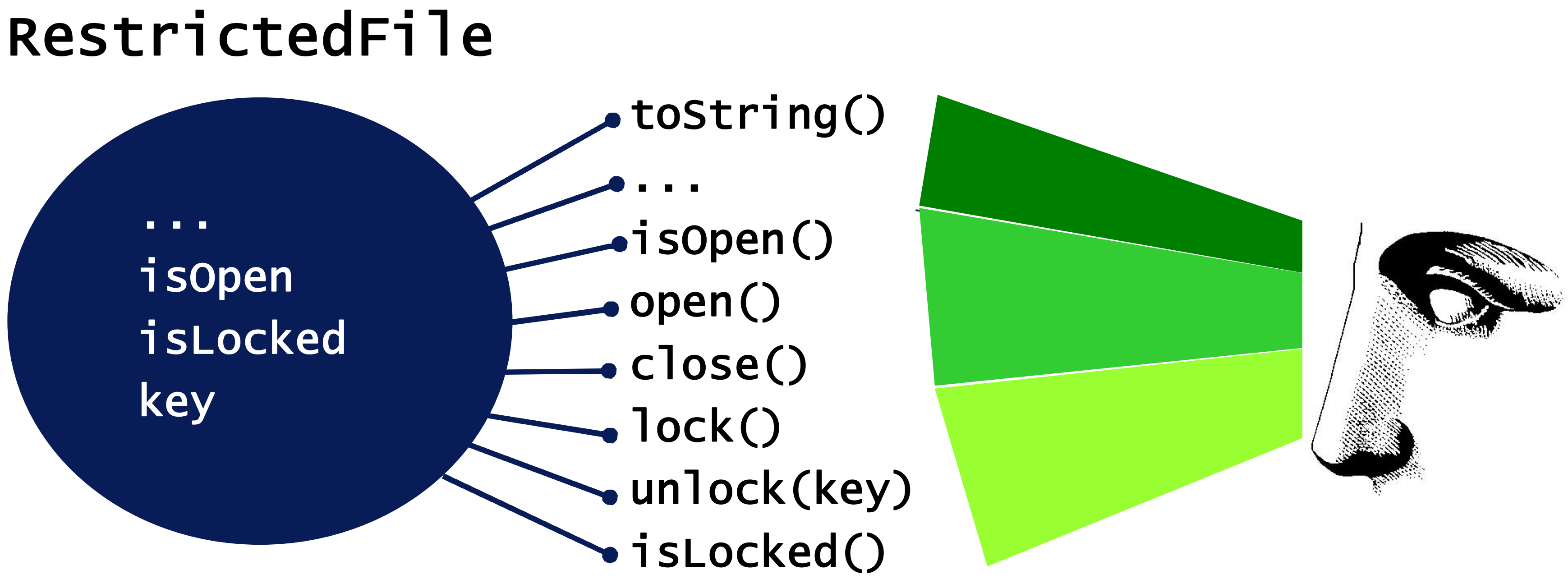
```
File f = new
 RestrictedFile(
 “visa.dat”, 12345);
✗f.lock();
✗f.unlock(12345);
✓f.close();
✓String s =
 f.toString();
```

View 3

- If we refer to a `RestrictedFile` object using an Object reference we have the Object point of view - which let us see only methods that are defined in class Object.

```
Object o = new
 RestrictedFile(
 “visa.dat”, 12345);
✗o.lock();
✗o.unlock(12345);
✗o.close();
✓ String s =
 o.toString();
```

Multiple Views



Object References and Inheritance

- An object reference can refer to an object of its class, or to an object of any class related to it by inheritance
- Assigning a descendant object to an ancestor reference is considered to be a widening conversion (upcast), and can be performed by simple assignment (implicit)
  - It is always possible to perform an upcast (relation is-a of inheritance)
- Assigning an ancestor object to a descendant reference can also be done, but it is considered to be a narrowing conversion (downcast) and must be done with a cast (explicit)
  - A downcast is not always possible; at runtime, the type of the object will be checked subclass (`instanceof`)

Widening

- Changing our point of view of an object, to a wider one (a less specific one) is called widening

```
File file;
file = new RestrictedFile((“visa”, 1234);
```

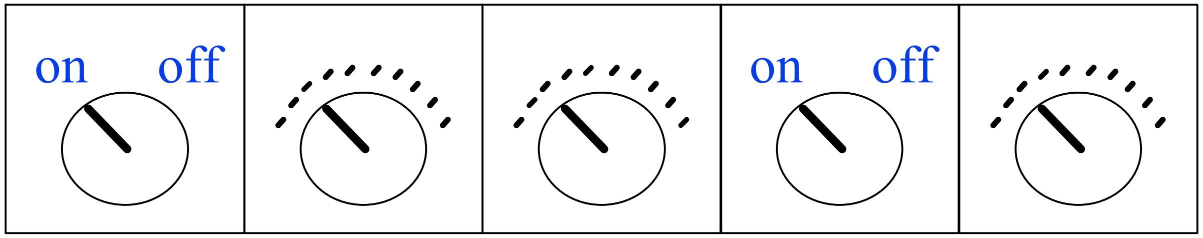
`File` reference
`File` point of view

`RestrictedFile` reference
`RestrictedFile` point of view

Widening

Heterogeneous Collections

- Widening is especially useful when we want to create a heterogeneous collection of objects
- For example, we want a class `SwitchPanel` that represents a panel of switches
  - Some of the switches in the panel are simple switches and some are adjustable switches
- When implementing our `SwitchPanel` class, we would like to store switches of both kinds in a single array, so we can easily write code that operates on both kinds of switches



SwitchPanel Example

```
/**
 * Represents a panel of switches
 */
public class SwitchPanel {
    // Holds all the switches in this panel
    private Switch[] switches;
    // constants representing the types of switches
    private final static int ADJUSTABLE_SWITCH = 1;
    private final static int REGULAR_SWITCH = 0;
    // ...here come SwitchPanel() constructor
    // and getConsumption() method
}
```

getConsumption() Method in Switch

- Suppose that we add the method **getConsumption**() in class **Switch** that returns the electrical consumption of the switch (which is 0 if the switch is off and **maxPower** if the switch is on)
- This method is overridden in class **AdjustableSwitch** (the consumption is 0 if the switch is off, or **level*maxPower/100** if it is on)

```
/**
 * An electronic switch that can be on/off.
 */
public class Switch {
  // ... same implementation as before
  // Returns the electrical consumption of the switch
  public float getConsumption() {
        return (isOn() ? maxPower : 0.0f);
     }
}
```

getConsumption() Override

```
/**
 * An adjustable electronic switch
 */
public class AdjustableSwitch extends Switch {
  // ... same implementation as before
  // Returns the electrical consumption of the switch
  public float getConsumption() {
     return
          super.getConsumption()*level/100;
    }
}
```

- We want to implement a method `getConsumption()` in class `SwitchPanel` that will compute the total electrical consumption of all the switches in the panel, whether they are adjustable switches or regular switches

SwitchPanel Constructor

```
// model is the name of the file that describes
// the panel
public SwitchPanel(String model) {
  int numberOfSwitches =
  // ...code for reading the numbers of switches
  switches = new Switch[numberOfSwitches];
  for (int i = 0; i < numberOfSwitches; i++) {
    int switchType = // ...read the switch type
    float maxPower = //...read maxPower
    if (switchType == REGULAR_SWITCH) {
      switches[i] = new Switch(maxPower);
    } else if (switchType == ADJUSTABLE_SWITCH {
      switches[i] = new AdjustableSwitch(maxPower);
    }
  }
}
```

getConsumption() Implementation

```
/**
 * Computes the total electricity consumption
 * of all the switches in the panel.
 */
public float getConsumption() {
   float total = 0.0f;
   for (int i = 0; i < switches.length; i++) {
      total += switches[i].getConsumption();
   }
   return total;
}
```

- We do not care if **switches[i]** refers to a regular **Switch** or an **AdjustableSwitch**, they both know how to compute their current consumption

Static versus Dynamic Binding

- In OOP calling a method is often referred to as sending a message to an object
  - ◆At runtime, the object responds to the message by executing the appropriate code of the method
- Binding refers to the association of a method invocation and the code to be executed on behalf of the invocation
  - ◆When we invoke a method on an object we always do it through a reference
- In static binding, all the associations are determined at compile time
  - ◆conventional function calls are statically bound
- In dynamic binding, the code to be executed in response to a method invocation (i.e., a message) will not be determined until runtime
  - ◆method invocations to objects are dynamically bound

Polymorphic Methods

- A method is polymorphic if the action performed by the method depends on the actual type of the object to which the method is applied
- In Java the code of the method which will be executed is dependent on the type of object (and not on the type of reference), and this type is determined at runtime

```
System.out.println(ref);
```

- is a message to the object referred to by `ref` (Which message?)
- Since the object knows of what type it is, it knows how to respond to the message:
  - If a `Switch` is referenced by `ref`, then `toString` method of `Switch` class is invoked
  - If `AdjustableSwitch` is referenced by `ref`, then `toString` method of `AdjustableSwitch` class is invoked

Polymorphic Methods: Example 1

If **pt** refers to **Switch**

```
public String toString() {
 return
  "(" + isOn + "," + maxPower ")";
}
```

```
System.out.println(pt);
```

If **pt** refers to **AdjustableSwitch**

```
public String toString() {
 return
  "(" + isOn + "," + maxPower ","
      + level + ")";
 }
```

Polymorphic Methods: Example 2

```
File file;
if (Math.random() >= 0.5) {
    file = new File();
} else {
    file = new RestrictedFile(“visa.dat”, 76543);
    // Recall that a RestrictedFile is
    // locked by default
}
file.open();
```

Will the file be opened if the number tossed < 0.5? - NO!

Polymorphic Methods: Example 2

```
public void workaroundAttempt(File file) {
    File workaroundReference = file;
    workaroundReference.open();
    //...
 }
...
...
workaroundAttempt(file);
```

Since file is of type `RestrictedFile`, this will invoke `open()` which is defined on restricted files and not on regular files. The workaround attempt will fail!!!

Static Methods Are Not Polymorphic!

- When we invoke a method on an object we always do it through a reference
- Static methods can be invoked using a class name! (but can also using a reference)
- They are resolved at compile time, when we do not know which type of object is actually referenced
  - Therefore they are NOT virtual, they depend on the type of reference

Narrowing

- We have seen how widening can be used in heterogeneous collections
- But if we look at all objects from a wide point of view, and would not be able to restore a more narrow view for some of them, there would not have been much point in having an heterogeneous collection in the first place

Narrowing Example

```
/**
 * Locks all the restricted files in the array
 * @param files The array of files to be locked
 */
public static void lockRestrictedFiles(File[] files)
{
  for (int i = 0; i < files.length; i++) {
    if (files[i] instanceof RestrictedFile) {
      RestrictedFile file = (RestrictedFile)files[i];
      file.lock();
    }
  }
}
```

`RestrictedFile` point of view ← **Narrowing** `File` **point of view**

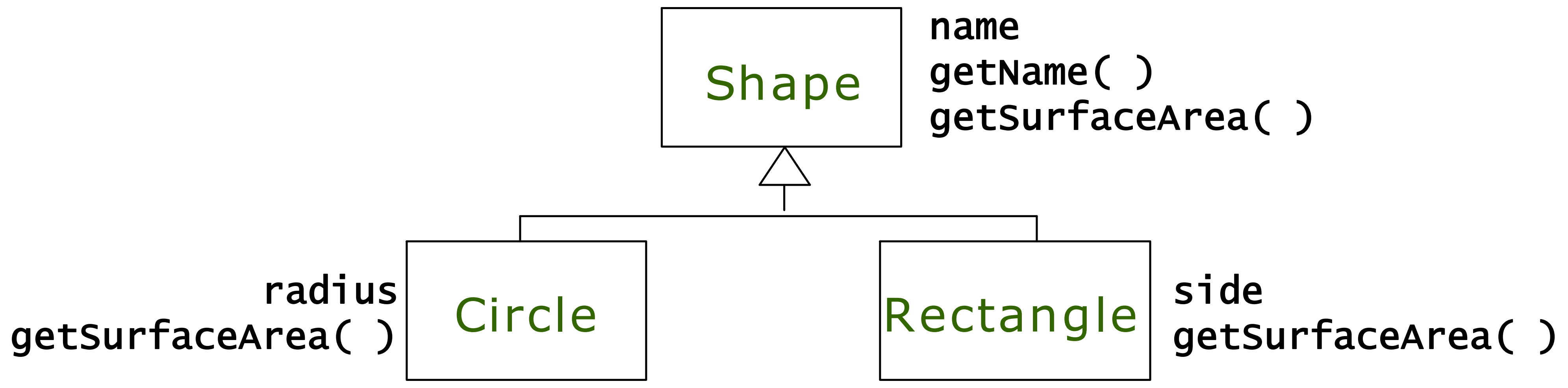
Narrowing - Equivalent Example

```
/**
 * Locks all the protected files in the array
 * @param files The array of files to be locked
 */
public static void lockRestrictedFiles(File[] files)
{
  for (int i = 0; i < files.length; i++) {
    if (files[i] instanceof RestrictedFile) {
      ((RestrictedFile)files[i]).lock();
    }
  }
}
```

Rules of Narrowing

- Narrowing let us restore a more specific point of view of an object using cast
- Casting a reference should be done only after verifying the object is indeed of the type we cast to!
- You cannot refer to an object through a `RestrictedFile` reference unless this object is indeed a RestrictedFile object!
- If we try to cast a `File` reference referring to a regular `File` object, into a `RestrictedFile`, a `ClassCastException` will be thrown

A More Complex Example: Geometric Shapes



```
class Shape {

   public final double PI=3.14159;
   protected String name;

   public String getName ()  {
        return (this.name);
   }  // getName
```

```
public int
     getSurfaceArea () {
       return (0);
   }  // area

} // Shape
```

A More Complex Example: Geometric Shapes

```
class Rectangle extends Shape {
   private int length, width;

   Rectangle () {
      this(0, 0); } // constructor

   Rectangle (int l, int w) {
      this( l, w, “rectangle”);
   } // constructor

   Rectangle (int l, int w,
              String n) {
      length = l; width = l;
      name = n; } // constructor

   public int getSurfaceArea () {
      return (length * width);
     } // area
```

```
  public String getName () {
   if (length == width)
      return ("square");
   else
      return (super.getName());
    }  // getName

  public String toString () {
    String s;
    s = new String ("A " +
        getName() +
        " with length " + length
        + " and width " + width);
    return (s);
   } // toString

} // Rectangle
```

Polymorphism is Possible Because of

- Inheritance: subclasses inherit attributes and method of the superclass.

```
public class Circle extends Shape {
  … …
}
```

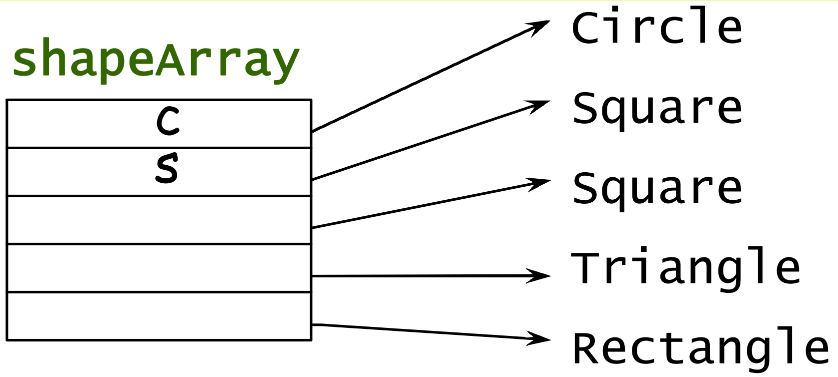
- Method overriding: subclasses can redefine methods that are inherited from the superclass

```
public class Shape {
  public float getSurfaceArea( ) {return 0.0f;}
  … …
}
public class Circle extends Shape {
  public float getSurfaceArea( ) {return (float)
  3.14f*radius*radius; }
  … …
}
```

Polymorphism is Possible Because of

- Polymorphic variables: variables that can hold value of different types (classes)

```
   Circle c = new Circle(“Circle C”);
   Square s = new Square(“Square S”);
   Shape shapeArray[ ] = {c, s};
```

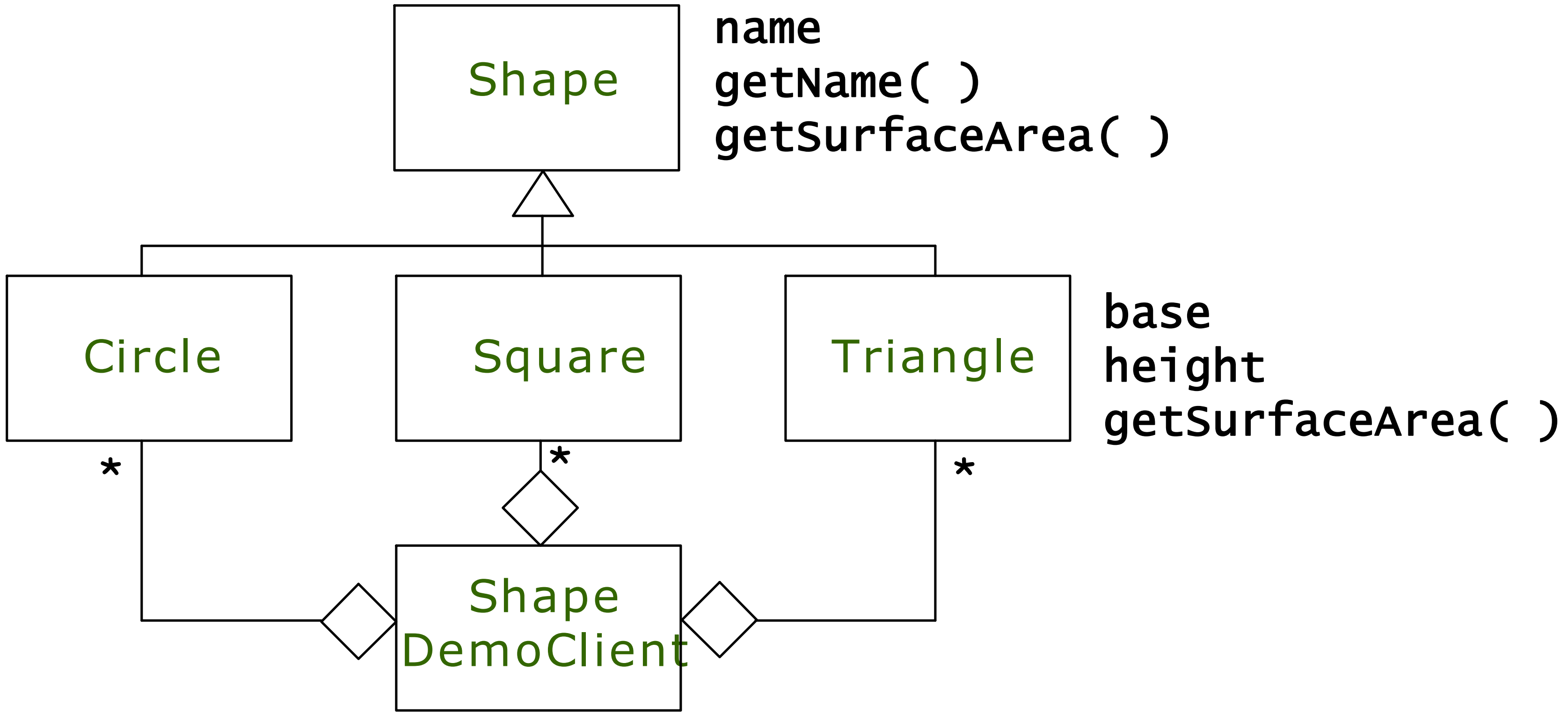


- Dynamic binding: method invocations are bound to methods during execution time

```
   for(int i = 0; i < shapeArray.lenth; i++)
       shapeArray[i].getSurfaceArea( ) ;
```

Impact of polymorphism on Software Development

- Incremental development
  - adding new class is made easy with inheritance and polymorphism



Impact of polymorphism on Software Development

```
public class Triangle extends Shape {
  private float base, height;
  public Triangle(String aName) {super(aName); base = 1.0f;
                                 height = 1.0f; }
  public Triangle(String aName, float base, float height)
    { super(aName); this.base = base; this.height = height; }
  public float getSurfaceArea( ) {return (float) 0.5f*base*height;}
} // End Triangle class
```

```
public class ShapeDemoClient {
  public static void main(String argv[ ]) {
    … …
    Triangle t = new Triangle(“Triangle T”, 4.0f, 5.0f);
    Shape shapeArray[ ] = {c1, c2, s1, s2, t};
    … …
    }
  } // End main
} // End ShapeDemoClient class
```

Impact of polymorphism on Software Development

- Increased code readability
  - polymorphism also increases code readability since the same message is used to call different objects to perform the appropriate behavior

```
for (i = 0; i < numShapes; i++)
  switch (shapeType[i]) {
    'c': calculateCircleArea(circles[c++] ); break;
    's': calculateSquareArea(squares[s++] ); break;
}
```

versus

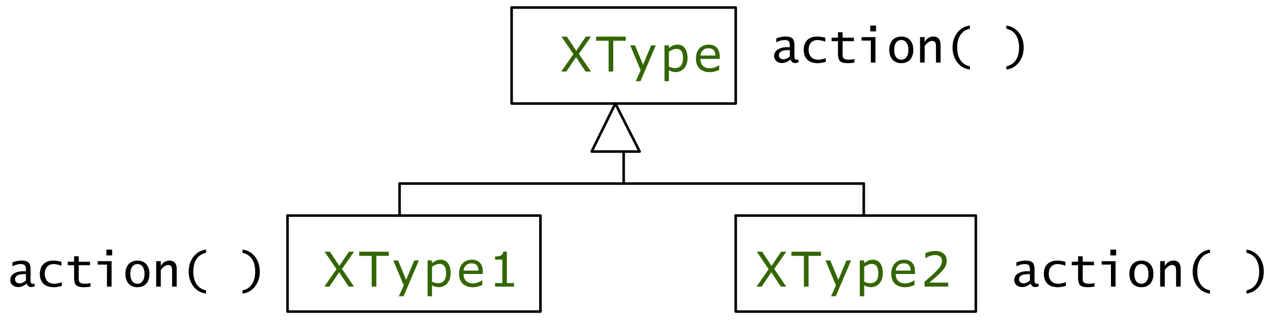
```
for(int i = 0; i < shapeArray.lenth; i++)
  shapeArray[i].calculateArea( );
```

Polymorphism Design Hints

- use polymorphism, not type information whenever you find the code of the form

```
if (x is of type 1)
  action1(x);
else if (x is of type 2)
  action2(x);
```

think polymorphism!



```
x.action( )
```

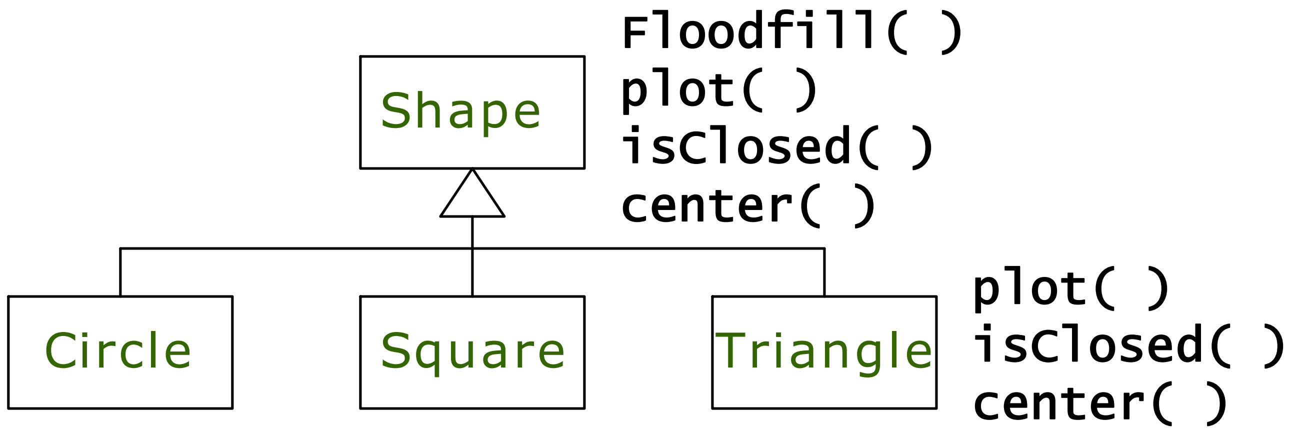
Polymorphism Design Hints

- move common behavior to the superclass
  - to flood fill a shape means to do the following:
    - plot the outline of the shape
    - if it isn't a closed shape, give up
    - find an interior point of the shape
    - fill the shape
  - these common behaviors can be put into the superclass Shape:

```
class Shape {
  ...
  public boolean
         floodfill(GraphicsPanel aPanel, Color aColor) {
    plot(aPanel);
    if ( ! isClosed( ) ) return false;
    Point aPoint = center( );
    aPanel.fill(aPoint.getX( ), aPoint.getY( ), aColor);
    return true;
  }
}
```

Polymorphism Design Hints

- Subclasses merely need to redefine: **`plot( )`**, **`isClosed( )`**, and **`center( )`**



```
Circle c = new Circle(“Circle C”);
Square s = new Square(“Square S”);
Triangle t = new Triangle(“Triangle T”);
Shape shapeArray[ ] = {c, s, t}
… …
for (int i = 0; i < shapeArray.length; i++)
  shapeArray[i].floodfill(aPanel, aColor);
...
```

Java Heterogeneous Collections of Objects

The Class Vector

- One of the most useful classes in the Java API is `java.util.Vector`
  - An array that dynamically resizes itself to whatever size is needed
  - You may add or remove objects from the vector at any position and its size grows and shrinks as needed to accommodate adding and removing items
- `Vector` is a class
  - Must have an object of type `Vector` instantiated via `new( )` to get an instance of `Vector`
- A `Vector` is designed to store `Object` references
  - Note that, because all classes inherit from the `Object` class, an `Object` reference can refer to any type of object
- All rules of good OO programming apply
  - Thus, access by requesting services via methods, not via direct access (such an array)

The Class Vector Contract

```
class Vector {
   public void     addElement( Object obj ) // adds to end
   public boolean  contains(Object elem)
   public Object   elementAt(int index) // returns reference to
                                          element at specified index
   public Object   firstElement()
   public int      indexOf(Object elem)
   public void     insertElementAt(Object obj, int index)
                                        // insertion into linked list
   public boolean  isEmpty()
   public Object   lastElement()
   public int      lastIndexOf(Object elem)
   public void     removeAllElements()
   public boolean  removeElement(Object obj)
   public void     removeElementAt(int index)
   public void     setElementAt(Object obj, int index) // overwrites that element
   public int      size() // returns current number of elements
}
```

Java Vectors

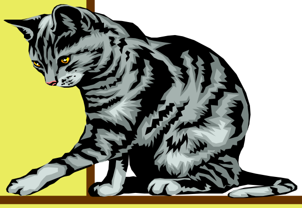
- Can be populated only with objects and not with primitives
- Can be populated with objects that contain primitives
  - If you need to populate them with primitives, use type wrapper classes e.g., `Integer` for `int`, etc.
- Will allow you to populate them with any type of object . . .
  - Thus, good programming requires that the programmer enforce typing within a Vector, because Java doesn't
- Capacity is dynamic
  - Capacity can grow and shrink to fit needs
  - Capacity grows upon demand
- Capacity shrinks when you tell it to do so via method **`trimToSize( )`**
  - It implies performance costs upon subsequent insertion
- When extra capacity is needed, then it grows by how much?
  - Depends on which of three constructors is used . . .

Java Vectors Capacity

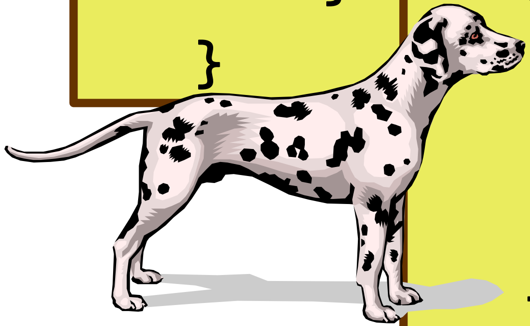
- Three Vector constructors:
  - `public Vector (int initialCapacity, int capacityIncrements);`
  - `public Vector (int initialCapacity);`
  - `public Vector( );`
  - `// there is another constructor taking as input a Collection (but we will not describe it now)`
- First constructor (2 parameters):
  - begins with **`initialCapacity`**
  - if/when it needs to grow, it grows by size `capacityIncrements`
- Second constructor (1 parameter):
  - begins with **`initialCapacity`**
  - if/when needs to grow, it grows by doubling current size
- Third constructor (no parameters):
  - begins with capacity of 10
  - if/when needs to grow, it grows by doubling current size

Vectors Example: Cats & Dogs…

```
class Cat {
    public String toString() {
        return new String(“meaw”);
    }
}
```

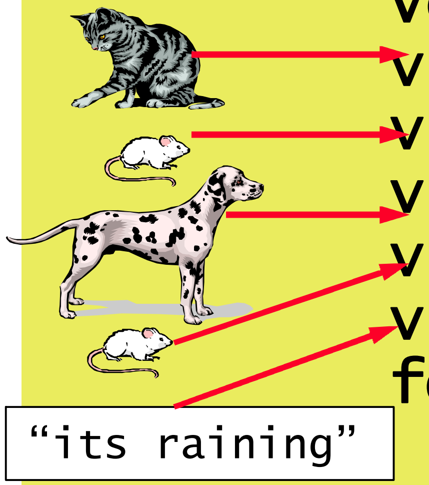


```
class Dog {
    public String toString() {
        return new String(“bark”);
    }
}
```



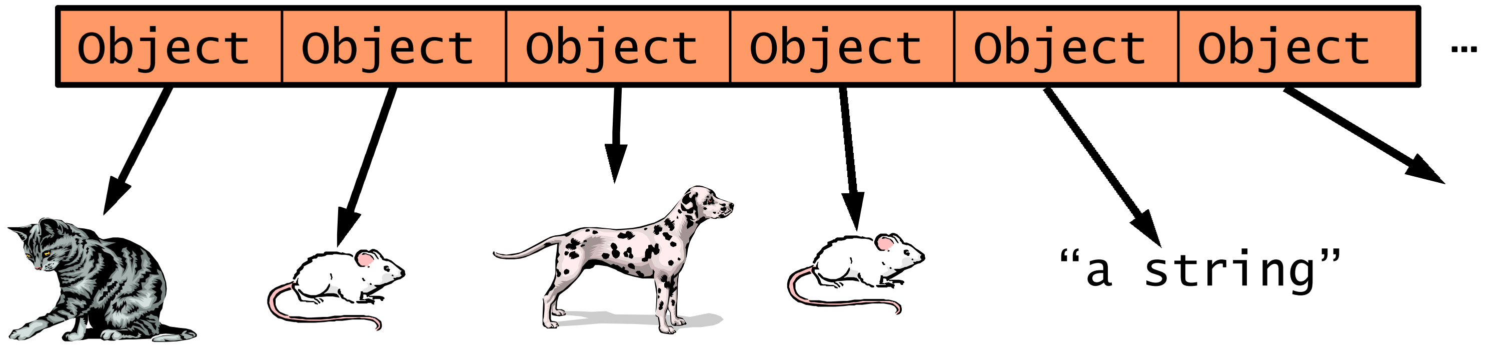
```
class Mouse {
    public String toString() {
        return new String(“squeak”);
    }
}
```

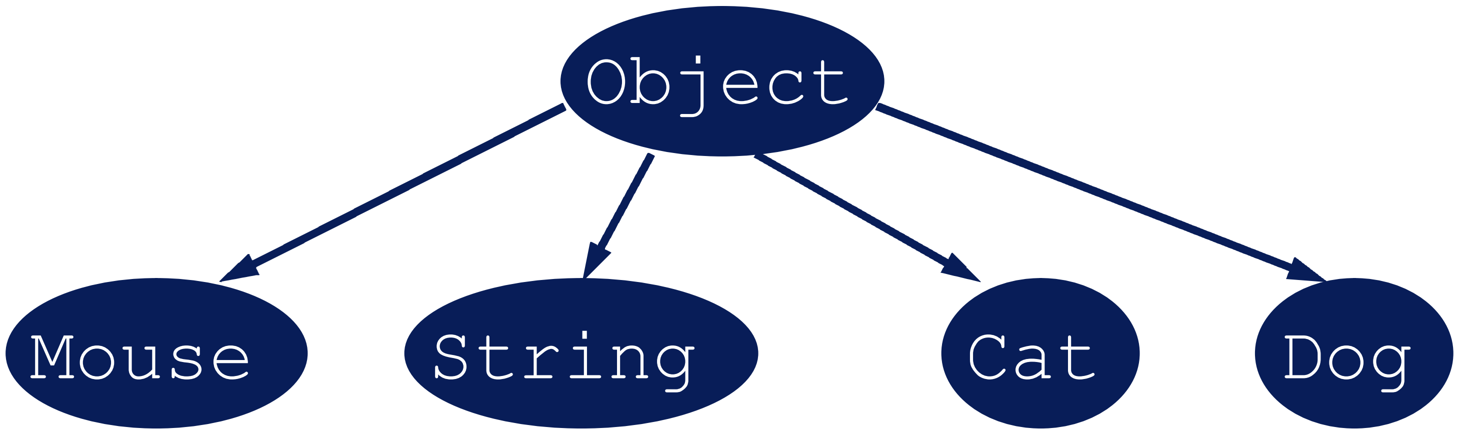
Vectors Example: Cats & Dogs...



```
class MouseTrap {
   public static void main(String[] args) {
       Vector v = new Vector();
       v.addElement(new Cat());
       v.addElement(new Mouse());
       v.addElement(new Dog());
       v.addElement(new Mouse());
       v.addElement(new String(“its raining”));
       for (int i = 0; i < v.size(); i++)
          System.out.println(v.elementAt(i));
       catchTheMice(v);
   }
```

The Vector Holds Object References





Vectors and Casting

- Vectors are a subclass of class **Object**
  - Thus, vectors can handle any class of object (i.e., no type checking)
- Thus, must cast any object obtained from a **Vector** before invoking any methods not defined in class **Object**

```
private static catchTheMice(Vector v) {
   int i = 0;
   while (i < v.size()) {
       if (v.elementAt(i) instanceof Mouse) {
           v.removeElementAt(i);
       } else {
           i++;
       }
   }
}
```

Vectors versus Arrays

- Arrays: statically sized
- Vectors: dynamically sized

- Arrays: can directly access, e.g., **`myArray[6]`**
  - but <u>shouldn't</u>
    (except maybe within the class in which they're declared if efficiency concerns; or for testing purposes.)

- Vectors: must use methods to access

- Vector services provide a good model for the Array services you should implement

Vectors versus Linked Lists

- Can use Vectors to simulate a Linked List:
  - Don't want direct access to data, so . . .
  - Provide methods for `getPrevious( )`, `getNext( )`, etc. that do the standard Linked List things
  - While the list is implemented as a Vector, the client uses it as if it's a Linked List
- BUT . . .
  - There are performance implications (that may or may not matter for a given instance)
  - What is the cost of:
    - insertion?
    - deletion?

Vectors versus Linked Lists

- For ordered Linked Lists:
  - cost of traversal to locate target: O(N)
  - cost of insert/delete: O(1)
  - total cost: O(N)

Thus, Vectors imply twice the work

- For ordered Vector:
  - cost of traversal to locate target: O(N) (if accessible via direct access, then O(1))
  - insertion or deletion of element implies (average case), moving O(N) elements
  - total cost: O(N)
- Thus, at first glance, equivalent…
- But what does Big Oh hide here?
  - Linked Lists: search thru N/2, plus insert/delete
  - Vectors: search thru N/2, plus moving N/2

Java vs. C++ Object Oriented Programming

- Similarities
  - User-defined classes can be used the same way as build-in types
  - Basic Syntax
- Differences
  - Methods (i.e., member functions) are the only function type
  - Object is the topmost ancestor for all classes
  - All methods use run-time and not compile-time types of objects (i.e., Java methods are like C++ virtual functions)
  - The type of all objects are known at run-time
  - It is always safe to return objects from methods
  - Single inheritance only