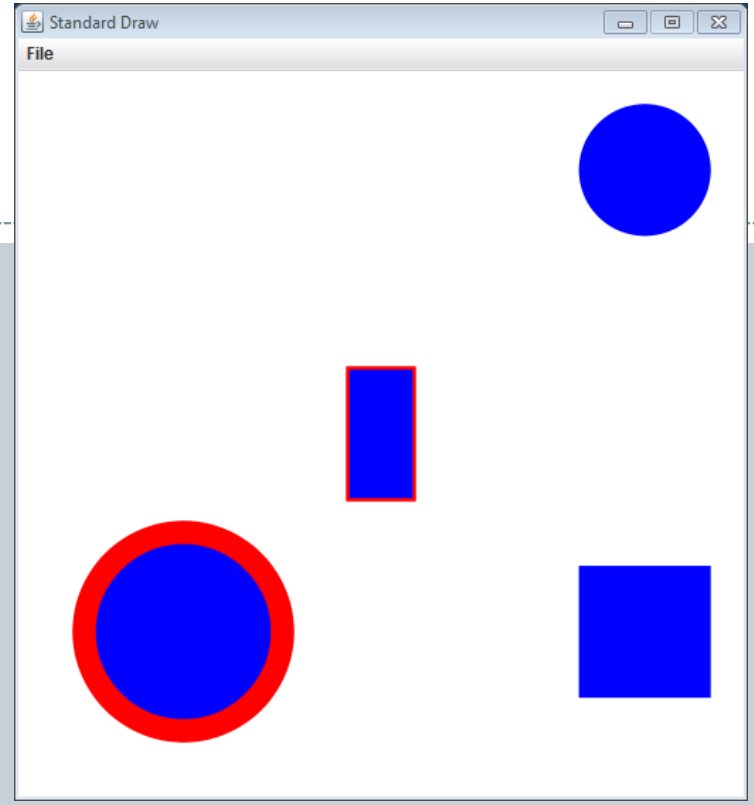
Polymorphism: Interfaces and Iteration

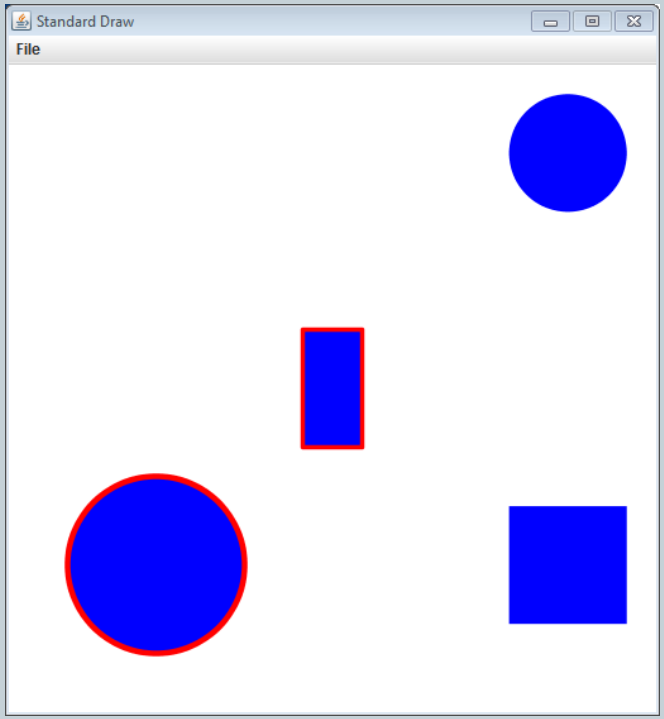


Outline

- A shape object hierarchy
  - Classes that *extend*
  - Versus classes that *implements*
- Java interfaces
  - How Java handles multiple-inheritance
  - A promise to implement a set of methods
    - Implementation left to class, all abstract methods
- Iteration
  - Moving through elements of a collection
  - In Java, class must implement iterable interface

Shape Object Hierarchy

- Represent shapes that can:
  - Draw themselves
  - Test for intersection with (x, y) coordinate
  - Change color
  - Support:
    - Circles
    - Rectangles
    - Circles with borders
    - Rectangles with borders



SHAPES

```
public abstract class Shape

private double x, y;
private Color color;

public           double getX();
public           double getY();
public            Color getColor();
public             void setColor(Color color);
public           double distance(double x, double y
public abstract    void draw();
public abstract boolean intersects(double x, double
```

```
public class Circle extends Shape

private double radius;

public  double getRadius();
public    void draw();
public boolean intersects(double x, double y);
```

```
publ

private do

public  do
public  do
public
public boolean intersects(double x, double y);
```

```
public class CircleBorder extends Circle

private double thickness;
private Color borderColor;

public   void draw();

public  Color getBorderColor();
public   void setBorderColor(Color color);
public double getBorderThickness();
public   void setBorderThickness(double thickness);
```

```
public class RectangleBorder extends Rectangle

private double thickness;
private Color borderColor;

public  void draw();

public Color getBorderColor();
public  void setBorderColor(Color color);
public  void getBorderThickness();
public  void setBorderThickness(double thickness);
```

1) Can we create a Shape object?
2) Which classes are abstract?
3) Which classes are concrete?
4) Which are subclasses of Shape?
5) Which are subclasses of Circle?
6) Which methods are overridden?
7) Which methods are overloaded?

Shapes with Borders

- CircleBorder and RectangleBorder
  - Share two identical instance variables
  - Share four identical methods
  - We'd like to consolidate to avoid repeated code

```
public class CircleBorder extends Circle
private double thickness;
private Color borderColor;

public   void draw();

public  Color getBorderColor();
public   void setBorderColor(Color color);
public double getBorderThickness();
public   void setBorderThickness(double thickness);
```

```
public class RectangleBorder extends Rectangle
private double thickness;
private Color borderColor;

public  void draw();

public Color getBorderColor();
public  void setBorderColor(Color color);
public  void getBorderThickness();
public  void setBorderThickness(double thickness);
```

SHAPES

Option 1: Move into Shape Base Class

```
public abstract class Shape

private double x, y;
private Color color;
private double thickness;
private Color borderColor;

public           double getX();
public           double getY();
public            Color getColor();
public             void setColor(Color color);
public           double distance(double x, double y);
public abstract    void draw();
public abstract boolean intersects(double x, double y);

public             Color getBorderColor();
public              void setBorderColor(Color color);
public            double getBorderThickness();
public              void setBorderThickness(double thickness);
```

This works and does share implementation, *but*:

Now `Circle` and `Rectangle` also have instance variables and methods related to having a border.

They have an API that *lies*.

```
public class Circle extends Shape

private double radius;

public  double getRadius();
public    void draw();
public boolean intersects(double x, double y);
```

```
public class Rectangle extends Shape

private double width, height;

public  double getWidth();
public  double getHeight();
public    void draw();
public boolean intersects(double x, double y);
```

```
public class CircleBorder extends Circle

public void draw();
```

```
public class RectangleBorder extends Rectangle

public void draw();
```

SHAPES

Option 2: Multiple Inheritance

abstract class Shape

```
private double x, y;
private Color color;

public           double getX();
public           double getY();
public            Color getColor();
public             void setColor(Color color);
public           double distance(double x, double y);
public abstract    void draw();
public abstract boolean intersects(double x, double y);
```

This does *NOT* work.

Java does not support multiple inheritance.

You can only extend a single class.

class Circle extends Shape

```
private double radius;

public  double getRadius();
public    void draw()
public boolean inters
```

class Rectangle extends Shape

```
private double width, height;

public  double getWidth();

                    , double y);
```

abstract class Bordered

```
private double thickness;
private Color borderColor;

public            Color getBorderColor();
public             void setBorderColor(Color color);
public           double getBorderThickness();
public             void setBorderThickness(double thickness);
```

class CircleBorder extends Circle, Border

```
public void draw();
```

class RectangleBorder extends Rectangle, Border

```
public void draw();
```

Java Interfaces

- Java's alternative to multiple inheritance
  - Classes promise to implement same API
    - An interface is just a list of abstract methods
    - If two classes implement same interface, they can live in the same array for polymorphic goodness
  - Example uses:
    - Allow any object type to be sorted
    - For-each (enhanced) loops
    - GUI event listeners
      - e.g. When a button is pushed
    - Classes that can run in their own thread

Bordered Interface

```
// Interface for a shape that has a border th
// different color and has a variable pen thi
public interface Bordered
{
   Color getBorderColor();
    void setBorderColor(Color color);
  double getBorderThickness();
    void setBorderThickness(double thickness);
}
```

Methods declared in an interface are abstract and public by default.

Implementation is not allowed.
(except for default methods, added in Java 1.8)

Also no instance variables allowed (except for constants declared `public static final`).

A class adds `implements Bordered` to the class declaration.

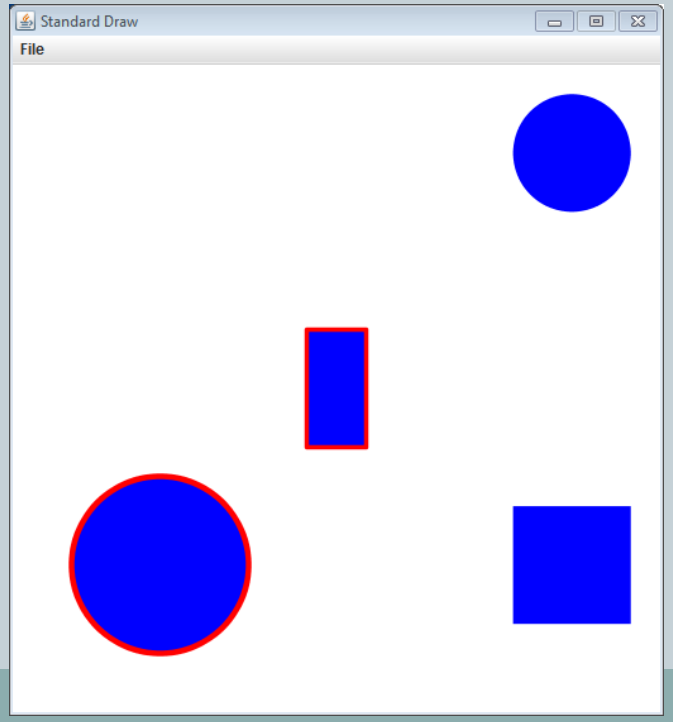
The class must then implement the four methods in interface Bordered.

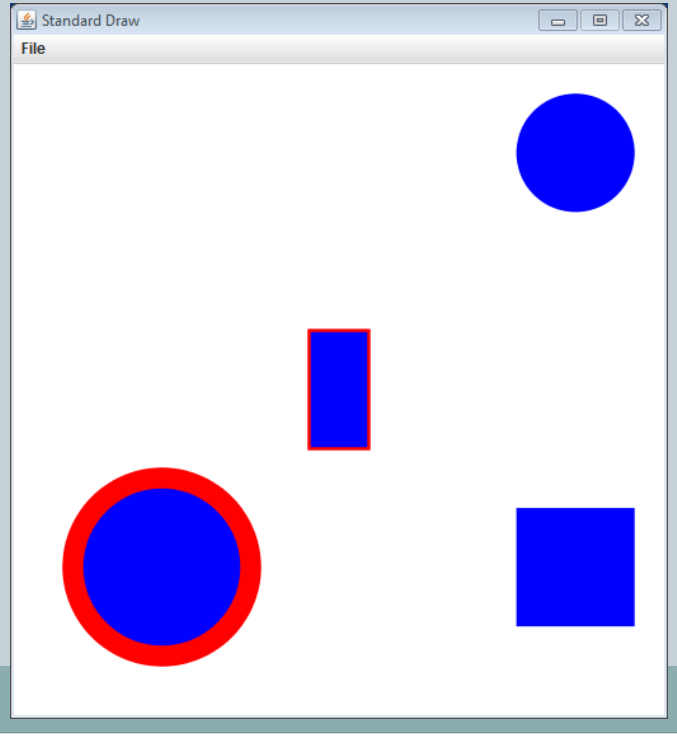
```
public class CircleBorder extends Circle implements Bordered
```

```
public class RectangleBorder extends Rectangle implements Bordered
```

GrowShape

- Show a bunch of Shape objects
  - If mouse is over a shape:
    - Temporarily change object's color
    - If object has a border, permanently grow the border





```java
public static void main(String [] args)
{
   Shape [] shapes = new Shape[4];

   shapes[0] = new RectangleBorder(0.5, 0.5, 0.1, 0.2);
   shapes[1] = new CircleBorder(0.2, 0.2, 0.15);
   shapes[2] = new Circle(0.9, 0.9, 0.1);
   shapes[3] = new Rectangle(0.9, 0.2, 0.2, 0.2);

   while (true)
   {
      StdDraw.clear();
      double x = StdDraw.mouseX();
      double y = StdDraw.mouseY();
      for (Shape shape : shapes)
      {
         if (shape.intersects(x, y))
         {
            shape.setColor(new Color(0.3f, 0.1f, 0.5f));
            if (shape instanceof Bordered)
            {
               Bordered bordered = (Bordered) shape;
               double currentThickness = bordered.getBorderThickness();
               bordered.setBorderThickness(currentThickness + 0.001);
            }
         }
         else
            shape.setColor(new Color(0.0f, 0.0f, 1.0f));

         shape.draw();
      }
      StdDraw.show(100);
   }
}
```

Polymorphic array holding objects in the `Shape` hierarchy. Some have borders, some don't.

Only increase the border on objects that implements the `Bordered` interface.

You must check using `instanceof` before casting object.

Loops over Things in a Collection

- Enhanced for-loop
  - Move through all items in many data types
    - e.g. arrays, `ArrayList`, `HashSet`, `Stack`, `LinkedList`
  - Caller doesn't know how items stored
  - Requires type implement the iterable interface
- Many Collections in Java are already iterable
  - http://docs.oracle.com/javase/8/docs/api/java/lang/Iterable.html

Examples of Iteration with Built-In Classes

```
String [] namesA = new String[2];
namesA[0] = "Bob";
namesA[1] = "Abe";
for (String s: namesA)
   System.out.println("array: " + s);

ArrayList<String> namesB = new ArrayList<String>();
namesB.add("Bob");
namesB.add("Abe");
for (String s: namesB)
   System.out.println("ArrayList: " + s);

HashSet<String> namesC = new HashSet<String>();
namesC.add("Bob");
namesC.add("Abe");
for (String s: namesC)
   System.out.println("HashSet: " + s);

Stack<String> namesD = new Stack<String>();
namesD.push("Bob");
namesD.push("Abe");
for (String s: namesD)
   System.out.println("Stack: " + s);

LinkedList<String> namesE = new LinkedList<String>();
namesE.add("Bob");
namesE.add("Abe");
for (String s: namesE)
   System.out.println("LinkedList: " + s);
```

```
array: Bob
array: Abe



ArrayList: Bob
ArrayList: Abe


HashSet: Abe
HashSet: Bob



Stack: Bob
Stack: Abe


LinkedList: Bob
LinkedList: Abe
```

The order of iteration through objects depend on the collection and its implementation.

Looping with Iterators

```
ArrayList<String> list = new ArrayList<String>();
list.add("Abe");
list.add("Bob");
list.add("Carol");

for (String s : list)
   System.out.println(s);


Iterator<String> i = list.iterator();
while (i.hasNext())
{
   String s = i.next();
   System.out.println(s);
}
```

Create some iterable collection.

Normal enhanced for-loop version printing out all the elements.

Using iterator object to explicitly loop over all elements in collection.

- To make a collection iterable:
  - Must implement an `iterator()` method that returns an `Iterator` object
  - The `Iterator` class must include two methods:
    - `hasNext()` - Returns a `boolean` indicating if there are more items
    - `next()` - Returns an item from the collection
    - http://docs.oracle.com/javase/8/docs/api/java/util/Iterator.html

Iterators Implement an Interface

```
public interface Iterator<Item>
{
   boolean hasNext();
   Item next();
   void remove();
}
```

"Removes from the underlying collection the last element returned by the iterator (optional operation)."

-Java API

"Interleaving iteration with operations that modify the data structure is best avoided."

-Robert Sedgewick, Kevin Wayne

- Iterable collections return an `Iterator` object
  - Object tracks where we are within the collection
  - For a collection backed by an array → integer index
  - For a collection backed by a linked list → a pointer

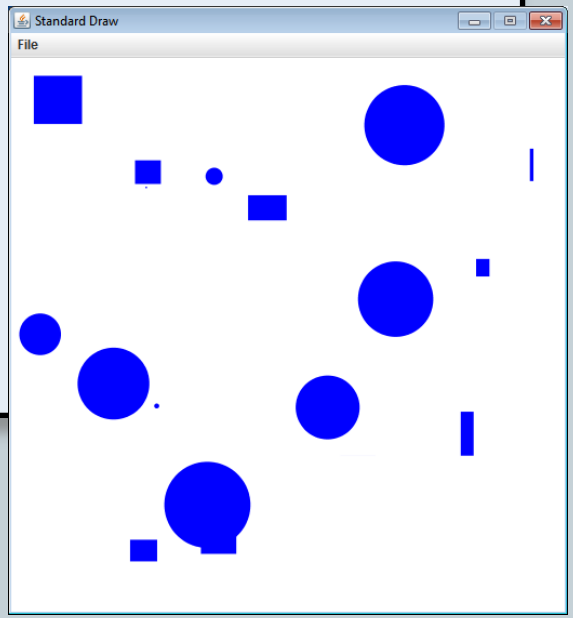
Collection of Random Shapes

```
public class RandomShapes
{
    private Shape [] shapes;

    public RandomShapes(int num)
    {
        if (num <= 0)
            return;
        shapes = new Shape[num];
        for (int i = 0; i < num; i++)
        {
            double x    = Math.random();
            double y    = Math.random();
            if (Math.random() < 0.5)
                shapes[i] = new Circle(x, y, Math.random() * 0.1);
            else
                shapes[i] = new Rectangle(x, y, Math.random() * 0.1, Math.random() * 0.1);
        }
    }

    public static void main(String [] args)
    {
        RandomShapes shapes = new RandomShapes(20);
        for (Shape s : shapes)
            s.draw();
    }
}
```

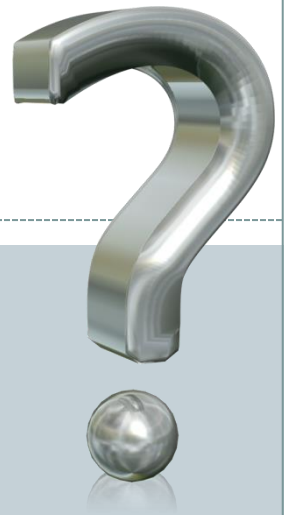
Can only iterate over an array or an object that implements `java.lang.Iterable`

Making Random Shapes Iterable

```
import java.util.Iterator;

public class RandomShapes implements Iterable<Shape>
{
    private Shape [] shapes;

    public Iterator<Shape> iterator()
    {
        return new ArrayIterator();
    }

    private class ArrayIterator implements Iterator<Shape>
    {
        private int i = 0;
        public boolean hasNext() { return i < shapes.length; }
        public Shape next()      { return shapes[i++];       }
        public void remove()     {                           }
    }
    ...
}
```



Summary



- Shape object hierarchy
  - Circle and Rectangle branches
  - CircleBorder and RectangleBorder
    - Share functionality with each other, but not with parent class
- Java interfaces: Promise to implement an API
  - Objects unrelated by inheritance can live in same array
  - A class can implement multiple interfaces
  - Used by Java for sorting objects and much more
- Iteration: Move through a collection's objects
  - Without knowledge of underlying data structure
  - Implements the iterable interface