Shapes, Inc.

We have been hired to model the business objects of Shapes, Inc. Following are their requirements.

1. All Shapes have an (x, y) position marking the Shape center
2. All Shapes are **red**
3. All Shapes respond to a request to display itself

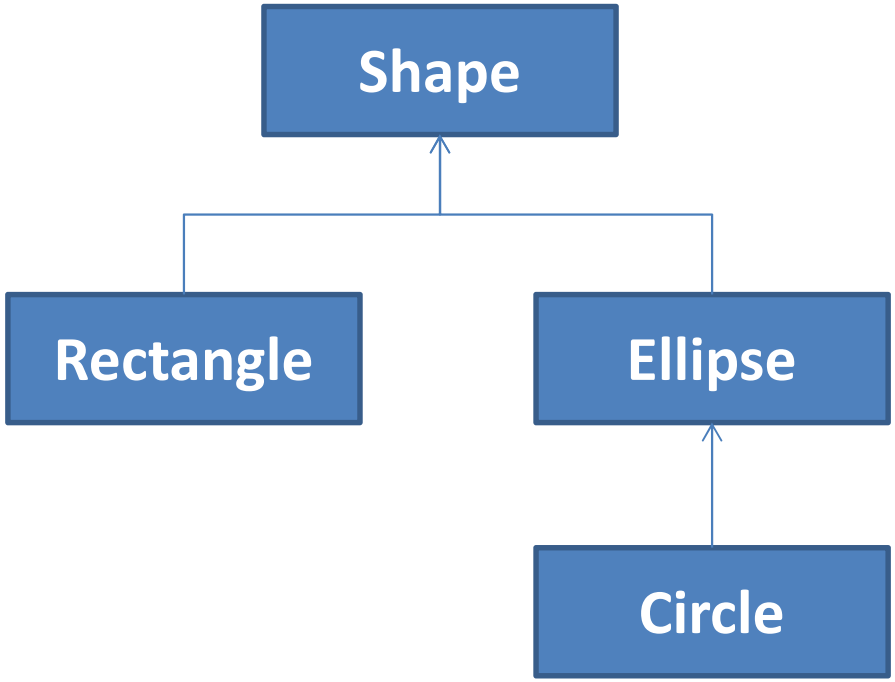
4. A Rectangle is a kind of Shape
5. An Ellipse is a kind of Shape
6. A Circle is a kind of Ellipse

7. An Ellipse turns white when the mouse hovers over it.
8. All Shapes can be dragged.

Questions

- What color is a Rectangle?
- How does a Circle specialize an Ellipse?
- What color is a Circle when the mouse is over it?

Modeling the Shapes, Inc. Business



A Shape Class

```
class Shape {
  float x;
  float y;
  color c;

  // Constructor
  Shape( float x, float y ) {
    this.x = x;
    this.y = y;
    this.c = color(255, 0, 0);
  }

 // Display the Shape
  void display() {
    fill(c);
    text("?", x, y);
  }
}
```

1. Shapes have a position

2. Shapes are red

3. Shapes respond to display

shapes1.pde

The `this` keyword

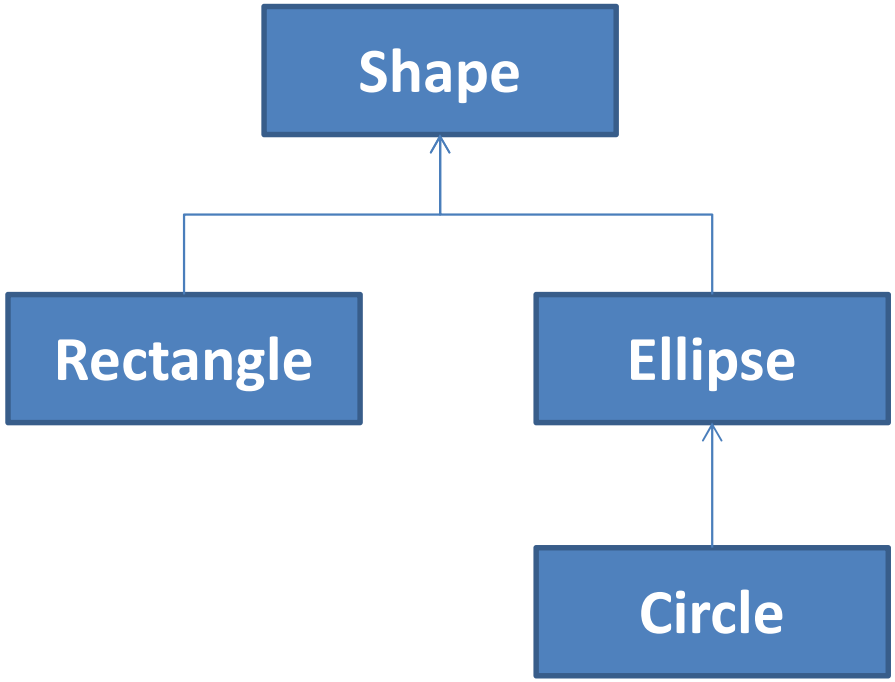
- Within an object, `this` is a shorthand for the object itself
- The most common use of `this` is to avoid a field access problems that occur due to shadowing
- The use of `this` explicitly changes the scope to the object level

- Reconsider the Shape constructor…

How to set up relationships?

Question:

If all Shapes have a position and all Shapes are red, how can we grant these properties to Rectangle and Ellipse, without reproducing them in every class?



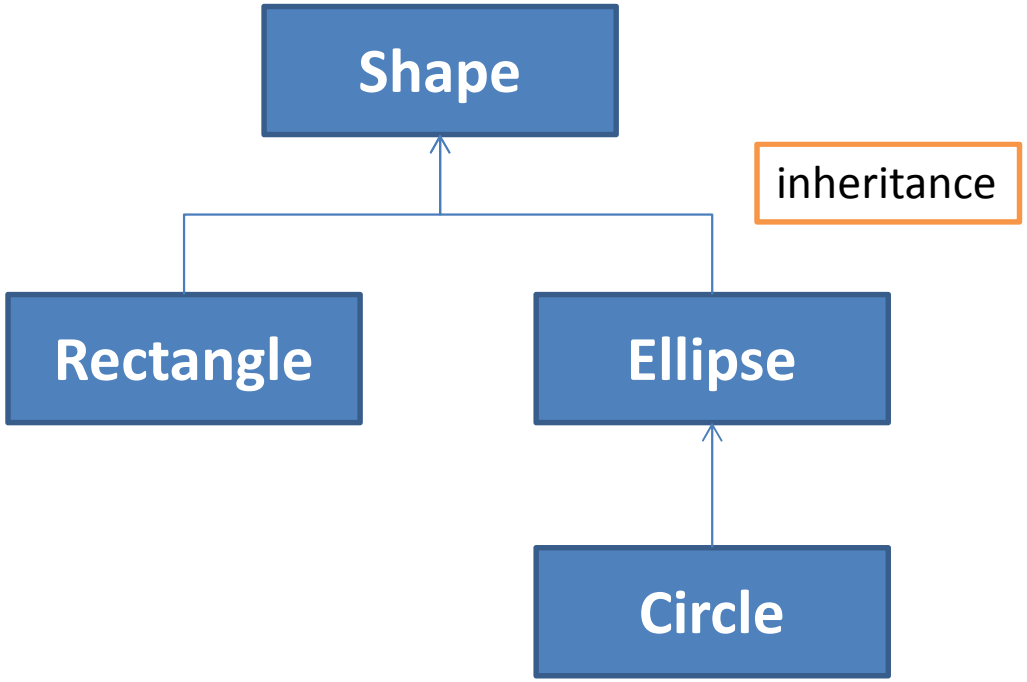
In a way, Rectangle and Ellipse `extend` the standard Shape object with specialized ways of displaying themselves.

How to set up relationships?

Answer:

We can set up an explicit relationship between Rectangle and Shape, and between Ellipse and Shape call ***Inheritance.***

This will automatically cause Shape fields and methods to be available to Rectangle and Ellipse.



Inheritance – Some Terminology

- A new class (subclass) can be declared to extend the behavior of an existing class (superclass)
  - A subclass is aka: derived class, child class, …
  - A superclass is aka: base class, parent class,
- A subclass automatically gets access to (i.e. inherits) all members of the superclass
  - Members include both fields and methods
- A subclass can override the members of its superclass by re-declaring them
  - Think of variable shadowing, but now for methods too

```
class Rectangle extends Shape {
  float w;
  float h;

  Rectangle( float x, float y, float w, float h) {
    super(x, y);
    this.w = w;
    this.h = h;
  }

  // Display the Ellipse
  void display() {
    fill(c);
    rect(x, y, w, h);
  }
}
```

sets up the inheritance relationship

adds two new fields, width and height

invokes the superclass constructor

overrides the Shape display() method

Where does a Rectangle find x and y?

shapes2.pde

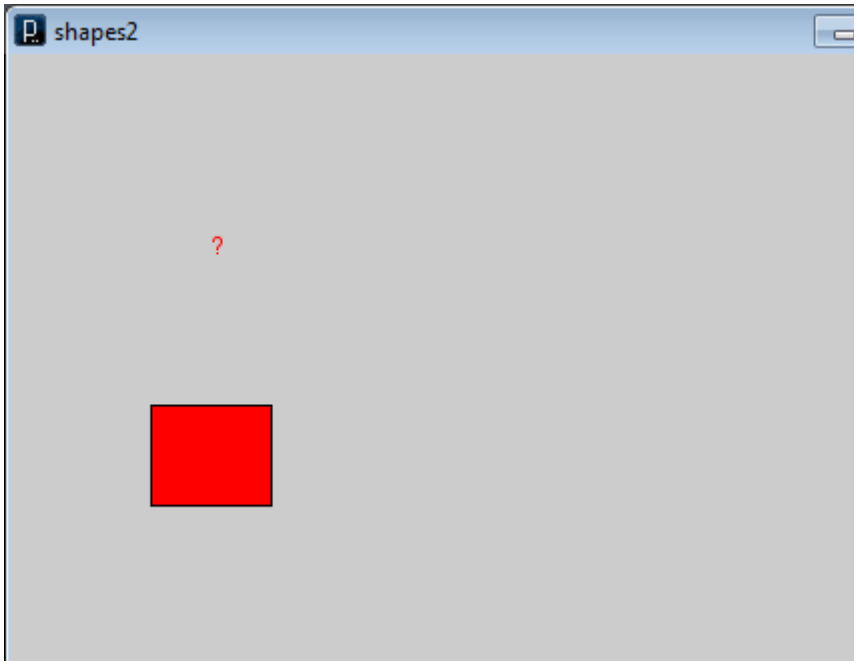
The `super` keyword

- Within an object, `super` is a shorthand for the superclass of the current object
- The most common use of `super` is to invoke a superclass constructor
- The use of `super` explicitly changes the scope to the superclass level

Test it

```
void setup() {
  size(500, 500);

  Shape     s = new Shape(100, 100);
  Rectangle r = new Rectangle (100, 200, 60, 50);

  s.display();
  r.display();
}
```

Note: The Rectangle knows where to draw itself, even though it does not have an x or y field. It inherits x and y from Shape.



shapes2.pde

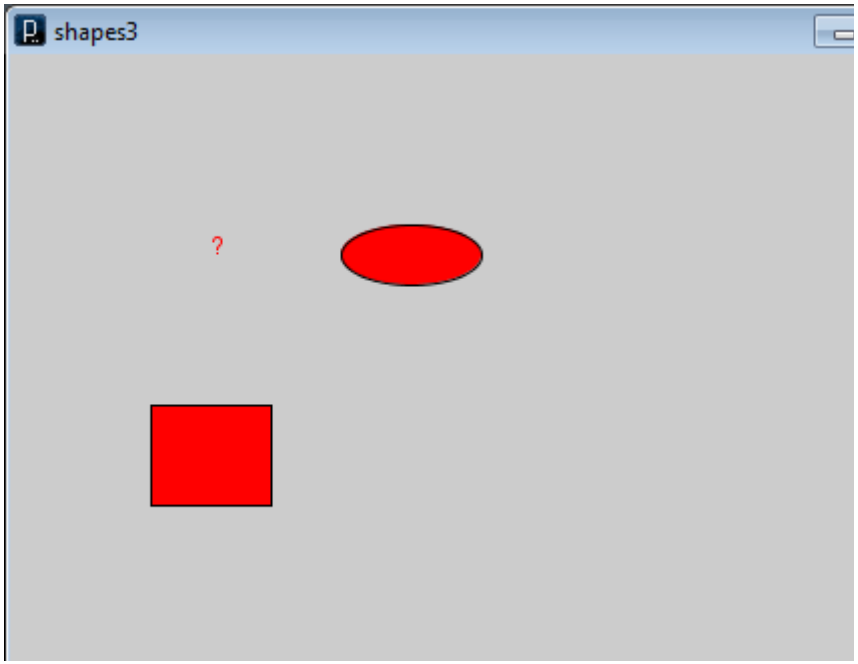
The Ellipse Class

```
class Ellipse extends Shape
{
  float w;
  float h;

  Ellipse( float x, float y, float w, float h) {
    super(x, y);
    this.w = w;
    this.h = h;
  }

  // Display the Ellipse
  void display() {
    fill(c);
    ellipse(x, y, w, h);
  }
}
```

shapes3.pde

Test it

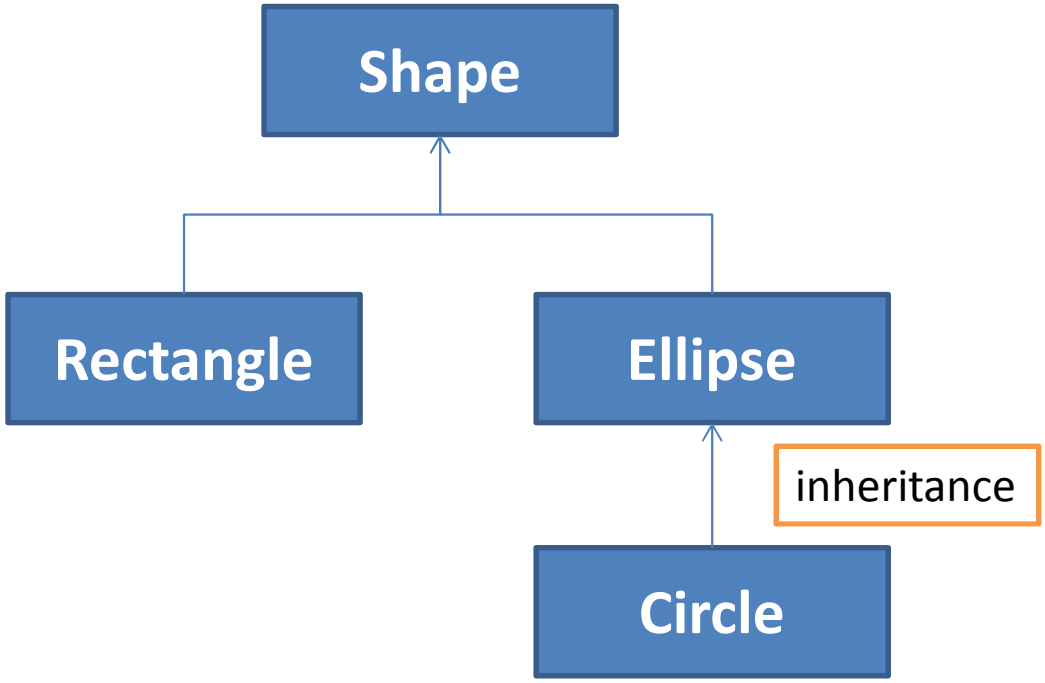
```
void setup() {
  size(500, 500);
  smooth();
  ellipseMode(CENTER);
  rectMode(CENTER);

  Shape     s = new Shape(100, 100);
  Rectangle r = new Rectangle (100, 200, 60, 50);
  Ellipse   e = new Ellipse(200, 100, 70, 30);

  s.display();
  r.display();
  e.display();
}
```



shapes3.pde

Inheritance, Cont'd

- Inheritance hierarchies can be used to establish multiple layers of objects



The Circle Class

```
class Circle extends Ellipse
{
  float r;

  Circle( float x, float y, float r ) {
    super(x, y, 2*r, 2*r);
    this.r = r;
  }
}
```

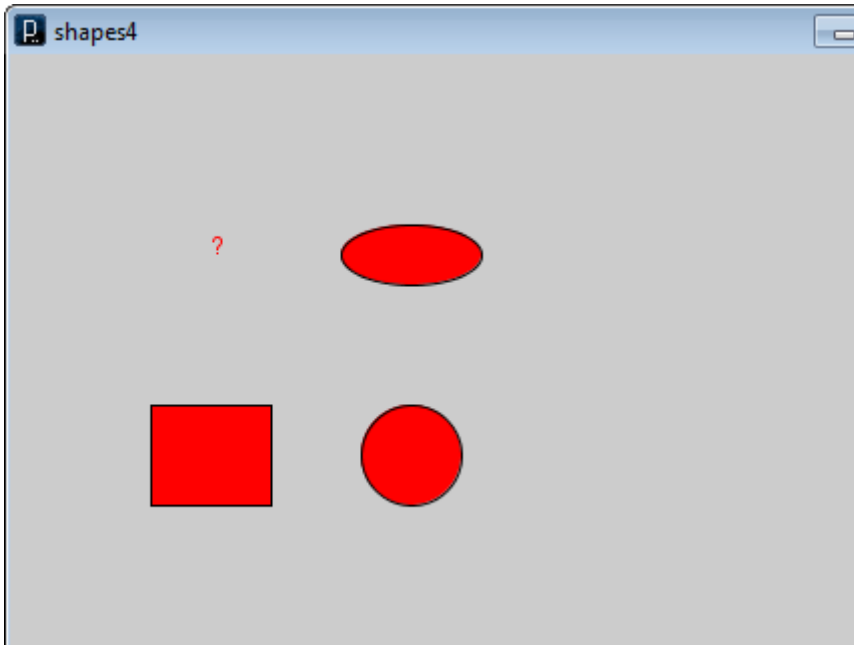
adds only a radius field

translates radius to Ellipse constructor width and height arguments

shapes4.pde

Test it

```
void setup() {
  size(500, 500);
  smooth();
  ellipseMode(CENTER);
  rectMode(CENTER);

  Shape     s = new Shape(100, 100);
  Rectangle r = new Rectangle(100, 200, 60, 50);
  Ellipse   e = new Ellipse(200, 100, 70, 30);
  Circle    c = new Circle(200, 200, 25);

  s.display();
  r.display();
  e.display();
  c.display();
}
```



shapes4.pde

Polymorphism

poly = many, *morph* = form

In Biology, when there is more than one form in a single population

Light-morph jaguar (typical)

Dark-morph or melanistic jaguar (about 6% of the South American population)

In Computing, we have two common types of Polymorphism

1. Signature Polymorphism
2. Subtype Polymorphism

http://en.wikipedia.org/wiki/Polymorphism_%28biology%29

Signature Polymorphism

- It is possible to define multiple functions with the same name, but different signatures.
  - A *function signature* is defined as
    - The function name, and
    - The order and type of its parameters

- Consider the built-in color() function …

```
color(gray)
color(gray, alpha)
color(value1, value2, value3)
color(value1, value2, value3, alpha)
…
```

Signature Polymorphism

```
void draw() { }

void mousePressed() {
  int i;
  i = 10;
  i = increment(i, 2);
  //i = increment(i);
  println(i);
}

// increment a variable
int increment(int j, int delta) {
  j = j + delta;
  return j;
}

int increment(int k) {
  k = increment(k, 1);
  return k;
}
```

In this case it is said that the increment function is ***overloaded***

Subtype Polymorphism

- Inheritance implements Subtype Polymorphism
  - A Rectangle is a type of Shape
  - An Ellipse is a type of Shape
  - A Circle is a type of Ellipse

- Implication:
  - A Rectangle can be stored in a variable of type Shape
  - What about Ellipses, Circles?

Using Subtype Polymorphism

Store everything that is a type of Shape in an array of Shapes.

```
Shape[] shapes = new Shape[3];

void setup() {
  size(500, 500);
  smooth();
  ellipseMode(CENTER);
  rectMode(CENTER);

  shapes[0] = new Rectangle(100, 200, 60, 50);
  shapes[1] = new Ellipse(200, 100, 70, 30);
  shapes[2] = new Circle(200, 200, 25);

  for (int i=0; i<shapes.length; i++) {
    shapes[i].display();
  }
}
```

an array of Shapes

all objects that are Shape subclasses can be stored in the array, even Circle

now we can use a loop

shapes5.pde

containsPoint()

- Let's give each shape a containsPoint() method that returns a boolean
  - Returns true if the shape contains a given point
  - Returns false otherwise

- Each subclass must implement a different version of containsPoint() because each uses a different calculation.

containsPoint() for Shape

- By default, the abstract Shape object cannot determine if it contains a point
- Always return false

```
class Shape {
  …
  // Test if a point is within a Shape
  boolean containsPoint( float x, float y ) {
    return false;
  }
}
```

shapes6.pde

containsPoint() for Rectangle

– Test the location of the point wrt the locations of Rectangle sides

```
class Rectangle extends Shape {
  …
  // containsPoint() for Rectangle
  boolean containsPoint( float x, float y ) {
    float w2 = 0.5*w;
    float h2 = 0.5*h;
    if (x < this.x-w2) { return false; }
    if (x > this.x+w2) { return false; }
    if (y < this.y-h2) { return false; }
    if (y > this.y+h2) { return false; }
    return true;
  }
}
```

shapes6.pde

containsPoint() for Ellipse

– Use a special formula to determine if a point is in an Ellipse

```
class Ellipse extends Shape {
  …
  // containsPoint() for an Ellipse
  boolean containsPoint( float x, float y ) {
    float dx = x - this.x;
    float dy = y - this.y;
    float hw = 0.5*w;
    float hh = 0.5*h;
    if ( (dx*dx)/(hw*hw) + (dy*dy)/(hh*hh) < 1.0 ) {
      return true;
    } else {
      return false;
    }
  }
}
```

shapes6.pde

containsPoint() for Circle

– Test the distance between the point and the Circle center to see if it is less than the radius

```
class Circle extends Ellipse {
  …
  // containsPoint() for a Circle
  boolean containsPoint( float x, float y ) {
    if ( dist(this.x, this.y, x, y) < r ) {
      return true;
    } else {
      return false;
    }
  }
}
```

shapes6.pde

All Subclasses Get New Superclass Methods

- Add a method to Shape that changes the fill color to white when the mouse is over the Shape
- Use containsPoint() to test this condition

- Plan
  1. Move the display() loop from setup() to draw()
  2. Add a mouseMoved() method to Shape that changes fill color based on containsPoint()
  3. Call all Shape class mouseMoved() methods from top-level mouseMoved().

New Top-level Program

```
Shape[] shapes = new Shape[3];

void setup() {
  size(500, 500);
  smooth();
  ellipseMode(CENTER);
  rectMode(CENTER);

  shapes[0] = new Rectangle (100, 200, 60, 50);
  shapes[1] = new Ellipse(200, 100, 70, 30);
  shapes[2] = new Circle(200, 200, 25);
}

void draw() {
  background(200);
  for (int i=0; i<shapes.length; i++) {
    shapes[i].display();
  }
}

void mouseMoved() {
  for (int i=0; i<shapes.length; i++) {
    shapes[i].mouseMoved();
  }
}
```

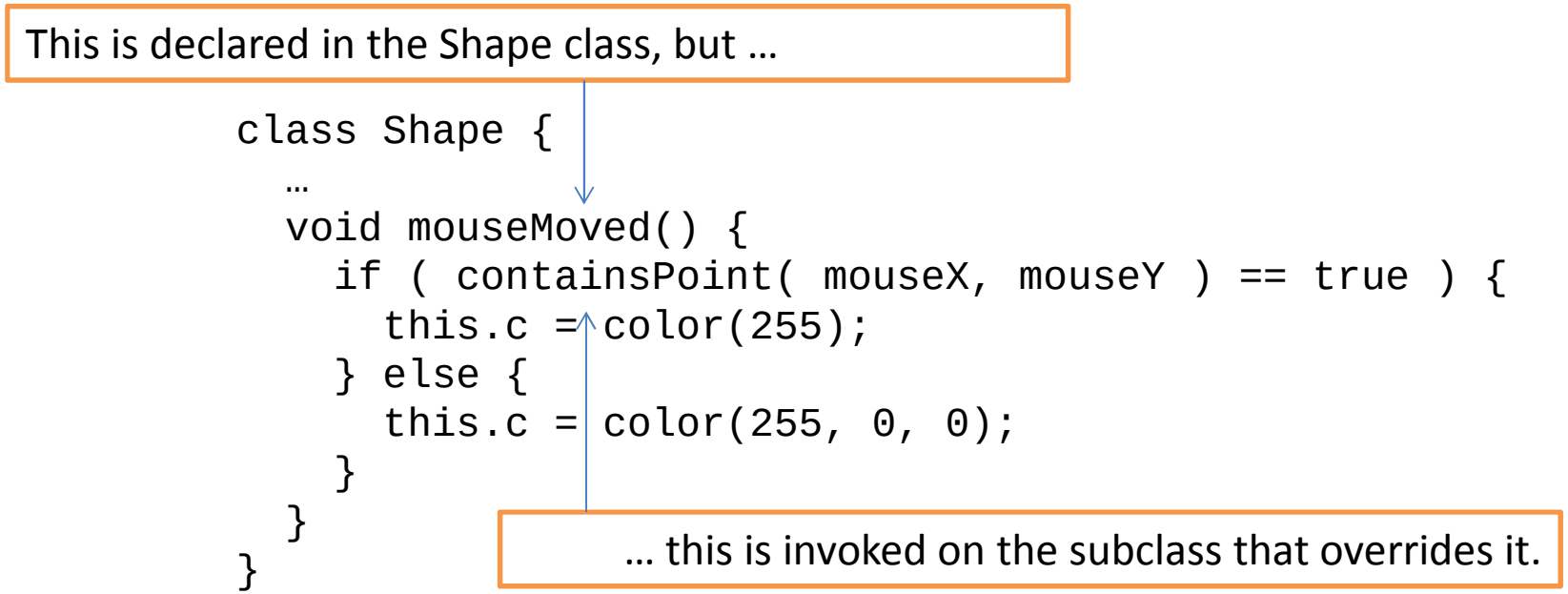
display loop moved to draw()

mouseMoved() called for all Shapes

shapes6.pde

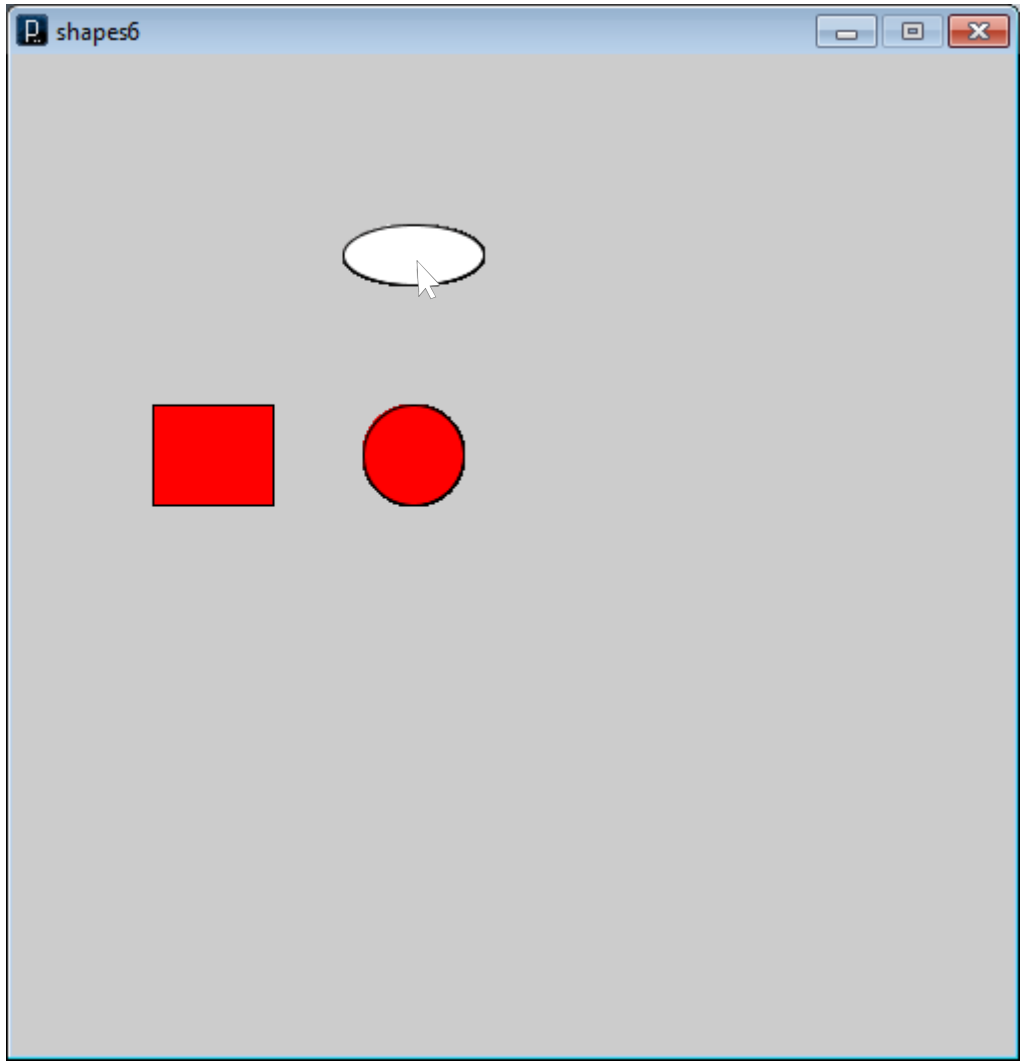
mouseMoved() method for Shape

- Uses containsPoint() to decide how to change fill color
- Note: The appropriate subclass implementation of containsPoint() will be invoked, depending upon the type of Shape subclass on which the method is invoke upon



shapes6.pde

Test it



shapes6.pde

- But wait, only Ellipse objects are supposed to turn white on mouse over, not Rectangles

- Overriding a method can also be used to cancel default behavior.

- Add the following method to Rectangle to override the Shape class mouseMoved() to replace behavior

```
void mouseMoved() {
   // Do nothing
}
```

shapes6.pde

Dragging Shapes

With only the following additions to the program, it is possible to implement interactive Shape dragging, for ALL Shape subclasses.

The power of inheritance…

```
Shape dragged = null;  // The Shape being dragged
float offsetX = 0.0;   // The offset between the Shape
float offsetY = 0.0;   // center and mouse position.

void mousePressed()
{ // If pressed on Shape, save Shape and offset
  for (int i=0; i<shapes.length; i++) {
    if (shapes[i].containsPoint( mouseX, mouseY )) {
      dragged = shapes[i];
      offsetX = shapes[i].x - mouseX;
      offsetY = shapes[i].y - mouseY;
      return;
    }
  }
}

void mouseReleased()
{ // Cancel all dragging on release
  dragged = null;
}

void mouseDragged()
{ // If dragging, move Shape on drag
  if (dragged == null) return;
  dragged.x = mouseX + offsetX;
  dragged.y = mouseY + offsetY;
}
```

Summary

- Inheritance
  - A relationship established between two classes
  - Fields and methods of the superclass become available to all subclass by default
  - Subclasses can replace (override) superclass members (fields and methods) by declaring new versions
  - Inheritance implements the concept of subtype polymorphism
    - Objects of a subclass type can be assigned to variables declared as one of its superclass types
- Keywords
  - `extends, this, super`