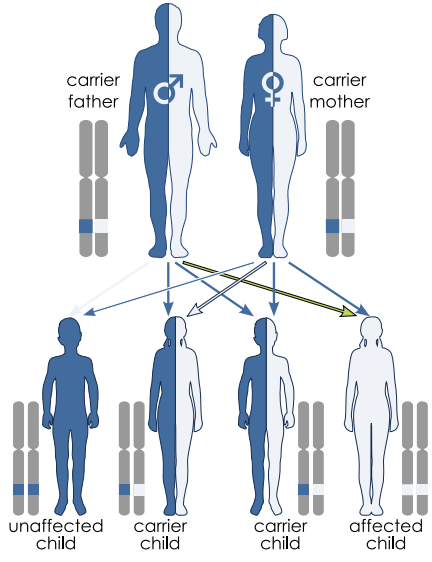
Guess who's inheriting the money

Biology and inheritance



Autosomal recessive inheritance

- *Unaffected*
- *Affected*
- *Carrier*

Duplicate code

```
public class Rectangle{
  // Center coordinate
  private double x; ❶
  private double y;

  public void move
    (double dx, double dy){ ❷
     x += dx;
     y += dy;
  }
  private double width, height; ❸ ...
}
```

```
public class Circle {
  // Center coordinate
  private double x; ❶
  private double y;

  public void move
    (double dx, double dy){ ❷
     x += dx;
     y += dy;
  }
  private double radius; ❸ ...
}
```

Idea: Centralize common code

- Create a parent class `Shape` containing common code portions.
- Relate both `Rectangle` and `Circle` to `Shape`.

Common and specific properties

Common `Rectangle` and `Circle` attributes:

```
double x;
double y;
```

`Rectangle` attributes

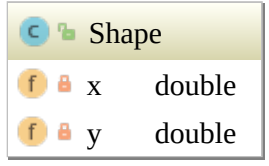
```
double width;
double height;
```

`Circle` attributes

```
double radius;
```

Basic shape inheritance

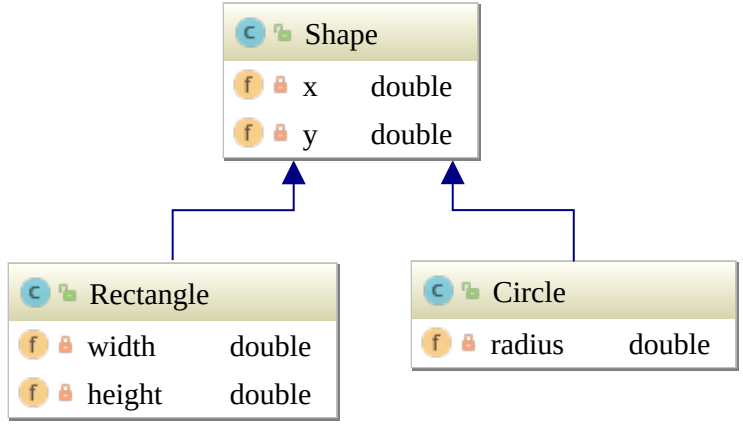
Superclass



Basic shape inheritance

Superclass

Derived classes



Inheritance

- Derived classes inherit state and behaviour.
- Refinement, specialization.
- “is-A” relationship:
  - A rectangle **is a** shape.
  - A circle **is a** shape.

Implementing Shape hierarchy

```java
public class Shape {
  private double x, y;
}
```

```java
public class Rectangle extends Shape {
  private double width;
  private double height;
}
```

```java
public class Circle extends Shape {
  private double radius;
}
```

Creating instances

```
final double x = 2, y = 3;
final Shape shape = new Shape(x, y);

final double width = 2, height = 5;
final Rectangle r = new Rectangle(x, y , width, height);

final double radius = 2.5;
final Circle circle = new Circle(x, y , radius);
```

Shape constructor

```
/**
  * Creating a shape located at center coordinate.
  * @param x The center's x component.
  * @param y The center's y component.
  */
public Shape(double x,double y) {
  this.x = x;
  this.y = y;
}
```

Creating `Rectangle` instances

```
final Rectangle r =
   new Rectangle(x, y ❶,
                 width, height ❷);
```

❶ Center coordinate components “belonging” to superclass `Shape`.

❷ width and height “belonging” to class `Rectangle`.

Solution: Nested constructor call. Coming soon ...

`Rectangle` constructor

```
/**
  * Creating a rectangle at (x|y) of given width and height.
  * @param x Center's x component.
  * @param y Center's y component.
  * @param width Rectangle's width.
  * @param height Rectangle's height.
  */
public Rectangle(double x, double y,
             double width, double height) {
  super(x, y) ❶;
  this.width = width; this.height = height ❷;
}
```

Shape.equals()

```
public abstract class Shape {
  ...
  @Override ❶ public boolean equals(final Object o) {
    if (o instanceof Shape s ❷) {
      return x == s.x && y == s.y; ❸
    } else {
      return false; ❹
    } ...
```

Rectangle.equals()

```
public class Rectangle extends Shape {
  ...
  @Override public boolean equals(final Object o) {
    if (o instanceof Rectangle r) {
      return super.equals(o) ❶ &&
             width == r.width && height == r.height ❷;
    } else {
      return false;
    } ...
```

Related exercises

Exercise 166: Let me pass, please!
Exercise 167: Why is == correctly comparing `enum` instances?

Printing a Shape's info

Code

```
package inherit;

public class Run {

  public static void main(String[] args) {
  final Shape shape =
     new Shape(2.0, 3.0); // Center coordinates
    System.out.println(shape);
```

Output

```
inherit.Shape@37d31475
```

Desired:

```
(2.0|3.0)
```

Overwriting `toString()`

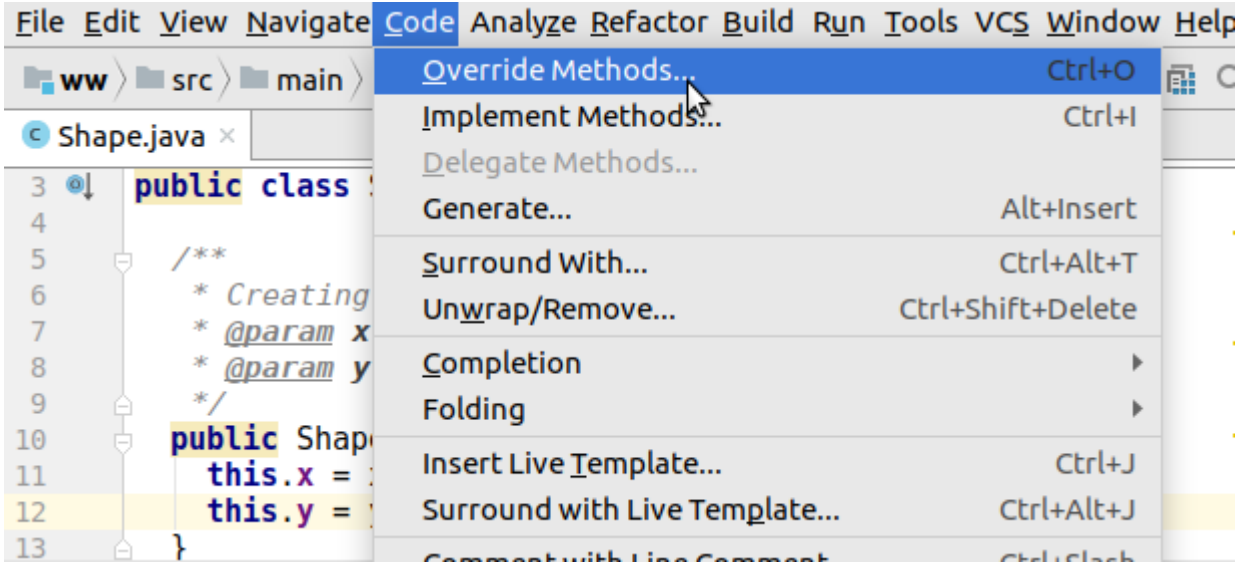
File Edit View Navigate Code Analyze Refactor Build Run Tools VCS Window Help

ww > src > main > java > inherit > Sh Grow

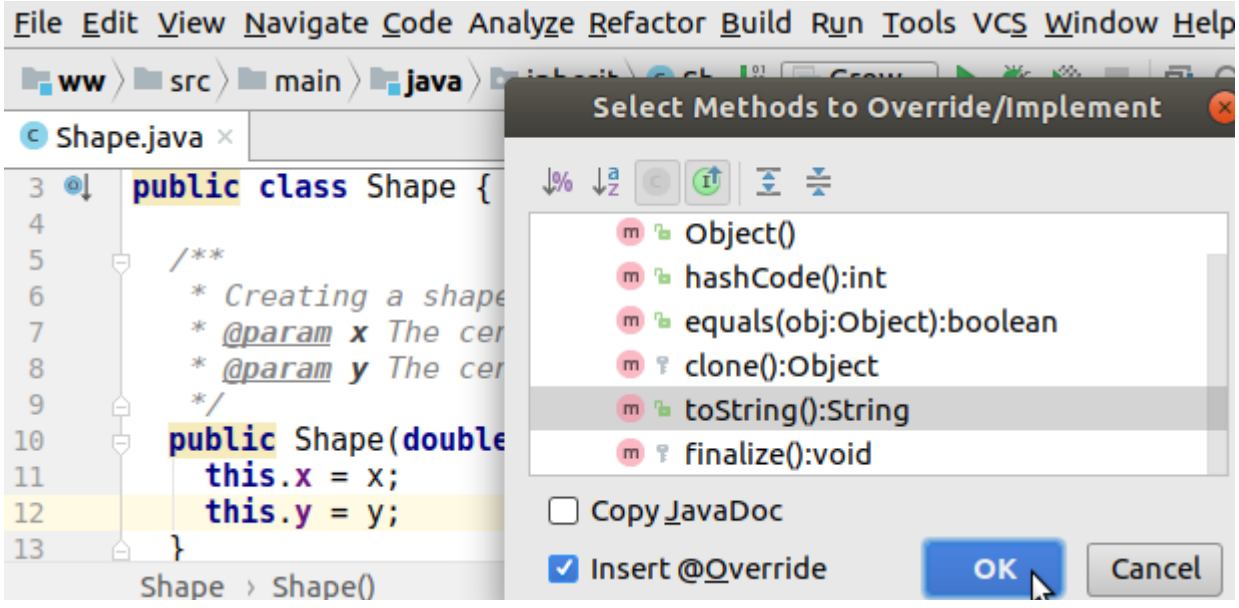
Shape.java

```
3   public class Shape {
4
5     /**
6      * Creating a shape located at center coordinate.
7      * @param x The center's x component.
8      * @param y The center's y component.
9      */
10    public Shape(double x,double y) {
11      this.x = x;
12      this.y = y;
13    }
```

Overwriting `toString()`



Overwriting `toString()`



Overwriting `toString()`

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ww > src > main > java > inherit > Sh Grow

Shape.java

```
3   public class Shape {
4
5     @Override
6     public String toString() {
7       return super.toString();
8     }
9
10    /**
11     * Creating a shape located at center coordinate.
12     * @param x The center's x component.
13     * @param y The center's y component
```

Tool provided default implementation, most likely to be changed

Overwriting `toString()`

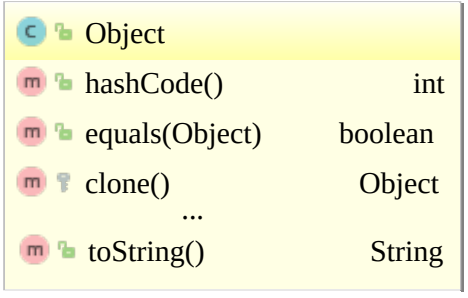
File Edit View Navigate Code Analyze Refactor Build Run Tools VCS Window Help

w > src > main > java > inherit > Shape > Grow

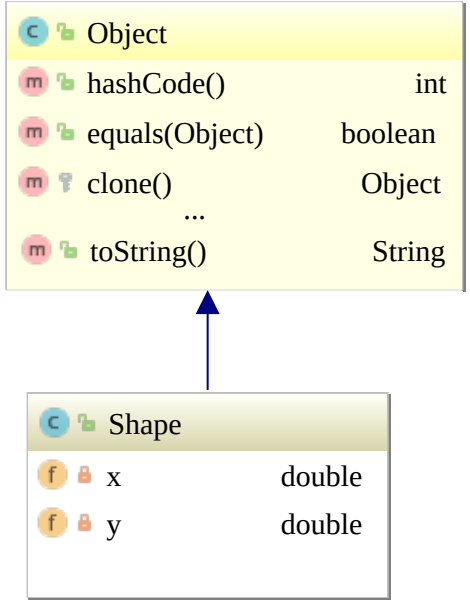
Shape.java

```
3   public class Shape {
4
5     @Override
6     public String toString() {
7       return "(" + x + "|" + y + ")";
8     }
9
10    /**
11     * Creating a shape located at center coordinate.
12     * @param x The center's x component.
13     * @param y The center's y component.
```

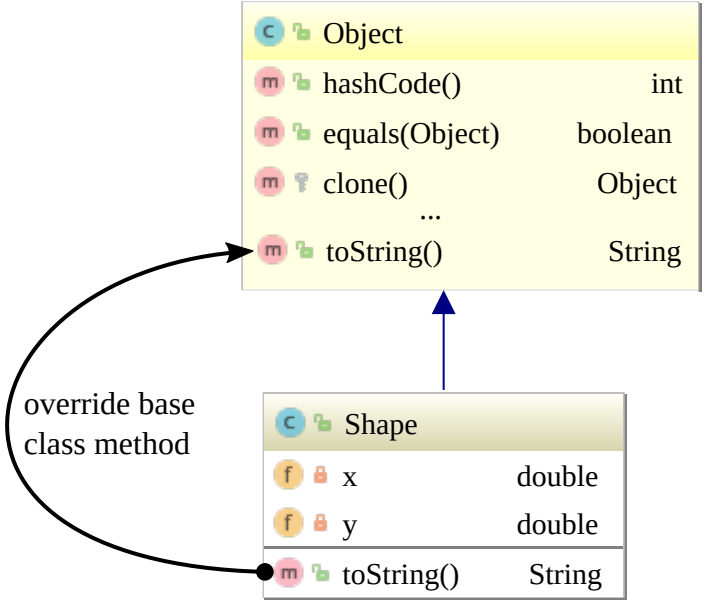
Shape extending Object



Shape extending Object



Shape extending Object



Logging `Rectangle` instances

Code

```
final Rectangle r =                    // Center coordinates
  new Rectangle(2.0, 3.0, 3.0, 4.0);  // width and height
System.out.println(r);
```

Output

```
(2.0|3.0)
```

Desired:

```
Rectangle at (2.0|3.0), width= 3.0, height=4.0
```

Override `toString()` in class `Rectangle`.

```
public class Rectangle extends Shape {
  @Override public String toString() {
    return "Rectangle at " + super.toString() ❶ +
      ", width= " + width + ", height=" + height; ❷
  } ...
```

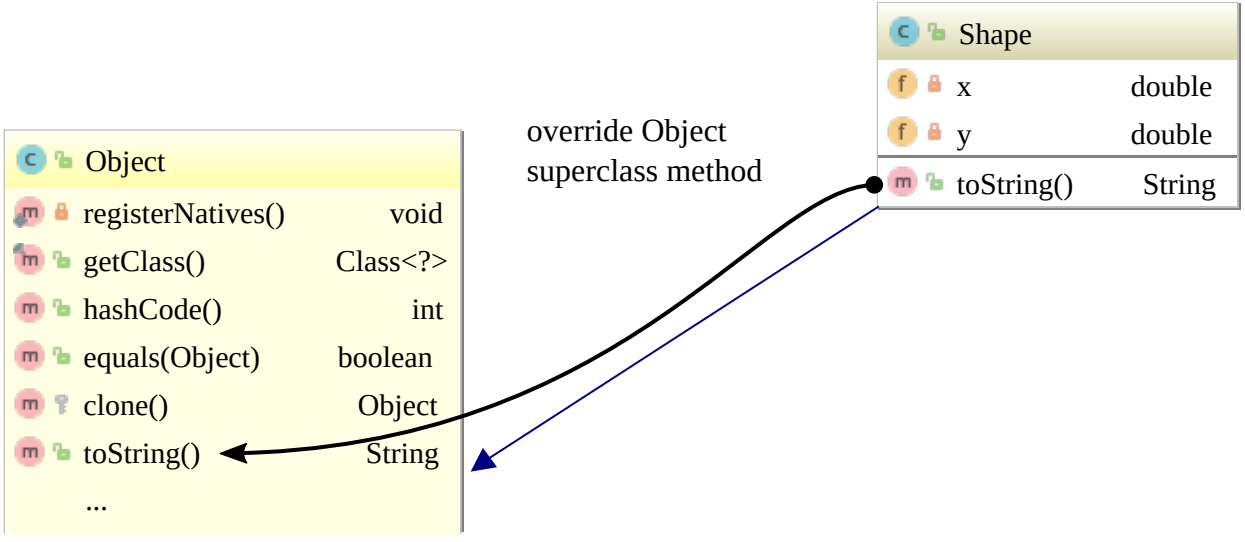
❶ The `super` keyword allows for calling the superclass `Shape`'s `toString()` method inserting the (2.0|3.0) center coordinate.

❷ Append class `Rectangle`'s “own” `width` and `height` attribute values.

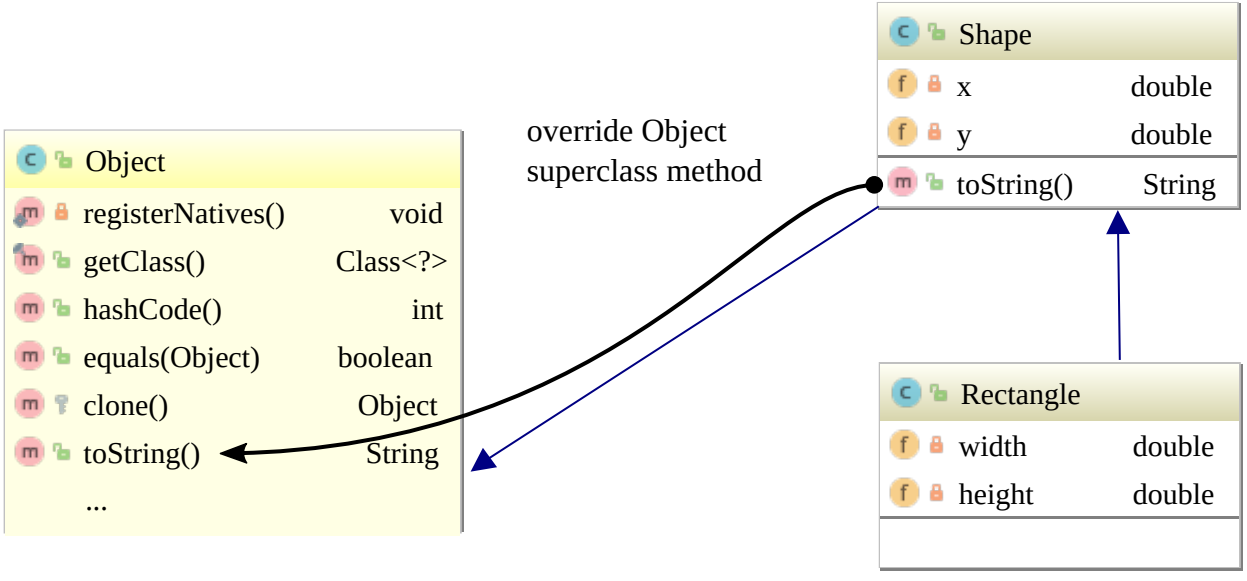
Rectangle extending Shape

Object	
registerNatives()	void
getClass()	Class<?>
hashCode()	int
equals(Object)	boolean
clone()	Object
toString()	String
...	

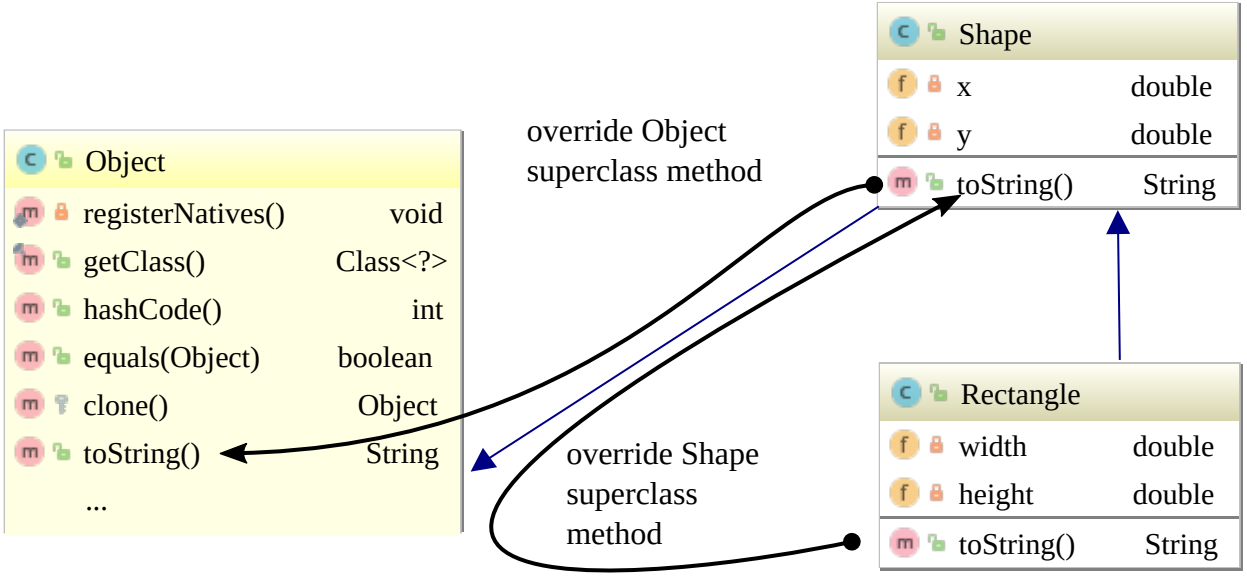
Rectangle extending Shape



Rectangle extending Shape



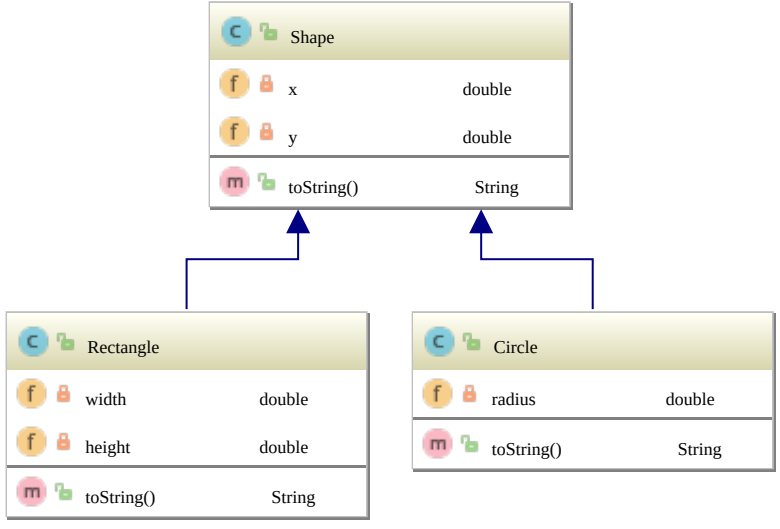
Rectangle extending Shape



Implementing `Circle.toString()`

```java
public class Circle extends Shape {
  /**
   * Creating a circle of given center and radius
   * @param x Center's x component.
   * @param y Center's y component.
   * @param radius The circle's radius.
   */
  public Circle(double x,double y, double radius) {
    super(x, y);
    this.radius = radius;
  }
  @Override public String toString() {
    return "Circle at " + super.toString() +", radius= " + radius;
  }
  private double radius;
}
```

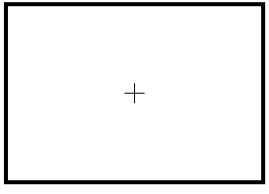
Shape and toString()



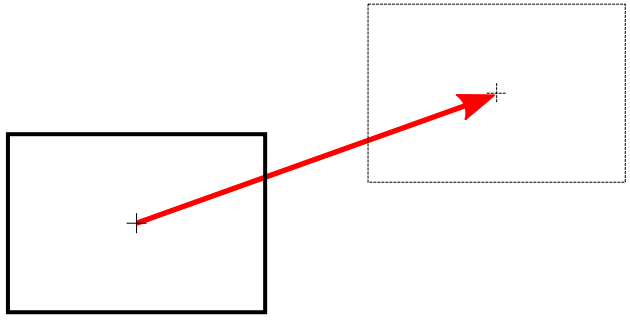
Related exercises

Exercise 168: `String` vs. `StringBuffer`
Exercise 169: Alternate implementation of opposite directions

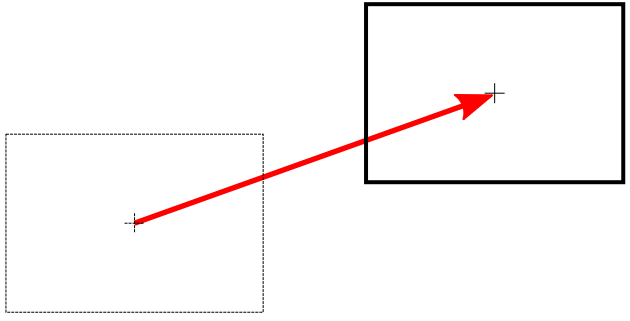
Moving Shape instances



Moving Shape instances



Moving Shape instances



Implementing Shape movements

```java
public class Shape {
  /**
   * Move by a given translation vector
   * @param xTrans Translation's x component
   * @param yTrans Translation's y component
   */
  public void move(final int xTrans, final int yTrans) {
    x += xTrans;
    y += yTrans;
  } ...
```

Fools are everywhere!

```java
public class Rectangle extends Shape {
  @Override public void move(int xTrans, int yTrans) {
    // I'm so dumb!
    ...
  }
```

Solution: **final** prevents overriding

```
public abstract class Shape {
... public final void move(final int xTrans, final int yTrans) {
      x += xTrans;
      y += yTrans;
    }...

public class Rectangle extends Shape {
  // Syntax error: 'move(int, int)' cannot override
  // 'move(int, int)' in 'inherit.Shape'; overridden method is final
  @Override public void move(int xTrans, int yTrans) {...
```

Calculating a shape's area

```java
public class Rectangle extents Shape {
  /**
   * Calculate the area.
   * @return The rectangle's area
   */
  public double getArea() {
    return width * height;
  } ...
```

```java
public class Circle extents Shape {
  /**
   * Calculate the area.
   * @return The circle's area
   */
  public double getArea() {
    return PI * radius * radius;
  } ...
```

Desired: Polymorphic `getArea()` call

```
final Shape[] shapes ❶ = {
    new Circle(1, 1, 2.) ❷,
    new Rectangle(1, -1, 2., 3.)❷};

for (final Shape s : shapes) {
  System.out.println(s.toString() + ": area = " + s.getArea()); ❸
}

Circle at (1.0|1.0), radius= 2.0: area = 12.566370614359172
Rectangle at (1.0|-1.0), width= 2.0, height=3.0: area = 6.0
```

Problems:

- No meaningful `getArea()` method in class `Shape` possible.
- Meaningful implementations exist both in subclass `Rectangle` and `Circle`.

Solution: Abstract method `getArea()` in superclass `Shape`.

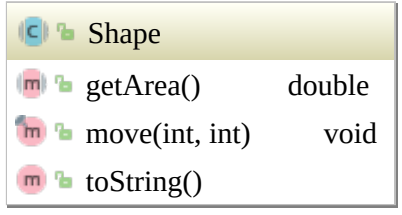
abstract method getArea()

```
abstract❶ public class Shape {
  /**
   * Calculate the shape's area.
   * @return The shape's area
   */
  abstract❷ public double getArea()❸; ...
```

```
public class Rectangle extends Shape {
  @Override❶
  public double getArea() {
    return width * height;
  }...
```

```
public class Circle ... {
 @Override❶
  public double getArea() {
    return Math.PI *
           radius * radius;
  } ...
```

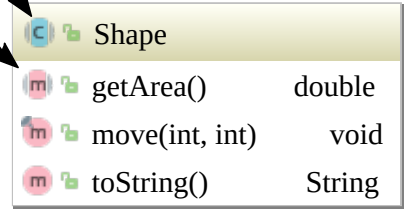
abstract method getArea()



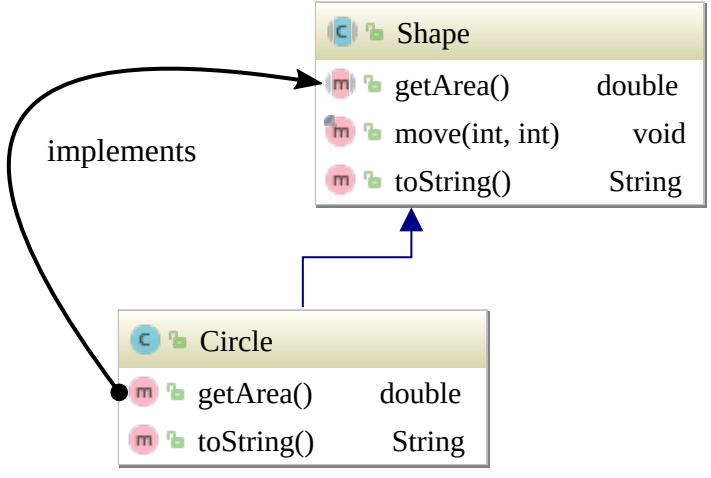
abstract method getArea()

abstract class icon

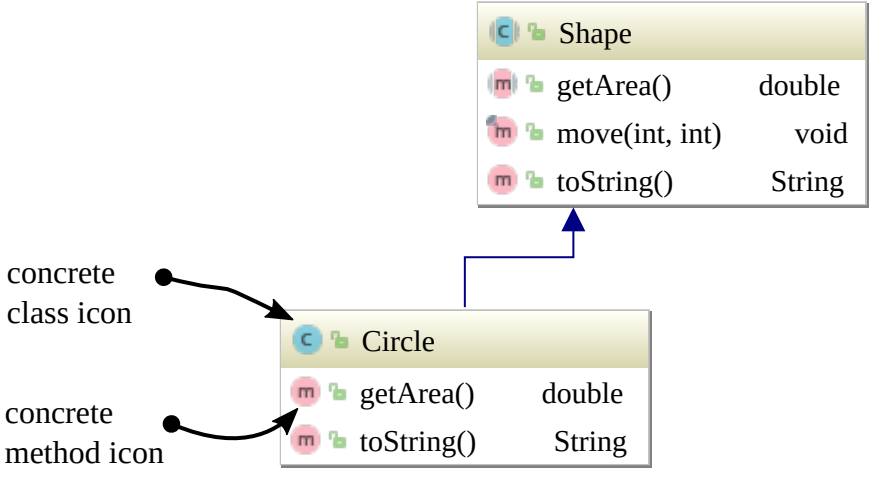
abstract method icon



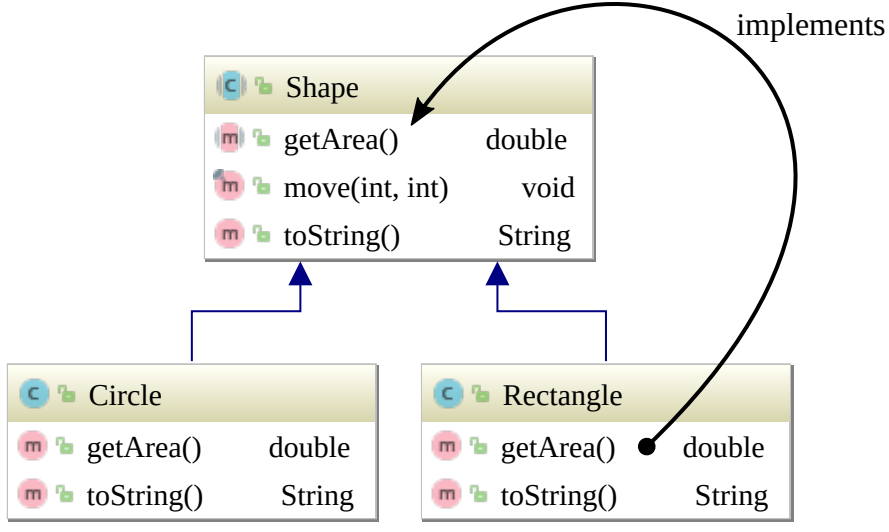
abstract method getArea()



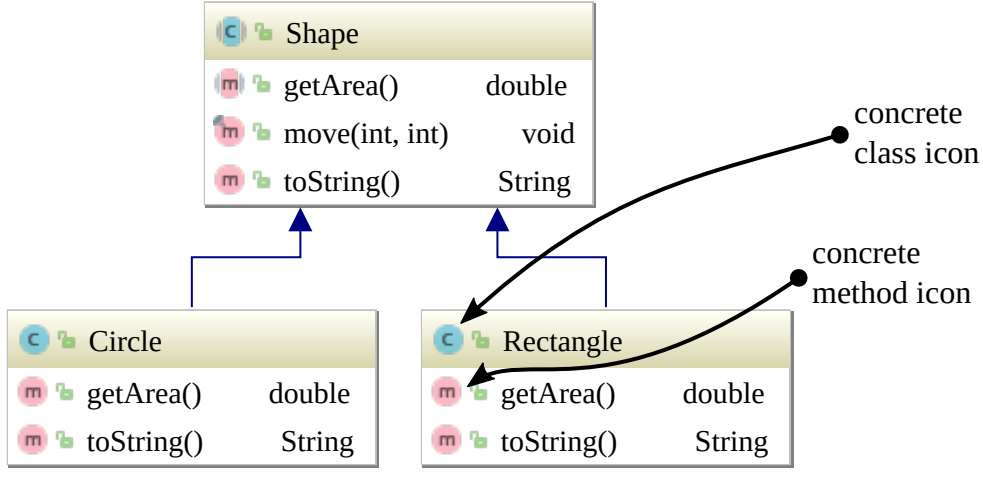
abstract method getArea()



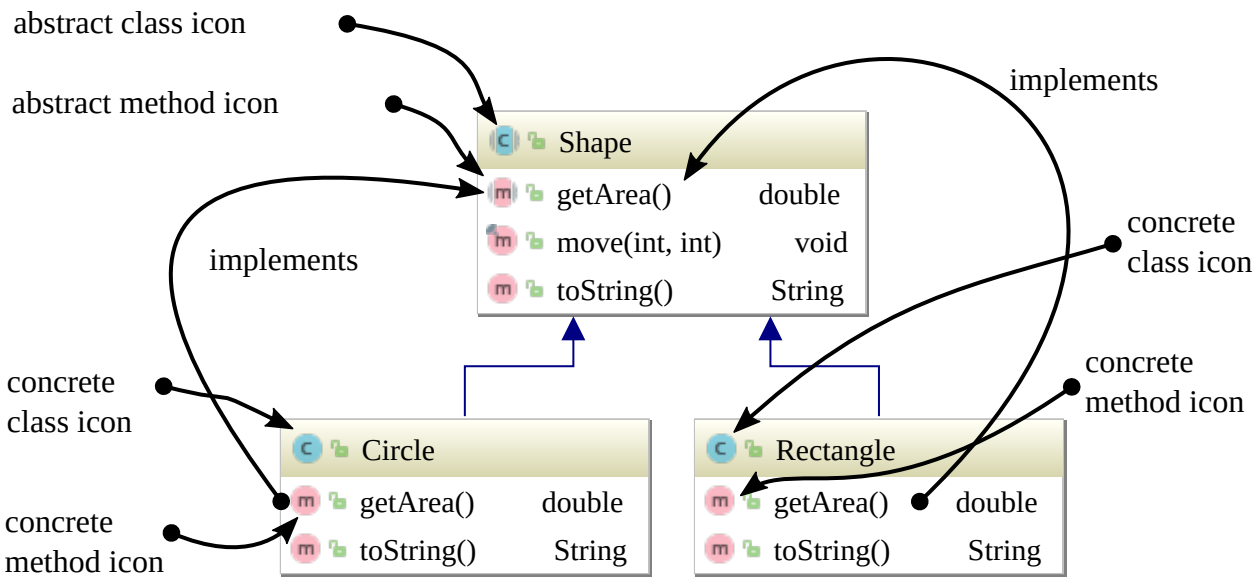
abstract method getArea()



abstract method getArea()



abstract method getArea()



What's a “shape” anyway?

No instances of `abstract` classes.

```
final Shape s =
   new Shape(1., 2.); // 'Shape' is abstract; cannot be instantiated
```

Mandatory `getArea()` implementation.

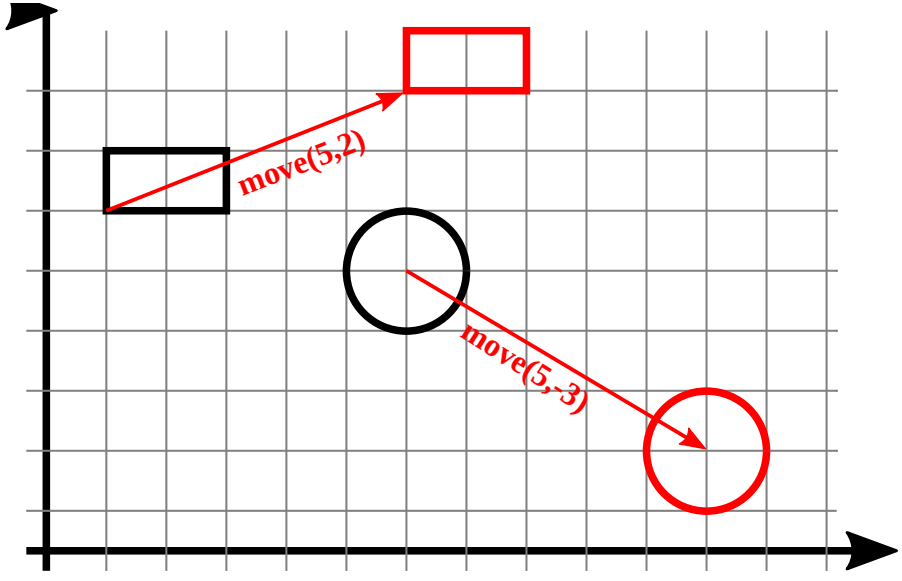
```
// Error: Class 'Circle' must either be declared abstract or
//        implement abstract method 'getArea()' in 'Shape'
public class Circle extends Shape {

  public Circle(double x,double y, double radius) {
    super(x, y);
    this.radius = radius;
  }
  private double radius;
}
```

Facts about `abstract` fields, methods and classes.

- A class containing an `abstract` method must itself be declared `abstract`.
- `abstract` classes are allowed to host non-`abstract` methods.
- A class may be declared `abstract` irrespective of purely containing non-`abstract` methods.

Moving shapes



Related exercises

Exercise 170: Defining a `Shape` class hierarchy
Exercise 171: Scaling shapes
Exercise 172: Providing `toString()` methods

protected access

```
package model;
public abstract class Shape ❶{

  final protected long creationTime ❷= System.nanoTime();
...
}
-------------------------------------------------
package model.sub;
public class Rectangle ❸extends Shape {
  static final Logger log = LogManager.getLogger(Rectangle.class);

  @Override public double getArea() {
    log.info("Rectangle creation time:" + creationTime ❹);
    return width * height;
  } ...
}
```

Related exercises

Exercise 173: `protected` vs. “package private”
Exercise 174: `protected` access involving different instances

final classes

```
public final class Shape { ... }

-------------------------
public class Rectangle
  extends Shape { // Error: final class cannot be extended
...
```

`final` classes rationale

- Design decision.
- Slight performance gain.

> **Note**
>
> Prominent Example: `java.lang.String`.

“Defeating” polymorphism

```java
public static void main(String[] args) {
  final Shape[] shapes = {
    new Circle(1, 1, 2.),
    new Rectangle(1, -1, 2., 3.)};
  print(shapes);
}
static void print(final Shape[] shapes) {
  for (final Shape s : shapes) {
    if (s instanceof Rectangle) {
      System.out.println("Type Rectangle");
    } else if (s instanceof Circle) {
      System.out.println("Type Circle");
    }
  }
}
```

```
Type Circle
Type Rectangle
```

Defining `equals(...)`: Expectations

```
Rectangle r1 = new Rectangle(1, 2, 5, 4),
          r2 = new Rectangle(1, 2, 1, 7),
          r3 = new Rectangle(1, 2, 5, 4);

Circle c = new Circle(-2, 3, 5);

System.out.print(r1.equals("Hi"));//false: Differing classes Rectangle and String.
System.out.print(r1.equals(r2));  //false: Differing width and height.
System.out.print(r3.equals(r1));  //true:  Two rectangles having identical
                                  //       (x|y), width and height.
System.out.print(r1.equals(c));   //false: Differing classes Rectangle and Circle.
System.out.print(c.equals(c));    //true: Object equal to itself.
```

Defining `equals(...)` of `Shape` instances

Two `Shape` instances shall be considered equal if:

- Both instances are of common type i.e. either `Rectangle` or `Circle`.
- Their center coordinates match within a threshold of .
- `width` and `height` or `radius` match within a threshold of .

Comparing center coordinates

```
public abstract class Shape {
  private double x, y;

  protected boolean equalCenter(final Shape o) {
      return Math.abs(o.x - x) + Math.abs(o.y - y) < 1.E-15;
  }
...
```

Implementing `Rectangle.equals()`

```
public class Rectangle extends Shape {
    @Override public boolean equals(Object o) {
    if (o instanceof Rectangle r) {

      final Rectangle oRectangle = (Rectangle) o; // Cast is «legal»
      return super.equalCenter(r) &&
             Math.abs(r.width- width) +
                 Math.abs(r.height- height) < 1.E-15;
    }
    return false;
  }
 ...
```

For `o == null` the expression `o instanceof Rectangle` evaluates to `false`.

Implementing `Circle.equals()`

```
public class Circle extends Shape {
  @Override public boolean equals(final Object o) {
    if (o instanceof Circle c){
      return super.equalCenter(c) &&
        Math.abs(c.radius - radius) < 1.E-15;
    }
    return false;
  } ...
```

Testing equality of Shape objects

```java
final Rectangle
    r1 = new Rectangle(2, 3, 1,4),
    r2 = new Rectangle(2, 3, 2,8),
    r3 = new Rectangle(2, 3, 1,4);

final Circle c = new Circle(2,3, 7);

System.out.println("r1.equals(r2): " + r1.equals(r2));
System.out.println("r1.equals(r3): " + r1.equals(r3));
System.out.println("c.equals(r1): " + c.equals(r1));
```

```
r1.equals(r2): false
r1.equals(r3): true
c.equals(r1): false
```

Overriding Object.toString()

```
public class Shape {

  double x, y;
 ...
  @Override  // Promise: Subsequent method overrides Object.toString();
  public String toString() {
    return "(" + x + "|" + y + ")";
  }
}
```

@Override: Easy compile time error detection

```
public class Shape {

  double x, y;
 ...
  @Override  // Error: method does not override a method from a supertype
  public String toString(int value) {
    return "(" + x + "|" + y + ")";
  }
}
```

Explanation: The given method does not override `Object.toString()`.