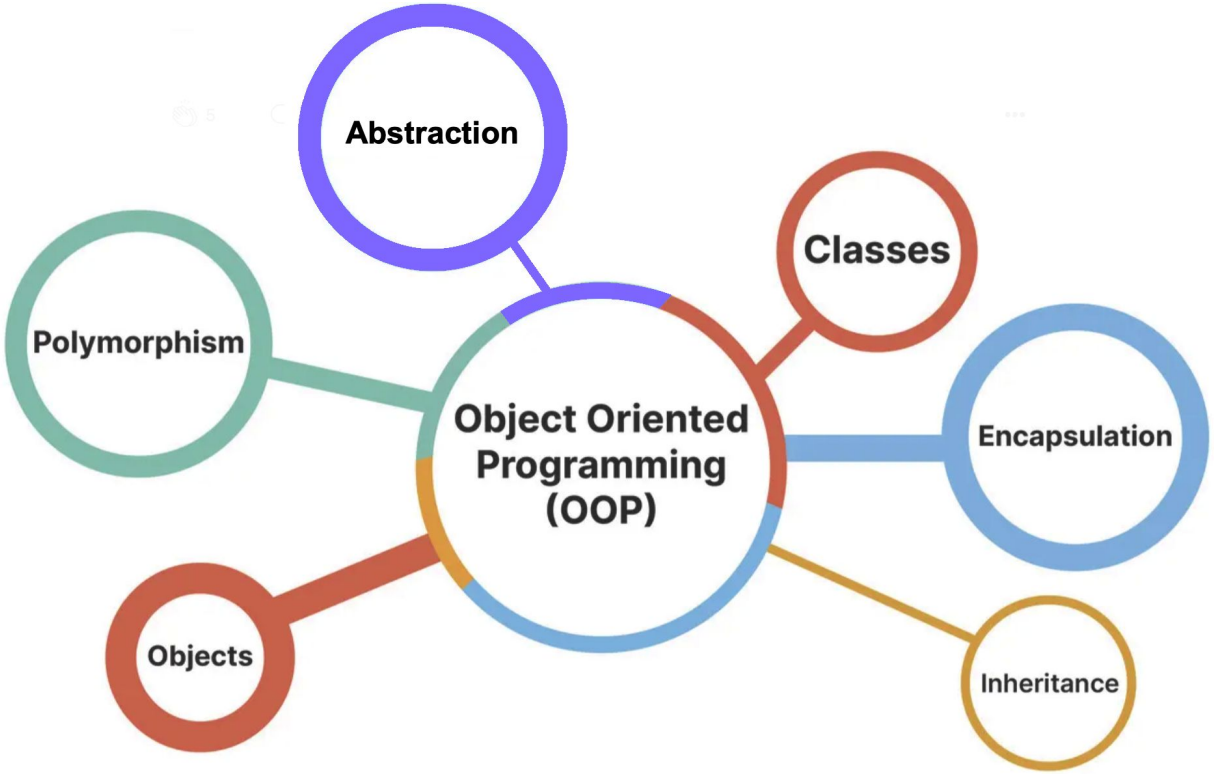
COSC 121: Computer Programming II



Today's Key Concepts

- Polymorphism is a new OOP technique for reference different object types that are related via inheritance or interface
- Implementation techniques:
  - Dynamic binding (as opposed to static binding)
  - The Three Rules
- Relationship to overriding
- Relationship to generic programming
- Using the instanceof operator
- Object casting (just like type casting)

Recall Use of Plus Sign (+)

- Consider the following +:
  - Ex: 4 + 5
    3.14 + 2.9
    str1 + “bar”
    System.out.println("the value is: " + n);
- What does + mean in each case?

Recall Use of Plus Sign (+)

- Consider the following +:
  - Ex: 4 + 5
    3.14 + 2.9
    str1 + “bar”
    System.out.println("the value is: " + n);
- What does + mean in each case?
- How to achieve this?

```
public int +( int x, int y ) {...}
public String +( String x, String y ) {...}
```

What does this remind you of?

Multiple Meanings Across Classes

- What if related classes have methods of the same signature?
- Suppose there are multiple Animal classes, each have their own talk() method implementation:

```
public String talk() { return ""; }     // Animal
public String talk() { return "woof"; }// Dog
public String talk() { return "meow"; }// Cat
public String talk() { return "beh"; } // Sheep
public String talk() { return "moo"; } // Cow
...
```

- Depending on caller object, different talk() would be called

Motivating Example

- Using previous talk() implementation

```
Animal[] myPets = new Animal[4];
                                        // an array of Animal objects
myPets[0] = new Dog();                  // Dog, Cat, Sheep, Cow are
myPets[1] = new Cat();                  // children classes of Animal
myPets[2] = new Sheep();
myPets[3] = new Cow();
for( int i=0; i<myPets.length; i++ )
{
  System.out.println( myPets[i].talk() );
}                                       // new flexibility
```

Motivating Example

- Using previous talk() implementation

```
Animal[] myPets = new Animal[4];

myPets[0] = new Dog();
myPets[1] = new Cat();
myPets[2] = new Sheep();
myPets[3] = new Cow();
for( int i=0; i<myPets.length; i++ )
{
  System.out.println( myPets[i].talk() );
}
```

Output

```
Woof
Meow
Beh
Moo
```

Motivating Example

- Using previous talk() implementation

```
Animal[] myPets = new Animal[4];

myPets[0] = new Dog();
myPets[1] = new Cat();
myPets[2] = new Sheep();
myPets[3] = new Cow();
for( int i=0; i<myPets.length; i++ )
{
  System.out.println( myPets[i].talk() );
}
```

Output

```
Woof
Meow
Beh
Moo
```

at i=0: calls talk() from the **Dog** class

Motivating Example

- Using previous talk() implementation

```
Animal[] myPets = new Animal[4];

myPets[0] = new Dog();
myPets[1] = new Cat();
myPets[2] = new Sheep();
myPets[3] = new Cow();
for( int i=0; i<myPets.length; i++ )
{
  System.out.println( myPets[i].talk() );
}
```

Output

```
Woof
Meow
Beh
Moo
```

at i=1: calls talk() from the **Cat** class

Motivating Example

- Using previous talk() implementation

```
Animal[] myPets = new Animal[4];

myPets[0] = new Dog();
myPets[1] = new Cat();
myPets[2] = new Sheep();
myPets[3] = new Cow();
for( int i=0; i<myPets.length; i++ )
{
  System.out.println( myPets[i].talk() );
}
```

Output

```
Woof
Meow
Beh
Moo
```

at i=1: calls talk() from the **Sheep** class

Motivating Example

- Using previous talk() implementation

```
Animal[] myPets = new Animal[4];

myPets[0] = new Dog();
myPets[1] = new Cat();
myPets[2] = new Sheep();
myPets[3] = new Cow();
for( int i=0; i<myPets.length; i++ )
{
  System.out.println( myPets[i].talk() );
}
```

Output

```
Woof
Meow
Beh
Moo
```

at i=1: calls talk() from the **Cow** class

Polymorphism

- Polymorphism is an OOP technique that allows us to reference different object types at different points in time
  - Literal meaning “having many forms”
- To make use of polymorphism, classes must be related via inheritance or interface relationships (interfaces next topic)
  - In example, Dog, Cat, Sheep, Cow are must all either extends or implements Animal
  - Then reference var of Animal can refer to any of its child objects

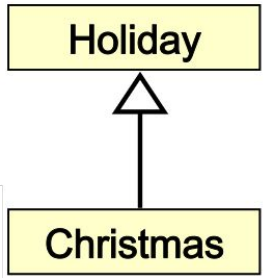
Dynamic Binding

- The call to myPets[i].talk() executes a different method definition in each loop iteration
- Achieved via dynamic binding
  - The call is bound to the definition of the method that it invokes
  - Java defers method binding until run time – so it delays binding until code execution (as late as possible)
  - Note: If this binding occurred at compile time, then that line of code would call the same method every time

General Idea

- An object reference can refer to an object of a related class by inheritance
- Ex: if Holiday is the superclass of Christmas then a Holiday reference could be used to refer to a Christmas object

```
Holiday day;
day = new Christmas();
```



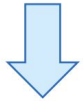
- Can assign Christmas object to a Holiday reference because Christmas is-a Holiday
- To assign child object to parent reference: just use =
- To assign parent object to child reference: need object casting
  (not recommended in practice – afterall, not all holidays are Christmases)

Polymorphism via Inheritance

```
Shape s = new Shape();
System.out.println(s);

Circle c = new Circle(1.5);
System.out.println(c);

Rectangle r = new Rectangle(3.1,2.1);
System.out.println(r);
```



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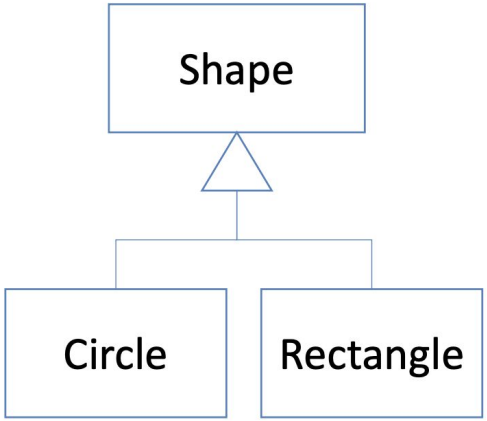


The Three Rules

- Terminology: A class defines a type.
  The type of a subclass (child) is called a subtype.
  The type of a superclass (parent) is called a supertype.
- **Rule 1:** A reference of a supertype can be used to refer to an object of a subtype (but not vice versa).
- **Rule 2:** You can only access class members known to the reference variable.
- **Rule 3:** When invoking a method using a reference variable x, the method in the object referenced by x is executed, regardless of the type of x (this is dynamic binding).

Example Illustrating Rule 1

- **Rule 1:** A reference of a supertype can be used to refer to an object of a subtype (but not vice versa). **"Supertype references can point to subtypes"**

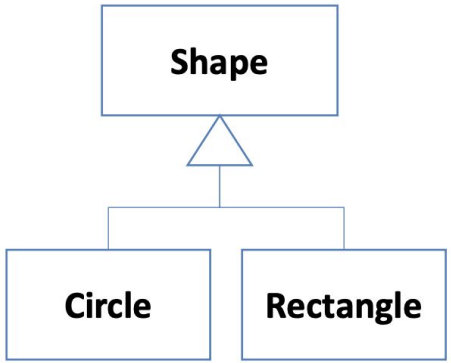
Example Illustrating Rule 1

- **Rule 1:** A reference of a supertype can be used to refer to an object of a subtype (but not vice versa). **"Supertype references can point to subtypes"**

All the following statements are valid:

```
Rectange r1 = new Rectangle();
Circle c1 = new Circle();

Shape s1 = new Rectangle();
Shape s2 = r1;
Shape s3 = c1;
```

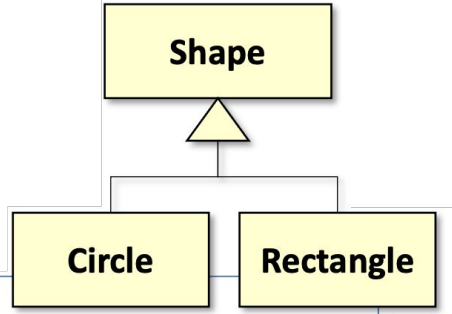


The following statements are **INVALID** :

```
Rectangle r2 = new Shape();  //invalid
Rectangle r3 = new Circle(); //invalid
```

Example 2 Illustrating Rule 1

- We can pass an instance of a subclass to a parameter of its superclass type



"Supertype references can point to subtypes"

```
public class PolymorphismDemo {
    public static void main(String[] args) {
        Shape s = new Shape("Black", true);
        Circle c = new Circle(10, "Blue", true);
        Rectangle r = new Rectangle(3, 4, "White", false);

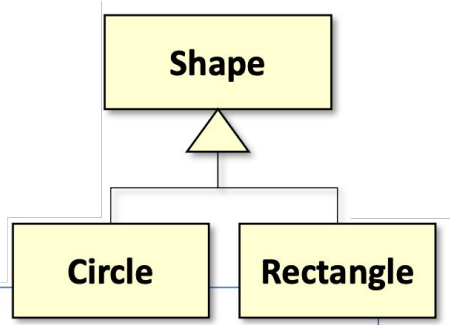



    }
    public static void printStatus(Shape sh){
        System.out.println(sh.toString());
    }
}
```

This is OK

Example 2 Illustrating Rule 1

- We can pass an instance of a subclass to a parameter of its superclass type



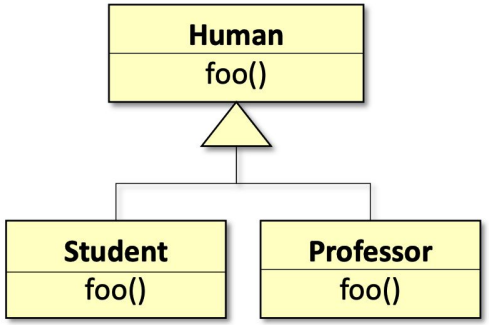
"Supertype references can point to subtypes"

```
public class PolymorphismDemo {
    public static void main(String[] args) {
        Shape s = new Shape("Black", true);
        Circle c = new Circle(10, "Blue", true);
        Rectangle r = new Rectangle(3, 4, "White", false);
        //print the properties of all three shapes
        printStatus(s);
        printStatus(c);
        printStatus(r);
    }
    public static void printStatus(Shape sh){
        System.out.println(sh.toString());
    }
}
```

iClicker Question

What type must go into the purple box in order for the code to be valid?

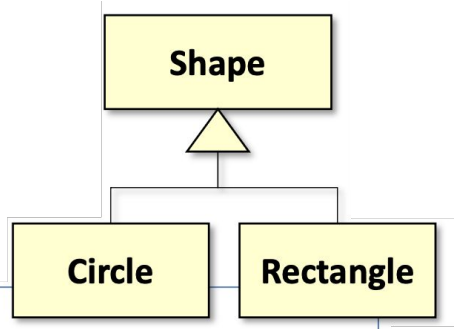
```
          x;
x = new Student();
x.foo();
x = new Professor();
x.foo();
```



A. Human
B. Student
C. Professor
D. None of the above

Example Illustrating Rule 2

- **Rule 2:** You can only access class members **known** to the reference variable.




```
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    public static void main(String[] args) {
        Shape s = new Shape("Black", true);
        Circle c = new Circle(10, "Blue", true);
        Rectangle r = new Rectangle(3, 4, "White", false);



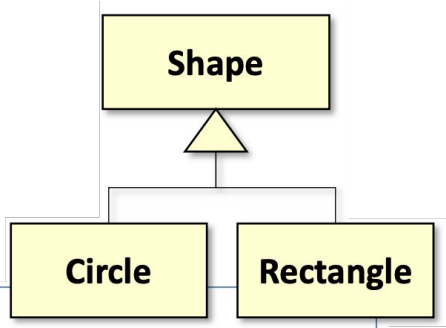
    }
    public static void printArea(Shape sh){
        System.out.println(sh.getArea());
    }
}
```

ERROR IF Shape doesn't have getArea()

RULE #2

Example Illustrating Rule 2

- **Rule 2:** You can only access class members **known** to the reference variable.

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        Rectangle r = new Rectangle(3, 4, "White", false);

        printArea(c);
        printArea(r);
    }
    public static void printArea(Shape sh){
        System.out.println(sh.getArea());
    }
}
```

c

r

This is OK

ERROR IF Shape doesn't have getArea()

RULE #2

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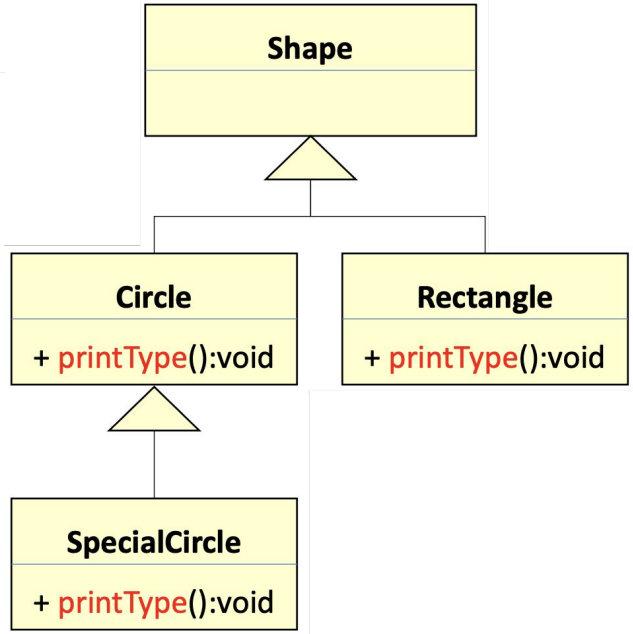
Assuming the printType() method prints the name of the class, what is the output of the following code?

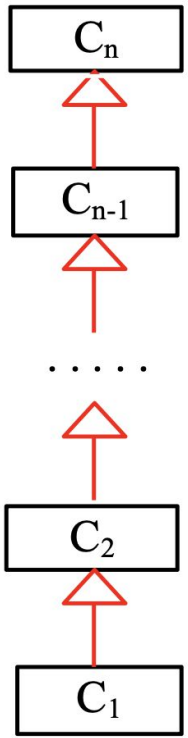
```
Shape x = new Rectangle();
x.printType();
x = new Circle();
x.printType();
x = new SpecialCircle();
x.printType();
```

A. Shape, Shape, Shape
B. Rectangle, Circle, Circle
C. Rectangle, Circle, SpecialCircle
D. Prints something else
E. Error



Explanation on Rule 3

- **Rule 3:** When invoking a method using a reference variable x, the method in the object referenced by x is executed, regardless of the type of x (this is dynamic binding).



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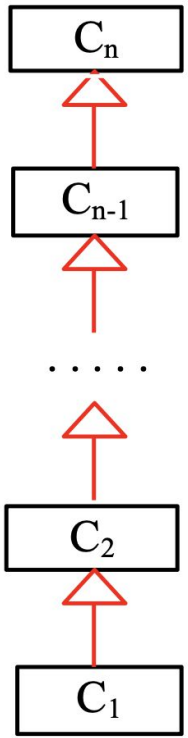
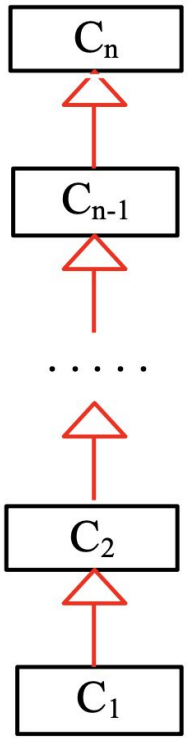
- **Rule 3:** When invoking a method using a reference variable x, the method in the object referenced by x is executed, regardless of the type of x (this is dynamic binding).
- Recall class hierarchy (with Object class at top)
- Suppose object obj is an instance of C_1 (and hence it is also an instance of C_2, ..., C_n).



Explanation on Rule 3

- **Rule 3:** When invoking a method using a reference variable x, the method in the object referenced by x is executed, regardless of the type of x (this is dynamic binding).
- Recall class hierarchy (with Object class at top)
- Suppose object obj is an instance of C_1 (and hence it is also an instance of C_2, ..., C_n).
- How dynamic binding works:
  If we invoke a method obj.p(), the JVM searches the implementation for the method p() in C_1, C_2, ..., C_{n-1} and C_n in this order, until it is found. Once an implementation is found, the search stops and the first-found implementation is invoked.



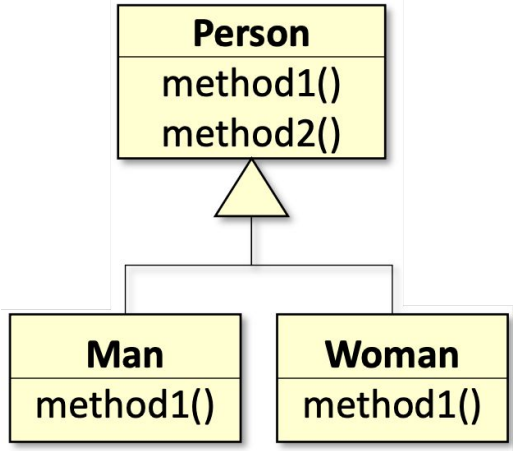
Example Illustrating Rule 3

```
public class Person {
    public void method1(){System.out.println("This is person 1.");}
    public void method2(){System.out.println("This is person 2.");}
}
```

```
public class Man extends Person{
    public void method1(){System.out.println("This is a man.");}
}
```

```
public class Woman extends Person{
    public void method1(){System.out.println("This is a woman.");}
}
```

```
public class DynamicBindingTest {
    public static void main(String[] args) {
        Person p1 = new Person();
        Person p2 = new Man();
        Person p3 = new Woman();
        p1.method1();
        p2.method1();
        p3.method1();
        p1.method2();
        p2.method2();
        p3.method2();
    }
}
```



What output gets printed?

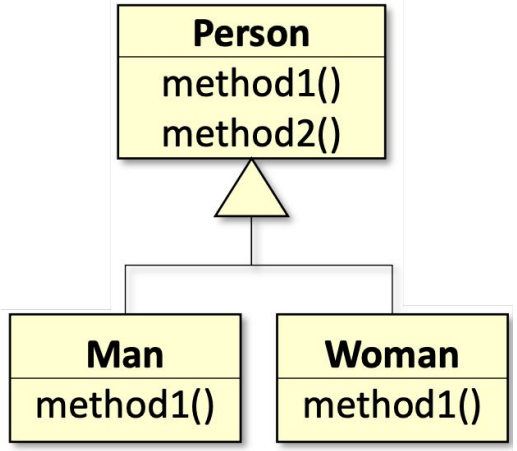
Example Illustrating Rule 3

```
public class Person {
    public void method1(){System.out.println("This is person 1.");}
    public void method2(){System.out.println("This is person 2.");}
}
```

```
public class Man extends Person{
    public void method1(){System.out.println("This is a man.");}
}
```

```
public class Woman extends Person{
    public void method1(){System.out.println("This is a woman.");}
}
```

```
public class DynamicBindingTest {
    public static void main(String[] args) {
        Person p1 = new Person();
        Person p2 = new Man();
        Person p3 = new Woman();
        p1.method1();
        p2.method1();
        p3.method1();
        p1.method2();
        p2.method2();
        p3.method2();
    }
}
```



Output:

```
This is person 1.
This is a man.
This is a woman.
This is person 2.
This is person 2.
This is person 2.
```

Example 2 Illustrating Rule 3

```
public class DynamicBindingTest2 {
    public static void main(String[] args) {
        m(new GradStudent());
        m(new Student());
        m(new Human());
        m(new Object());
    }
    public static void m(Object x) {
        System.out.println(x.toString());
    }
}

class Human extends Object {
    public String toString() {return "Human";}
}

class Student extends Human {
    public String toString() {return "Student";}
}

class GradStudent extends Student {
}
```

method m() takes an Object parameter, which means you can invoke it with any object type

- when m() is called, x's toString() is invoked

What output gets printed?

Example 2 Illustrating Rule 3

```
public class DynamicBindingTest2 {
    public static void main(String[] args) {
        m(new GradStudent());
        m(new Student());
        m(new Human());
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    }
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    }
}

class Human extends Object {
    public String toString() {return "Human";}
}

class Student extends Human {
    public String toString() {return "Student";}
}

class GradStudent extends Student {
}
```

method m() takes an Object parameter, which means you can invoke it with any object type

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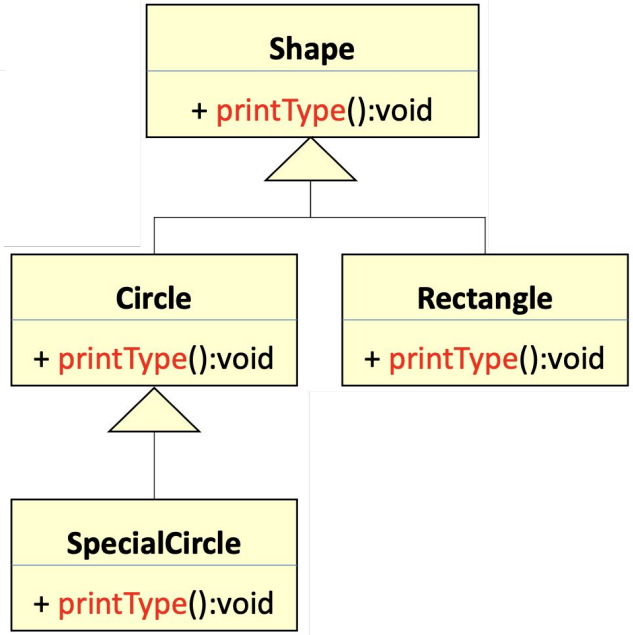
Output:

```
Student
Student
Human
java.lang.Object@5e65ab77
```

iClicker Question

Assuming the printType() method prints the name of the class, what is the output of the following code?

```
Shape x = new Rectangle();
x.printType();
x = new Circle();
x.printType();
x = new SpecialCircle();
x.printType();
```



A. Shape, Shape, Shape
B. Rectangle, Circle, Circle
C. Rectangle, Circle, SpecialCircle
D. Prints something else
E. Error

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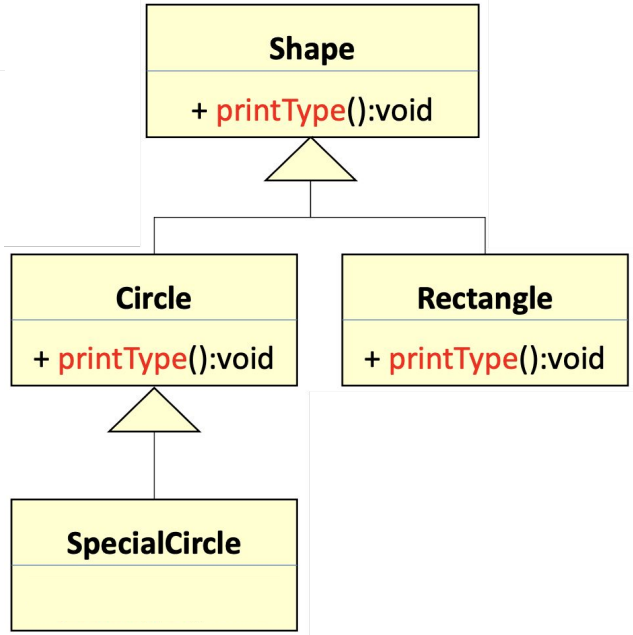

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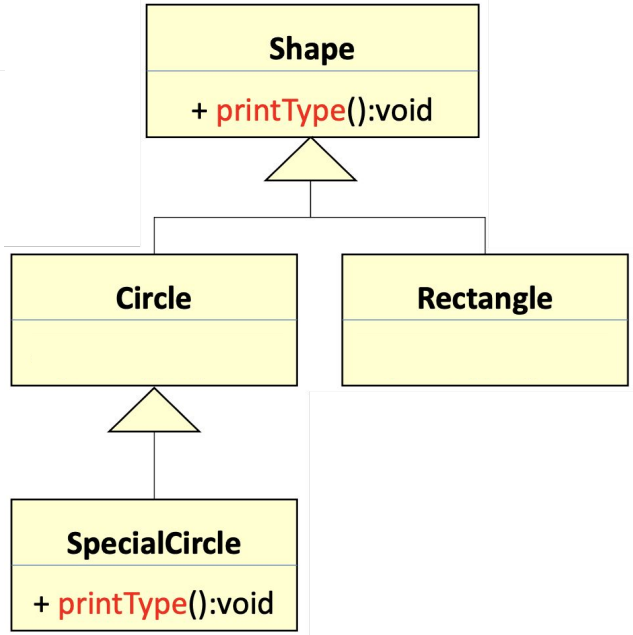

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Reflecting on Polymorphism

- How does inheritance support polymorphism?

- Is polymorphism same as overriding?

Reflecting on Polymorphism

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  - A reference variable of class X can be used to refer to an object of class Y if Y is a descendent of X
  - If both classes contain the same method (i.e., same signature and return type), the parent reference can be polymorphic
- Is polymorphism same as overriding?

Reflecting on Polymorphism

- How does inheritance support polymorphism?
  - A reference variable of class X can be used to refer to an object of class Y if Y is a descendent of X
  - If both classes contain the same method (i.e., same signature and return type), the parent reference can be polymorphic
- Is polymorphism same as overriding?
  - Polymorphism is the ***concept*** that an object has the ability to take many forms
  - Overriding is one of several ***techniques*** to achieve polymorphism

iClicker Question

What is polymorphism in Java?

A. It is when a single parent class has many child classes
B. It is when a program uses several different types of objects, each with its own variable
C. It is when a single variable is used with several different types of related objects at different places in a program
D. It is when a class has several methods with the same name but different parameter types

Relation to Generic Programming

- Recall motivating example:

```
Animal[] myPets = new Animal[4];
// instantiate with various objects
for( int i=0; i<myPets.length; i++ )
  System.out.println( myPets[i].talk() );
```

- Generic programming is a methodology for writing algorithms and data structures using types that are not specified until the algorithm is used
  - Ex: generic sort() function that can order integers, doubles, floats, strings, etc.
- Implementation techniques:
  - Templates (e.g., C++)
  - Generics (e.g., Java Collections Framework)

Next Class:

- Continue with polymorphism
  - Relationship to generic programming
  - Using the instanceof operator
  - Object casting (just like type casting)