Topic 6
Inheritance and Polymorphism

"Question: What is the object oriented way of getting rich?
Answer: Inheritance.“

“Inheritance is new code that reuses old code. Polymorphism is old code that reuses new code.”

Outline

- Explanation of inheritance.
- Using inheritance to create a SortedIntList.
- Explanation of polymorphism.
- Using polymorphism to make a more generic List class.

Explanation of Inheritance

Main Tenets of OO Programming

- Encapsulation
  - abstraction, information hiding
- Inheritance
  - code reuse, specialization "New code using old code."
- Polymorphism
  - do X for a collection of various types of objects, where X is *different* depending on the type of object
  - "Old code using new code."

Things and Relationships

- Object oriented programming leads to programs that are models
  - sometimes models of things in the real world
  - sometimes models of contrived or imaginary things
- There are many types of relationships between the things in the models
  - chess piece has a position
  - chess piece has a color
  - chess piece moves (changes position)
  - chess piece is taken
  - a rook is a type of chess piece

The “has-A” Relationship

- Objects are often made up of many parts or have sub data.
  - chess piece: position, color
  - die: result, number of sides
- This “has-a” relationship is modeled by composition
  - the instance variables or fields internal to objects
- Encapsulation captures this concept

The “is-a” relationship

- Another type of relationship found in the real world
  - a rook is a chess piece
  - a queen is a chess piece
  - a student is a person
  - a faculty member is a person
  - an undergraduate student is a student
- “is-a” usually denotes some form of specialization
- it is not the same as “has-a”

Inheritance

- The “is-a” relationship, and the specialization that accompanies it, is modeled in object oriented languages via *inheritance*
- Classes can inherit from other classes
  - base inheritance in a program on the real world things being modeled
  - does “an A is a B” make sense? Is it logical?

Nomenclature of Inheritance

- In Java the `extends` keyword is used in the class header to specify which preexisting class a new class is inheriting from

```
public class Student extends Person
```

- Person is said to be
  - the parent class of Student
  - the super class of Student
  - the base class of Student
  - an ancestor of Student
- Student is said to be
  - a child class of Person
  - a sub class of Person
  - a derived class of Person
  - a descendant of Person

Results of Inheritance

public class A

public class B extends A

- the sub class inherits (gains) all instance variables and instance methods of the super class, **automatically**
- additional methods can be added to class B (specialization)
- the sub class can replace (redefine, override) methods from the super class

Attendance Question 1

What is the primary reason for using inheritance when programming?

A. To make a program more complicated
B. To duplicate code between classes
C. To reuse pre-existing code
D. To hide implementation details of a class
E. To ensure pre conditions of methods are met.

Inheritance in Java

- Java is a pure object oriented language
- all code is part of some class
- all classes, except one, must inherit from exactly one other class
- The `Object` class is the *cosmic super class*
  - The `Object` class does not inherit from any other class
  - The `Object` class has several important methods: `toString`, `equals`, `hashCode`, `clone`, `getClass`
- implications:
  - all classes are descendants of `Object`
  - all classes and thus all objects have a `toString`, `equals`, `hashCode`, `clone`, and `getClass` method
    - `toString`, `equals`, `hashCode`, `clone` normally overridden

Inheritance in Java

- If a class header does not include the extends clause the class extends the `Object` class by default

```
public class Die
```

  - `Object` is an ancestor to all classes
  - it is the only class that does not extend some other class

- A class extends exactly one other class
  - extending two or more classes is *multiple inheritance.* Java does not support this directly, rather it uses *Interfaces*.

Overriding methods

- any method that is not `final` may be overridden by a descendant class
- same signature as method in ancestor
- may not reduce visibility
- may use the original method if simply want to add more behavior to existing

Attendance Question 2

What is output when the `main` method is run?

```
public class Foo{
    public static void main(String[] args){
        Foo f1 = new Foo();
        System.out.println( f1.toString() );
    }
}
```

A. `0`

B. `null`

C. Unknown until code is actually run.

D. No output due to a syntax error.

E. No output due to a runtime error.

Shape Classes

- Declare a class called `ClosedShape`
  - assume all shapes have x and y coordinates
  - override `Object`'s version of `toString`
- Possible sub classes of `ClosedShape`
  - `Rectangle`
  - `Circle`
  - `Ellipse`
  - `Square`
- Possible hierarchy

  `ClosedShape` **<-** `Rectangle` **<-** `Square`

A ClosedShape class

```
public class ClosedShape
{  private double myX;
   private double myY;

   public ClosedShape()
   {  this(0,0);  }

   public ClosedShape (double x, double y)
   {  myX = x;
      myY = y;
   }

   public String toString()
   { return "x: " + getX() + " y: " + getY();   }

   public double getX(){ return myX; }
   public double getY(){ return myY; }
}
// Other methods not shown
```

Constructors

- Constructors handle initialization of objects
- When creating an object with one or more ancestors (every type except Object) a chain of constructor calls takes place
- The reserved word `super` may be used in a constructor to call a one of the parent's constructors
  - must be first line of constructor
- if no parent constructor is explicitly called the default, 0 parameter constructor of the parent is called
  - if no default constructor exists a syntax error results
- If a parent constructor is called another constructor in the same class may no be called
  - no `super();this();` allowed. One or the other, not both
  - good place for an initialization method

A Rectangle Constructor

```
public class Rectangle extends ClosedShape
{  private double myWidth;
   private double myHeight;

   public Rectangle( double x, double y,
          double width, double height )
   {   super(x,y);
       // calls the 2 double constructor in
       // ClosedShape
       myWidth = width;
       myHeight = height;

   }

    // other methods not shown
}
```

A Rectangle Class

```
public class Rectangle extends ClosedShape
{  private double myWidth;
   private double myHeight;

   public Rectangle()
   {  this(0, 0);
   }

   public Rectangle(double width, double height)
   {  myWidth = width;
      myHeight = height;
   }

   public Rectangle(double x, double y,
                    double width, double height)
   {    super(x, y);
        myWidth = width;
        myHeight = height;
   }

   public String toString()
   {  return super.toString() + " width " + myWidth
         + " height " + myHeight;
   }
}
```

The Keyword `super`

- `super` is used to access something (any protected or public field or method) from the super class that has been overridden
- Rectangle's `toString` makes use of the `toString` in ClosedShape my calling `super.toString()`
- without the super calling `toString` would result in infinite recursive calls
- Java does not allow nested supers

  ```
  super.super.toString()
  ```

  results in a syntax error even though technically this refers to a valid method, `Object`'s toString
- Rectangle *partially* overrides ClosedShapes `toString`

Initialization method

```
public class Rectangle extends ClosedShape
{  private double myWidth;
   private double myHeight;

   public Rectangle()
   {  init(0, 0);
   }

   public Rectangle(double width, double height)
   {  init(width, height);
   }

   public Rectangle(double x, double y,
                    double width, double height)
   {  super(x, y);
      init(width, height);
   }

   private void init(double width, double height)
   {  myWidth = width;
      myHeight = height;
   }
```

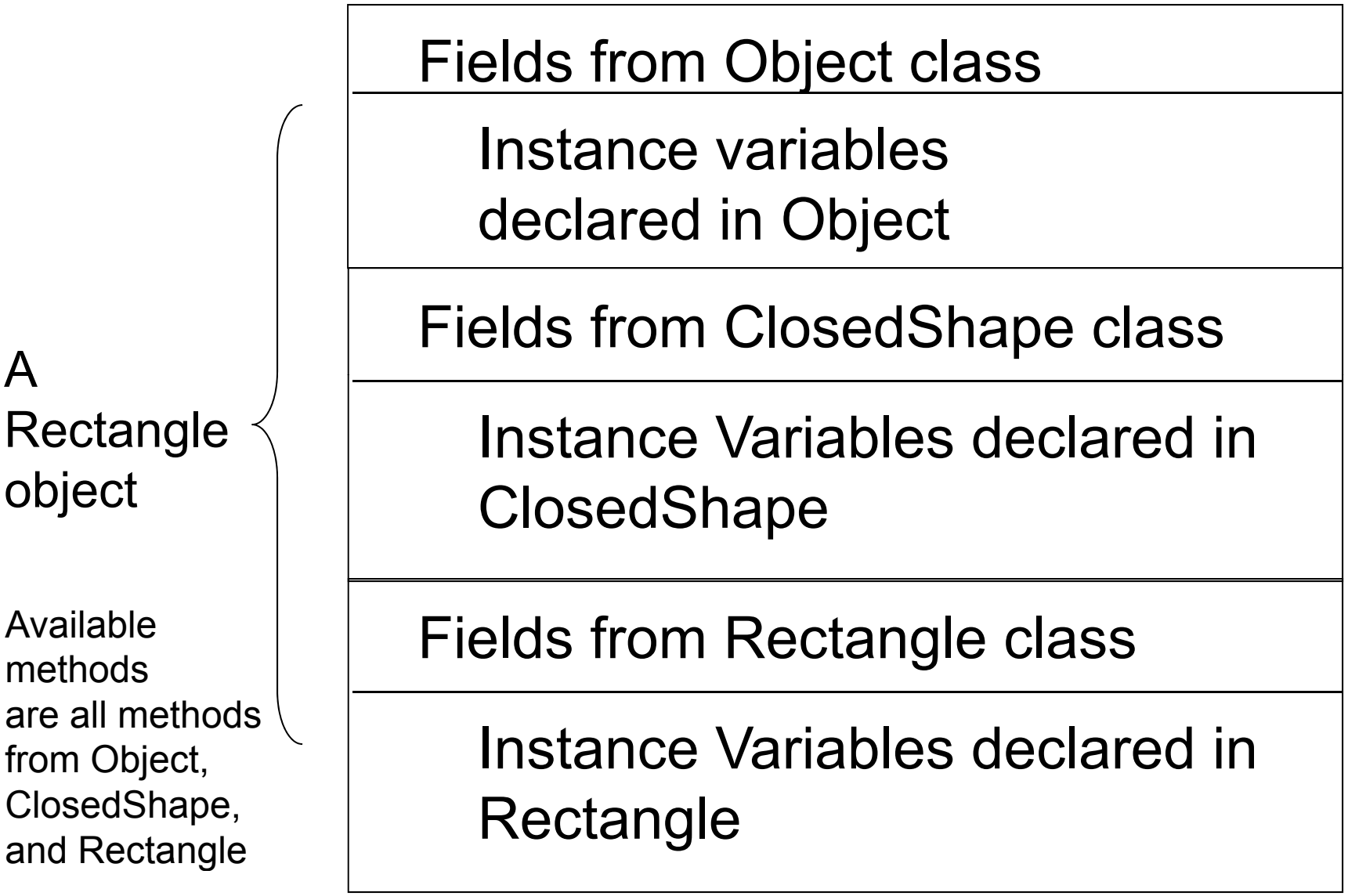
Result of Inheritance

Do any of these cause a syntax error?

What is the output?

```
Rectangle r = new Rectangle(1, 2, 3, 4);
ClosedShape s = new CloseShape(2, 3);
System.out.println( s.getX() );
System.out.println( s.getY() );
System.out.println( s.toString() );
System.out.println( r.getX() );
System.out.println( r.getY() );
System.out.println( r.toString() );
System.out.println( r.getWidth() );
```

The Real Picture



Access Modifiers and Inheritance

- public
  - accessible to all classes
- private
  - accessible only within that class. Hidden from all sub classes.
- protected
  - accessible by classes within the same *package* and all descendant classes
- Instance variables *should* be private
- protected methods are used to allow descendant classes to modify instance variables in ways other classes can't

Why private Vars and not protected?

- In general it is good practice to make instance variables private
  - hide them from your descendants
  - if you think descendants will need to access them or modify them provide protected methods to do this
- Why?
- Consider the following example

Required update

```
public class GamePiece
{       private Board myBoard;
        private Position myPos;

        // whenever my position changes I must
        // update the board so it knows about the change

        protected void alterPos( Position newPos )
        {       Position oldPos = myPos;
                myPos = newPos;
                myBoard.update( oldPos, myPos );
        }
```

Creating a SortedIntList

A New Class

- Assume we want to have a list of ints, but that the ints must always be maintained in ascending order

  `[-7, 12, 37, 212, 212, 313, 313, 500]`

  `sortedList.get(0)` returns the min

  `sortedList.get( list.size() - 1 )`
  returns the max

Implementing `SortedIntList`

- Do we have to write a whole new class?
- Assume we have an `IntList` class.
- Which of the following methods would have to be changed?

```
add(int value)
int get(int location)
String toString()
int size()
int remove(int location)
```

Overriding the `add` Method

- First attempt
- Problem?
- solving with `protected`
  - What `protected` really means
- solving with insert method
  - double edged sort

Problems

- What about this method?

```
void insert(int location, int val)
```

- What about this method?

```
void insertAll(int location,
    IntList otherList)
```

- `SortedIntList` is not the cleanest application of inheritance.

Explanation of Polymorphism

Polymorphism

- Another feature of OOP
- literally “having many forms”
- object variables in Java are polymorphic
- object variables can refer to objects or their declared type AND any objects that are descendants of the declared type

```
ClosedShape s = new
ClosedShape();
s = new Rectangle(); // legal!
s = new Circle(); //legal!

Object obj1; // = what?
```

Data Type

- object variables have:
  - a *declared type*. Also called the static type.
  - a *dynamic type*. What is the actual type of the pointee at run time or when a particular statement is executed.
- Method calls are syntactically legal if the method is in the declared type *or any ancestor* of the declared type
- **The actual method that is executed at runtime is based on the dynamic type**
  - dynamic dispatch

Attendance Question 3

Consider the following class declarations:

```
public class BoardSpace
public class Property extends BoardSpace
public class Street extends Property
public class Railroad extends Property
```

Which of the following statements would cause a syntax error? Assume all classes have a default constructor.

A. `Object obj = new Railroad();`

B. `Street s = new BoardSpace();`

C. `BoardSpace b = new Street();`

D. `Railroad r = new Street();`

E. More than one of these

What's the Output?

```
ClosedShape s = new ClosedShape(1,2);
System.out.println( s.toString() );
s = new Rectangle(2, 3, 4, 5);
System.out.println( s.toString() );
s = new Circle(4, 5, 10);
System.out.println( s.toString() );
s = new ClosedShape();
System.out.println( s.toString() );
```

Method LookUp

- To determine if a method is legal the compiler looks in the class based on the declared type
  - if it finds it great, if not go to the super class and look there
  - continue until the method is found, or the Object class is reached and the method was never found. (Compile error)
- To determine which method is actually executed the run time system
  - starts with the actual run time class of the object that is calling the method
  - search the class for that method
  - if found, execute it, otherwise go to the super class and keep looking
  - repeat until a version is found
- Is it possible the runtime system won't find a method?

Attendance Question 4

What is output by the code to the right when run?

A. `!!live`
B. `!eggegg`
C. `!egglive`
D. `!!!`
E. `eggegglive`

```
public class Animal{
  public String bt(){ return "!"; }
}

public class Mammal extends Animal{
  public String bt(){ return "live"; }
}

public class Platypus extends Mammal{
  public String bt(){ return "egg";}
}

Animal a1 = new Animal();
Animal a2 = new Platypus();
Mammal m1 = new Platypus();
System.out.print( a1.bt() );
System.out.print( a2.bt() );
System.out.print( m1.bt() );
```

Why Bother?

- Inheritance allows programs to model relationships in the real world
  - if the program follows the model it may be easier to write
- Inheritance allows code reuse
  - complete programs faster (especially large programs)
- Polymorphism allows code reuse in another way (We will explore this next time)
- Inheritance and polymorphism allow programmers to create *generic algorithms*

Genericity

- One of the goals of OOP is the support of code reuse to allow more efficient program development
- If a algorithm is essentially the same, but the code would vary based on the data type genericity allows only a single version of that code to exist
  - some languages support genericity via *templates*
  - in Java, there are 2 ways of doing this
    - polymorphism and the inheritance requirement
    - generics

the createASet example

```
public Object[] createASet(Object[] items)
{     /*
      pre: items != null, no elements
      of items = null
      post: return an array of Objects
      that represents a set of the elements
      in items. (all duplicates removed)
      */
```

```
{5, 1, 2, 3, 2, 3, 1, 5} -> {5, 1, 2, 3}
```

createASet examples

```
String[] sList = {"Texas", "texas", "Texas",
                  "Texas", "UT", "texas"};
Object[] sSet = createASet(sList);
for(int i = 0; i < sSet.length; i++)
    System.out.println( sSet[i] );

Object[] list = {"Hi", 1, 4, 3.3, true,
                 new ArrayList(), "Hi", 3.3, 4};
Object[] set = createASet(list);
for(int i = 0; i < set.length; i++)
    System.out.println( set[i] );
```

A Generic List Class

Back to `IntList`

- We may find `IntList` useful, but what if we want a List of `String`s? `Rectangle`s? `List`s?
  - What if I am not sure?
- Are the List algorithms going to be very different if I am storing `String`s instead of `int`s?
- How can we make a generic List class?

Generic List Class

- required changes
- How does `toString` have to change?
  - why?!?!
  - A good example of why keyword `this` is necessary from `toString`
- What can a `List` hold now?
- How many `List` classes do I need?

Writing an `equals` Method

- How to check if two objects are equal?

```
if(objA == objA)
    // does this work?
```

- Why not this

```
public boolean equals(List other)
```

- Because

```
public void foo(List a, Object b)
    if( a.equals(b) )
        System.out.println( same )
```

  – what if b is really a `List`?

`equals` method

- read the javadoc carefully!
- don't rely on `toString` and `String`'s equal
- lost of cases