Topic 4
Inheritance

"Question: What is the object oriented way of getting rich?

Answer: Inheritance.“

Features of OO Programming

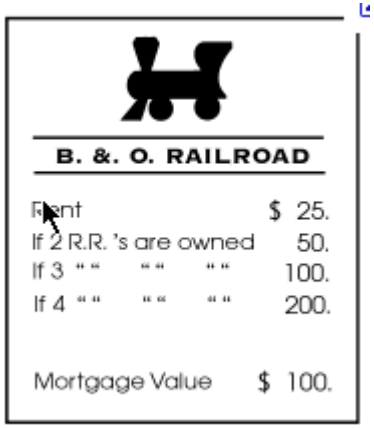
- Encapsulation
  - abstraction, creating new data types
  - information hiding
  - breaking problem up based on data types
- Inheritance
  - code reuse
  - specialization
  - "New code using old code."

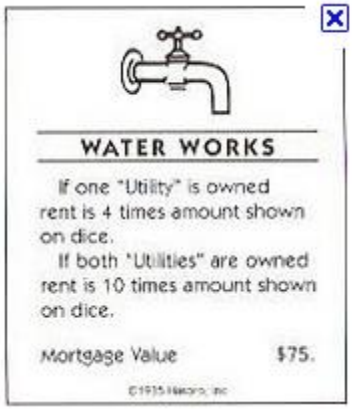
Encapsulation

- Create a program to allow people to play the game Monopoly
  - Create classes for money, dice, players, the bank, the board, chance cards, community chest cards, pieces, etc.
- Some classes use other classes. Are *clients*
  - the board *consists of* spaces
  - a player *has* properties they own
  - a piece *has* a position
- Also referred to as *composition*

Inheritance

- Another kind of relationship exists between things in the world and data types in programs
- There are properties in Monopoly
  - a street *is a kind* of property
  - a railroad *is a kind* of property
  - a utility *is a kind* of property





Inheritance

- In Monopoly there is the concept of a Property
- All properties have some common traits
  - they have a name
  - they have a position on the board
  - they can be owned by players
  - they have a purchase price
- *But* some things are different for each of the three kinds of property
  - determine rent when another player lands on the Property, only Streets can have houses

What to Do?

- If we have a separate class for Street, Railroad, and Utility there is going to be a lot of code copied
  - hard to maintain
  - an *anti-pattern*
- Inheritance is a programming feature to allow data types to build on pre-existing data types without repeating code

Mechanics of Inheritance

1. extends keyword
2. inheritance of instance methods
3. inheritance of instance variables
4. object initialization and constructors
5. calling a parent constructor with **`super()`**
6. overriding methods
7. partial overriding, **`super.parentMethod()`**
8. inheritance requirement in Java
9. the **`Object`** class
10. inheritance hierarchies

Inheritance in Java

- Java is designed to encourage object oriented programming
- 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

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

Clicker 1

What is the primary reason for using inheritance when programming?

A. To make a program more complicated

B. To copy and paste 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.

Clicker 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.

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
  - super.originalMethod()

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

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`

Creating a SortedIntList - A Cautionary Tale of Inheritance

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.
- Clicker 3 - Which of the following methods have to be changed?

```
A. add(int value)
B. int get(int location)
C. String toString()
D. int remove(int location)
E. More than one of A – D.
```

Overriding the `add` Method

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

Clicker 4

```
public class IntList {
    private int size
    private int[] con
}
public class SortedIntList extends IntList {
     public SortedIntList() {
          System.out.println(size); // Output?
     }
}
```

A. 0
B. null
C. unknown until code is run
D. no output due to a compile error
E. no output due to a runtime error

Problems

- What about this method?

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

- What about this method?

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

- `SortedIntList` is **not** a good application of inheritance given **all** the behaviors `IntList` provides.

More Example Code

ClosedShape and Rectangle classes

Simple Code Example

- Create a class named Shape
  - what class does Shape inherit from
  - what methods can we call on Shape objects?
  - add instance variables for a position
  - *override* the toString method
- Create a Circle class that extends Shape
  - add instance variable for radius
  - debug and look at contents
  - try to access instance var from Shape
  - constructor calls
  - use of key word *super*

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
```

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;
   }
}
```

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;
   }
```

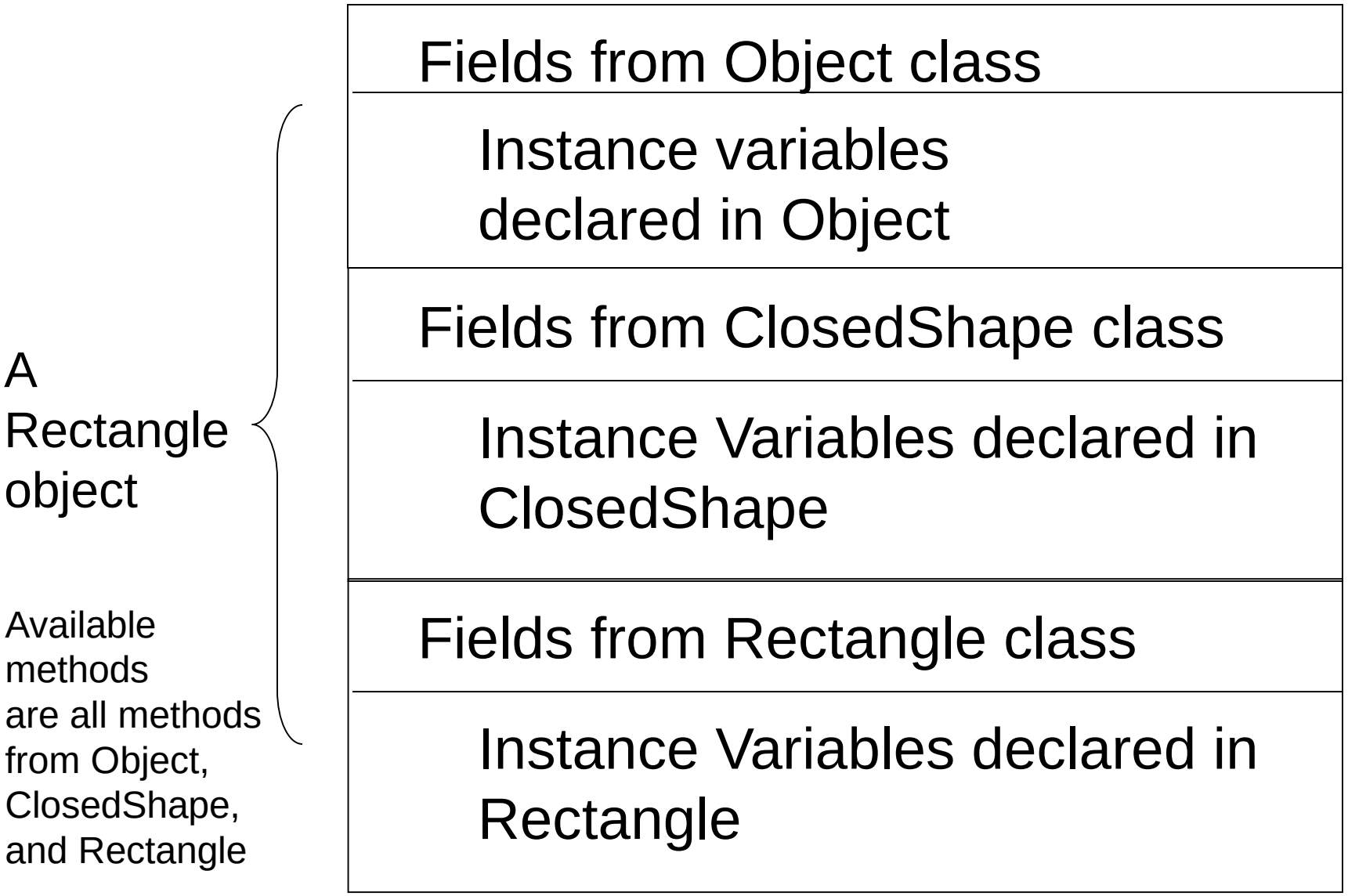
Result of Inheritance

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 are *typically* 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);
        }
```