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

- Encapsulation
  - abstraction
  - 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:

- the board consists of spaces
- a player has money
- a piece has a position
- also referred to as composition
Inheritance

- Another kind of relationship exists between data types
- 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 price to buy
- *But* some things are different for each of the three kinds of property
  - How to determine rent when another player lands on the Property
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
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 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.
Clicker Question 2

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

```java
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.
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*
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
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 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) \textbf{returns the min}

sortedList.get( \text{list.size()} – 1 ) \textbf{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 \texttt{add} Method

\begin{itemize}
\item First attempt
\item Problem?
\item solving with insert method
  \begin{itemize}
  \item double edged sort
  \end{itemize}
\item solving with \texttt{protected}
  \begin{itemize}
  \item What \texttt{protected} really means
  \end{itemize}
\end{itemize}
Problems

- What about this method?
  ```java
  void insert(int location, int val)
  ```
- What about this method?
  ```java
  void insertAll(int location, IntList otherList)
  ```
- `SortedIntList` is not a good application of inheritance given the `IntList` we developed
More Example Code

ClosedShape and Rectangle classes
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`
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

```java
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

```java
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

<table>
<thead>
<tr>
<th>Fields from Object class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instance variables declared in Object</td>
</tr>
</tbody>
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<th>Fields from ClosedShape class</th>
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<td>Instance Variables declared in Rectangle</td>
</tr>
</tbody>
</table>

A Rectangle object

Available methods are all methods from Object, ClosedShape, and Rectangle

Inheritance
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 );
    }
}