Lecture 36: Polymorphism

Last time:

1. Method overriding
2. Shadowing
3. Access issues in inheritance

Today:

1. Project #7 assigned
2. Object
3. Polymorphism and abstract methods
4. Upcasting / downcasting

Project #7 Assigned!

- Project due Sunday, 4/29 at 11 pm
- Project is closed
  - You must complete the project by yourself
  - Assistance can only be provided by teaching assistants (TAs) and instructors
  - You must not look at other students' code
- FINISH!

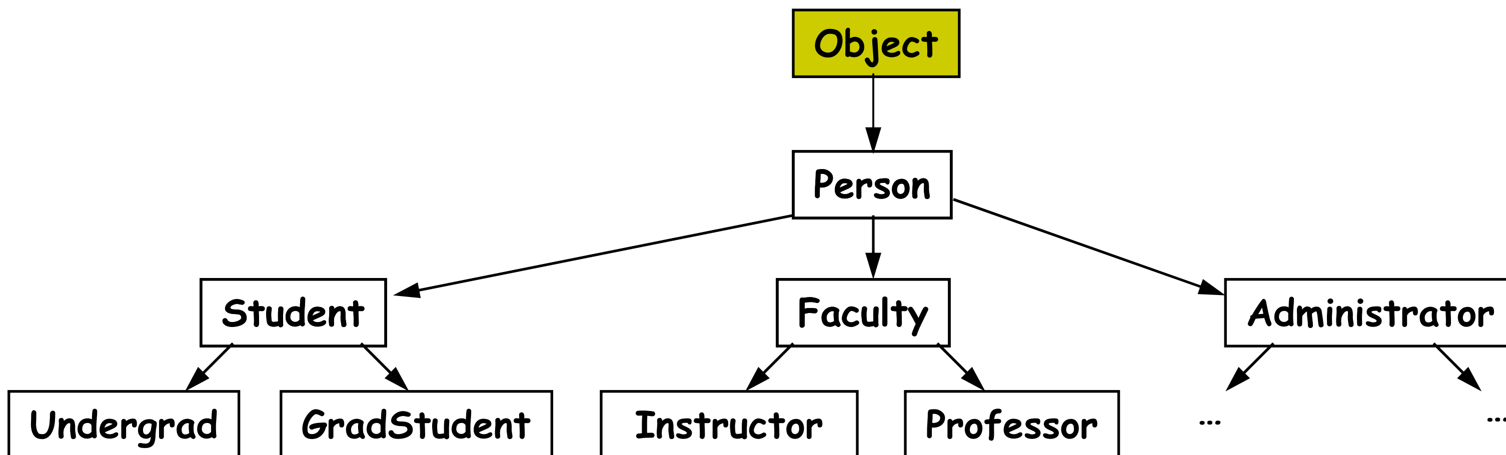
Recap

- Inheritance occurs when one class (derived class, subclass) is defined from another class (base / parent class, superclass).
- To derive a class D from a base class B, use:

  `public class D extends B { … }`
- Derived class inherits all instance variables, methods from base class. It can also define new instance variables, methods
- In derived-class constructor, **`super`**`( … )` can be used to invoke constructor from base class
- Derived class can explicitly refer to entities from base class using **`super`**, e.g. `super.toString( )`
- Polymorphism: object in derived class can be used anywhere base class is expected (a `Student` "is a" `Person`!)
- Derived class can override base-class methods (and variables)
  - **`final`** can be used to disallow overriding
  - Java uses late binding to determine which version of method to use
- **`protected`** modifier exposes declarations to subclasses (and package)

Object

- Recall: inheritance induces "is-a" hierarchy on classes
  - Undergrad "is-a" Student
  - Student "is-a" Person
  - etc.
- Person "is-a" ….?
- Person "is-a"(n) `Object`



More on `Object`

- Special class at top of class inheritance hierarchy
- Defined in `java.lang` (so available in every program)
- Every class is derived (either directly or indirectly) from `Object`
  - If a class is not derived from anything, it is automatically derived from `Object`
  - e.g.

    ```
    public class Foo { …}
    ```

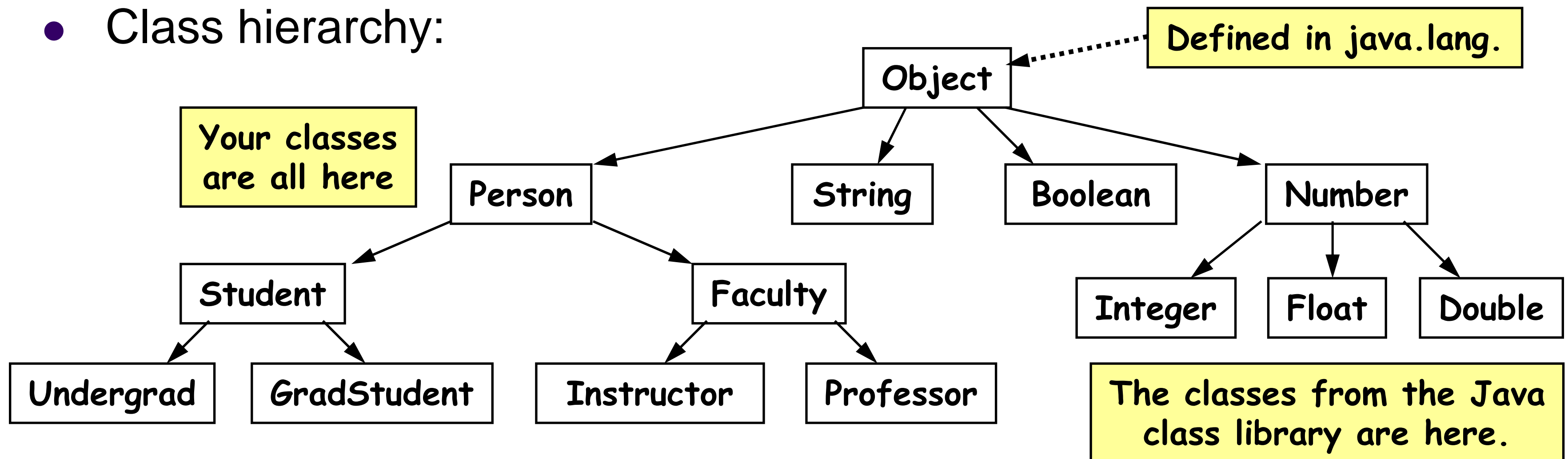
    is equivalent to

    ```
    public class Foo extends Object {…}
    ```

Structure of `Object`

- No instance variables
- A number of methods, including:
  - `toString()`
  - `equals (Object o)`

    Note: parameter to `equals` has type `Object`, so any object can be an argument
- These methods can (and usually should) be overridden
- Class hierarchy:



Polymorphism and Inheritance

- Recall
  - Objects in derived classes can be used wherever objects in base classes are needed

    e.g. `Person p = new Student ();`
  - Java uses late binding to determine which version of overridden method to use
- This means reference variables like `p` are polymorphic
  - Object referred to by `p` may be from any class derived from `Person`
  - An object is not modified when assigned to `p`; it retains its original form (e.g. `Student` in above case)

Polymorphism and Arrays

- Example: Create an array of various university people and print

```
Person[ ] list = new Person[3];
list[0] = new Person("Col. Mustard","000-00-0000");
list[1] = new Student ("Ms. Scarlet","111-11-1111",
          1998, 3.2);
list[2] = new Faculty ("Prof. Plum","222-22-2222",
          1981);
for (int i = 0; i < list.length; i++)
  System.out.println( list[i].toString( ) );
```

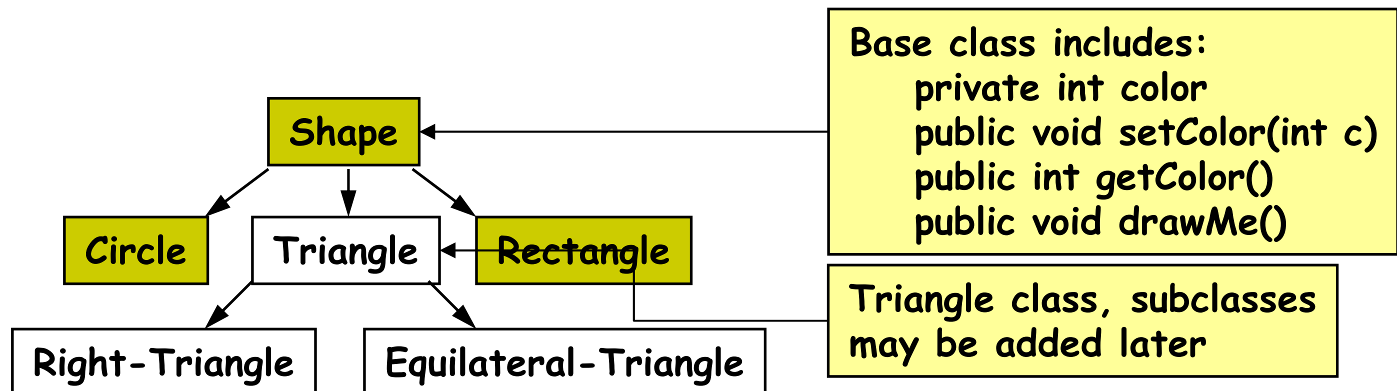
- What type is list[i]?
  - It can be a reference to any object that is derived from `Person`
  - Late binding ensures the appropriate `toString()` will be called

An Inheritance Example

- Goal: picture-drawing program
  - Picture is array of different shapes
  - Program should draw each shape on screen
- Desiderata
  - Shapes to handle initially are circles, rectangles
  - Want to leave door open for new shapes in future
  - Drawing shapes depends on kind of shape (drawing a rectangle different from drawing a circle)

Class Design

- Use inheritance hierarchy for shapes
- Base class (`Shape`) includes
  - Color field (as in Lecture #34)
  - **`drawMe()`** method for drawing shape
- Derived classes will override `drawMe()`

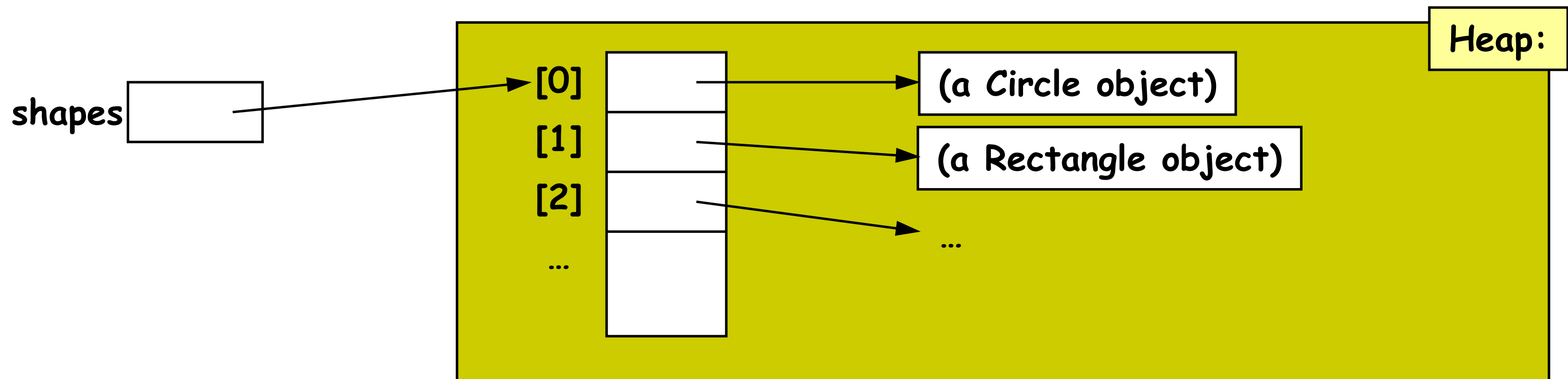


Picture Drawing

- Picture: array `shapes` of type `Shape[ ]`
- To draw picture, invoke `drawMe( )` for each shape:

```
Shape[ ] shapes = new Shape[…];
shapes[0] = new Circle( … );
shapes[1] = new Rectangle( … );
…
for ( int i = 0; i < shapes.length; i++ )
    shapes[i].drawMe();
```

- Note importance of late binding for this strategy!



Java Code

- Assume: class `Point` storing x, y coordinates
- Code layout

```
public class Shape {
   private int color;          // Color of shape
   …
   public void drawMe () { … }
}

public class Circle extends Shape {
   private double radius;      // Radius of circle
   private Point center;       // Center of circle
   …
   public void drawMe () { … }  // Draws a circle
}

public class Rectangle extends Shape {
   private Point upperLeft;    // Upper left corner
   private Point lowerRight;   // Lower right corner
   …
   public void drawMe () { … }  // Draws a rectangle
}
```

Abstract Methods

- Problem: how to implement `drawMe()` method for `Shape`?
  `Shape` class is for generic shapes … insufficient info to draw
- Could just do something ad hoc in implementation:
  - Raise an exception
  - Do nothing
  - Bad idea!
    - Point of `drawMe()` method is to override it in derived classes
    - If we don't override ad hoc implementation: run-time errors!
- Could leave out `drawMe()` method from Shape …
  but then we lose access to `drawMe()` method in picture drawing
- Better solution: Abstract methods/classes
  - What we want is for the compiler to know that Shape is an incomplete class: it declares but does not define some methods (e.g. `drawMe()`) that will be implemented in derived classes
  - To do this we use abstract methods

Abstract Methods and Classes

- Abstract methods
  - Like method declarations in an interface
    - Prototype info (return type, name, arguments)
    - No body
  - Derived classes can provide implementation
  - Notation

    ```
    public abstract void drawMe ();
    ```
- Abstract classes
  - Abstract class: class with at least one abstract method
  - **abstract** modifier must be used when declaring abstract classes

    ```
    public abstract Shape { … }
    ```
  - Abstract classes are incomplete, because not all methods implemented
    - `new` cannot be used on abstract classes

      ```
      Shape s = new Shape( … );// Illegal! Shape is abstract
      ```
    - Abstract classes can be used as types, however

      ```
      Shape s = new Circle( … );
      ```
- Classes that are not abstract are called concrete

Java Code Revisited

```
public abstract class Shape {          // Abstract class
   private int color;                  // Color of shape
   …
   public abstract void drawMe ();     // Abstract method
}

public class Circle extends Shape {  // Concrete class
   private double radius;    // Radius of circle
   private Point center;     // Center of circle
   …
   public void drawMe () { … }         // Draws a circle
}

public class Rectangle extends Shape {        // Concrete class
   private Point upperLeft; // Upper left corner
   private Point lowerRight;           // Lower right corner
   …
   public void drawMe () { … }         // Draws a rectangle
}
```

Recap Redux

- Inheritance occurs when one class (derived class, subclass) is defined from another class (base / parent class, superclass).
- To derive a class D from a base class B, use:

  ```
  public class D extends B { … }
  ```
- Derived class inherits all instance variables, methods from base class. It can also define new instance variables, methods
- In derived-class constructor, **`super`**`( … )` can be used to invoke constructor from base class
- Derived class can explicitly refer to entities from base class using **`super`**, e.g. `super.toString( )`
- Polymorphism: object in derived class can be used anywhere base class is expected (a `Student` "is a" `Person`!)
- Derived class can override base-class methods (and variables)
  - **`final`** can be used to disallow overriding
  - Java uses late binding to determine which version of method to use
- **`protected`** modifier exposes declarations to subclasses (and package)
- All objects are derived (directly or indirectly) from Object
- Late binding and inheritance allows you to create polymorphic variables
- When a method in a base class is not provided, the method and class are said to be abstract. Abstract methods may be implemented in (concrete) derived classes

Class vs. Type Information

- In Java
  - Every object is in one class (the one it was created from using `new`)
  - Objects may have many types
    - Interfaces
    - Superclasses
- E.g. consider

```
Student bob = new Student();
Person p = bob;
```

  - Class of object pointed to by `bob`, `p` is `Student`
  - Type of object can be `Student`, `Person`, `Object`, etc.

Accessing Class / Type Information

- Objects can access their class info at run-time
- **`getClass()`**
  - Method defined in `Object`
  - Returns representation of object's class
  - E.g.

```
Person bob = new Person( … );
Person ted = new Student( … );

if ( bob.getClass() == ted.getClass() )
// false (ted is really a Student)
```

- **`instanceof`**
  - Java boolean operator (not a method)
  - Returns true if given object "is-a"(n) object of given (class) type
  - E.g.

```
Student carol = new Student ( … );
if (carol instanceof Person) // true, because carol "is-a" Person
```

Object Casting

- Recall casting in primitive types
  - Casting: conversion of elements from one type to another
  - Upcasting
    - Every element in source type "is-a" element in destination type
    - Can be done automatically

      ```
      double x = 3;  // 3 (int) upcast to double
      ```
  - Downcasting
    - Elements in source type are not necessarily elements in destination type
    - Must use explicit type conversions to perform this casting

      ```
      int x = (int)3.0; // 3.0 explicitly cast to int
      ```
- Similar notions can be found with object types also
  - Upcasting
    - Casting a reference to a superclass (casting up the inheritance tree)
    - Always done automatically and is always safe
  - Downcasting
    - Casting a reference to a derived class
    - Requires explicit casting operator, which checks type info at run-time
    - May not be legal (depending on the actual object type)

Casting Example

```
Person bob = new Person( … );
Student ted = new Student( … );
Student carol = new Student( … );
GradStudent alice = new GradStudent( … );

bob = ted;                      // Upcasting.  OK

carol = bob;                    // Implicit downcasting.
                                // Compile error!

carol = (Student) bob;          // Explicit downcasting.
                                // OK:  bob holds Student object

alice = (GradStudent) ted;      // Explicit downcasting.
                                // Run-time error; ted not a
                                // GradStudent object
```