COMP 110-003
Introduction to Programming
Inheritance and Polymorphism

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THE UNIVERSITY *of* NORTH CAROLINA *at* CHAPEL HILL

Daily Joke

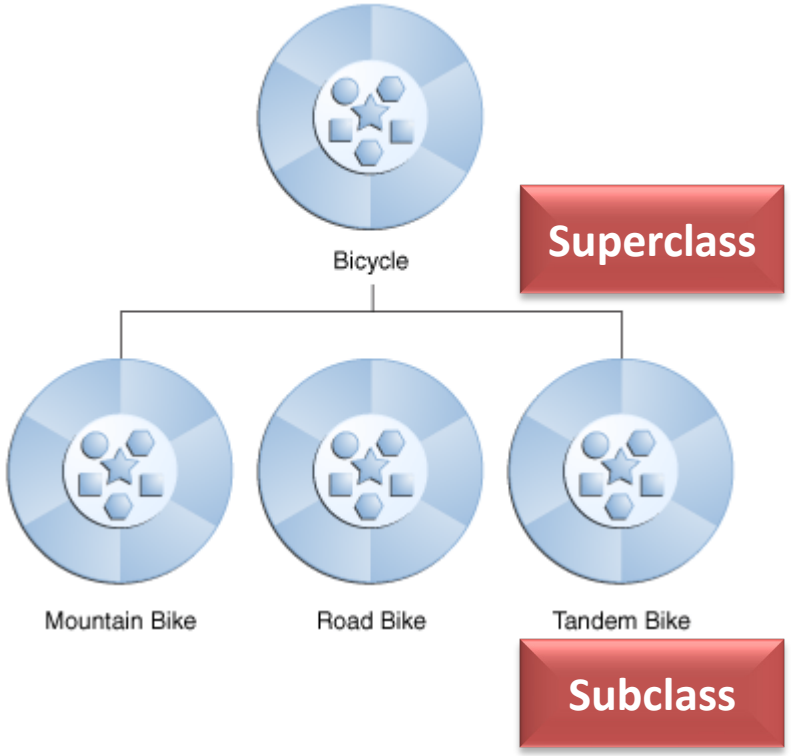
- Q: What's the object-oriented way to become wealthy?
- A: Inheritance

Inheritance

- Important questions:
  - What is inheritance?
  - How to use inheritance?
- The biggest difficulty:
  - Inheritance is specifically used for “better design”
  - Design is harder than implementation, so you haven’t done much design

Inheritance

- A way to organize classes
- Derived classes share the characteristics of base classes
- Usually referred as **subclass** and **superclass**
  - We don't use child class and parent class because it's inaccurate



Example: Bike

```
public class Bicycle {
     // the Bicycle class has three fields
     public int cadence, gear, speed;

     // the Bicycle class has one constructor
     public Bicycle(int startCadence, int startSpeed, int startGear) {
          gear = startGear; cadence = startCadence; speed = startSpeed;
     }

     // the Bicycle class has four methods
     public void setCadence(int newValue) {
          cadence = newValue;
     }
     public void setGear(int newValue) {
          gear = newValue;
     }
     public void applyBrake(int decrement) {
          speed -= decrement;
     }
     public void speedUp(int increment) {
          speed += increment;
     }
}
```

Example: MountainBike

```
public class MountainBike extends Bicycle {

     // the MountainBike subclass adds one field
     public int seatHeight;

     // the MountainBike subclass has one constructor
     public MountainBike(int startHeight, int startCadence, int startSpeed,
          int startGear) {
          super(startCadence, startSpeed, startGear); // introduce later
          seatHeight = startHeight;
     }

     // the MountainBike subclass adds one method
     public void setHeight(int newValue) {
          seatHeight = newValue;
     }
}
```

Syntax Rules

- public class **Derived_Class_Name extends Base_Class_Name**
  - `public class MountainBike extends Bicycle`
- After the inheritance, the subclass inherits all the **public** variables and methods of the superclass
  - Also, the subclass can add new variables and methods
    - Bicycle class has *cadence, gear, speed*, constructor and four setters
    - MountainBike class has ***cadence, gear, speed***, seatHeight, constructor, **four setters** and a new setter setHeight()

First Summary

- Subclasses inherit all public variables and methods from superclass
  - They can use these variables and methods as their own
    - MountainBike mb = new MountainBike(110, 50, 30, 4);
    - mb.setGear(5);
  - You don't have to copy and paste the duplicate methods. It ***seems*** a good way to reuse your old code

More Inheritance: Override

- Moreover, you can write a method (and variables) in the subclass to **hide** the method **with the same name** in the superclass
  - In this example, the MountainBike has a powerful break so it immediately reduce the speed to 0

```
public class MountainBike extends Bicycle {
     // the MountainBike subclass overrides one method
     public void applyBrake(int decrement) {
          speed = 0;
     }
}
```

  - Now if we call mb.applyBrake(3), the speed will be 0
    - It won't be the old speed minus 3, as the superclass defines

Wait a Minute……

- What's the point of overriding a method
  - If we want to reuse a method by inheritance, why do we rewrite the method?
- If we think more – why do we reuse our code by inheritance?
  - We can simply **use** the old class in the new class
  - Remember that we only inherit the public variables and methods – there is no difference between using the superclass

Example: MountainBike2

```
public class MountainBike2 {
     public int seatHeight;
     // the Bicycle class is used -- instead of inherited
     public Bicycle mb;

     public MountainBike2(int startHeight, int startCadence, int startSpeed,
          int startGear) {
          mb = new Bicycle(startCadence, startSpeed, startGear);
          seatHeight = startHeight;
     }

     public void setGear(int newValue) {
          mb.setGear(newValue);
     }

     public void applyBrake(int decrement) {
          mb.speed = 0;
     }
}
```


Inheritance is NOT for Reusability

- Though inheritance can be good for reusability, it is not intended for reusability
  - That means, if you want to reuse your code, you shall **not** think about inheritance first!
- Inheritance is for **flexibility**
  - It is used when different objects need different methods
  - We call this property **"polymorphism"**

Polymorphism

- It means “many forms”
- Same instruction to mean different things in different contexts.
  - Example: “Go play your favorite sport.”
    - I’d go play soccer
    - Others of you would play basketball or football instead.
- In programming, this means that the **same** method name can cause **different actions** depending on what object it is applied to

Why is Polymorphism Required?

- Let's consider if we want to design a set of classes that represents animals
  - Every animal can play its own sound
  - If we have to write a method for each animal, the class design will be a disaster

Animal Class without Polymorphism

```
public class Animal {
     private String animalName;
     private String species;
     private void playDuckSound() {
          // play "QUACK"
     }
     private void playDogSound() {
          // play "WOOF"
     }
     private void playCatSound() {
          // play "MEW"
     }

     public void speak() {
          if (species.equals("Duck")) {
               this.playDuckSound();
          } else if (species.equals("Dog")) {
               this.playDogSound();
          } else if (species.equals("Cat")) {
               this.playCatSound();
          }
     }
}
```


If We Want to Add Cow to the Class

- We must add a method called playCowSound()
  - Let it play “moo”
- Then we must change the speak() method by adding a new case in the multibranch statement
  - If there is more than one method that depends on the species, we need more
    - eat(), hunt(), sleep()
  - Again, modifying this class is a disaster

Loops, Arrays and Polymorphism

- Loops are used to repeatedly access similar statements
- Arrays are used to repeatedly access similar variables
- Polymorphism are used to access similar methods

- Their syntax rules are very different, but you shall see a similar purpose

Polymorphism and Overriding

- Key point:
  - You can create a subclass object for a superclass type variable
  - When you invoke the methods from the superclass variable, the overridden method is called

```
// Animal.java
public class Animal {
     private String animalName;
     public void speak() {
          // default method -- can be empty
     }
}

// In another file Cat.java
public class Cat extends Animal {
     public void speak() {
          // play "MEW"
     }
     public static void main(String[] args) {
          Animal c = new Cat();
          c.speak(); // will play "MEW"
     }
}
```


Polymorphism and Overriding

```
public class Animal {
     private String animalName;
     public void speak() {
     // default method -- can be empty
     }

     public static void main(String[] args)
     {
          Animal a[] = new Animal[3];
          a[0] = new Cat();
          a[1] = new Dog();
          a[2] = new Duck();
          for (int i = 0; i < 3; i++) {
               a[i].speak();
          }
     }
}
```

```
public class Cat extends Animal {
     public void speak() {
          System.out.println("MEW");
     }
}

public class Dog extends Animal {
     public void speak() {
          System.out.println("WOOF");
     }
}

public class Duck extends Animal {
     public void speak() {
          System.out.println("QUACK");
     }
}
```

Output: MEW, WOOF, QUACK

Polymorphism and Dynamic Binding

- What if we want to add a new animal: cow?
  - Just write a new class ***Cow***
    - Nothing in ***Animal*** shall be changed
  - If you have another method in ***Animal*** that calls speak(), it won't be affected
    - The method invocation is not bound to the method definition until the program executes
    - Java dynamically decide what method to call at ***run-time***

```
public class Cow extends Animal {
     public void speak() {
          System.out.println("MOO");
     }
}
```

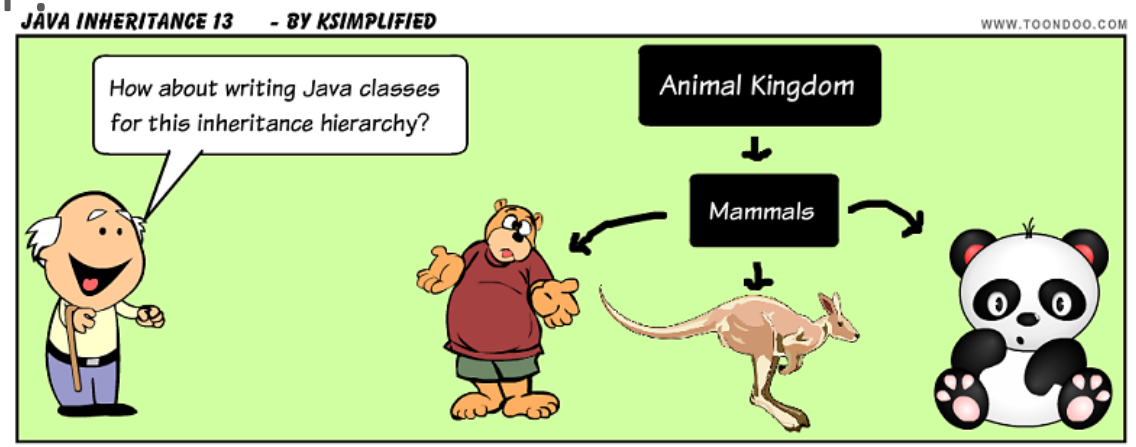
```
public class Animal {
     public static void groupSpeak
               (Animal[] group) {
          for (int i = 0; i < group.length; i++)
               group[i].speak();
}}
```


Second Summary: Polymorphism

- In programming, this means that the same method name can cause different actions depending on what object it is applied to
  - You can create a subclass object for a superclass type variable
  - When you invoke the methods from the superclass variable, the overridden method is called

The *is-a* Relationship

- This inheritance relationship is known as an ***is-a relationship***
  - A Bear ***is a*** Mammal
  - A Mammal ***is an*** Animal
- Is a Mammal a Bear?
  - Not necessarily!



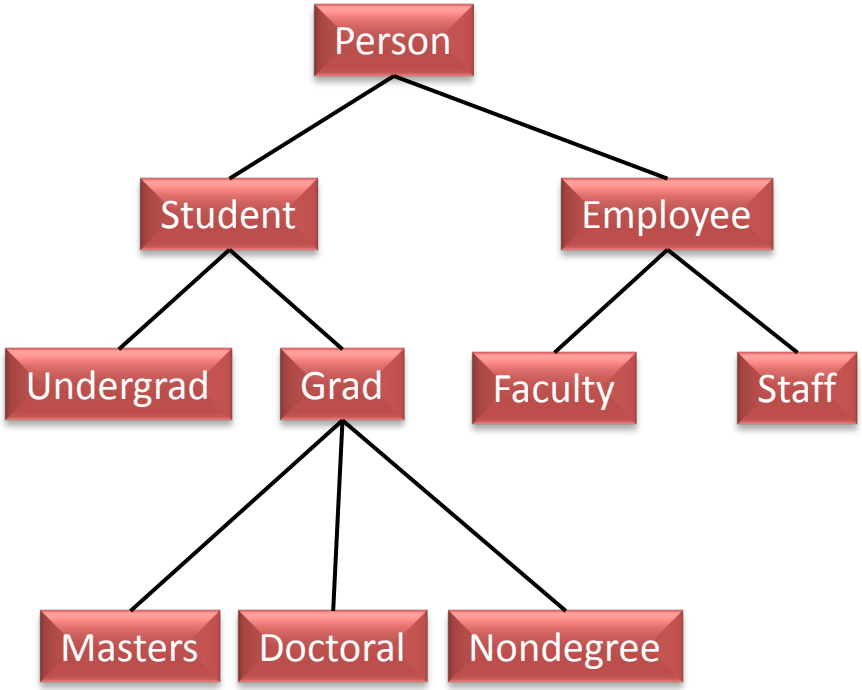
The *is-a* Relationship

```
public class Animal {
     public void eat() {
          System.out.println("Get
               anything to eat");
     }
}

public class Mammal extends Animal {
}

public class Bear extends Mammal {
     public void eat() {
          System.out.println("Find a
               fish to eat");
     }
     public void hibernate() {
          System.out.println("Zzzzzz");
     }
}
```

```
public static void main(String[]
args) {
     Animal a = new Mammal();
     // YES! A Mammal is an Animal
     Animal b = new Bear();
     // YES! A Bear is an Animal
     Mammal c = new Bear();
     // YES! A Bear is a Mammal
     // Bear d = new Mammal(); NO! A
     // Mammal may not be a Bear!
     a.eat(); // OK. Mammal doesn't
     // override eat(). Eat anything.
     b.eat(); // OK. Bear overrides
     // eat(). Eat fish.
     // c.hibernate(); WRONG! Mammal
     // doesn't have this method!
}
```

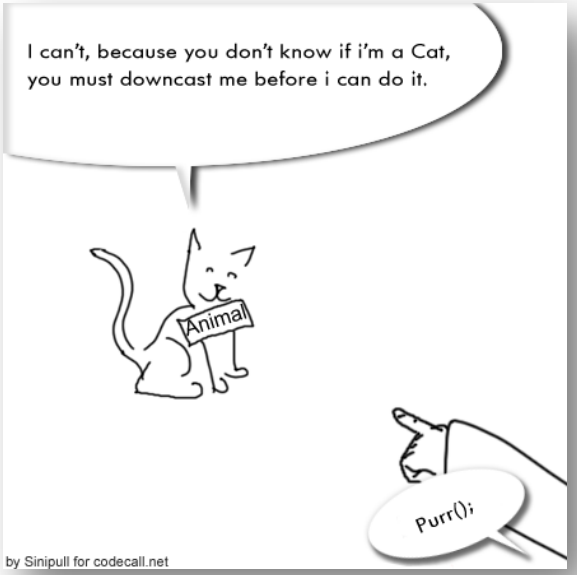

More Complicated Hierarchy

- Who *is a* whom?



Third Summary

- A subclass object can be assigned to a superclass type variable
  - After the assignment, it loses its newly added methods
  - However, it can still perform its own action from overridden methods
- Therefore, a superclass object acts as a superclass all the time, though it can be actually a subclass object



Liskov Substitution Principle

- Derived types must be **completely substitutable** for their base types
  - Inheritance in fact means “detailed substitute”
    - A bear can do anything that a mammal can do
  - Therefore we don’t name them as parent/child class
    - Children is not substitutes of their parent
- In a design, you must understand if a class **is** another class, or **uses** another class
  - Never inherit another class just because you want to use it!

is-a vs. *use-a*

- Sometimes it is easy to determine
  - A sedan is a car; a sedan uses an engine
- Sometimes it is hard
  - Is Square a Rectangle?
    - In program design, a square is not a rectangle!
    - Because a square can not substitute a rectangle!
      - In a rectangle, changing length won't change its width
      - In a square, it will – it's not acting like a rectangle!
  - Square can be implemented by using a rectangle
    - Still, not straightforward
      - Basically they are different

Square vs. Rectangle

```
public class Rectangle {
      protected int m_width;
      protected int m_height;

      public void setWidth(int width) {
            m_width = width;
      }

      public void setHeight(int height) {
            m_height = height;
      }

      public int getWidth() {
            return m_width;
      }

      public int getHeight() {
            return m_height;
      }

      public int getArea() {
            return m_width * m_height;
      }
}
```

```
public class Square extends Rectangle {
      public void setWidth(int width) {
            m_width = width;
            m_height = width;
      }

      public void setHeight(int height) {
            m_width = height;
            m_height = height;
      }

      public static void main(String args[]) {
            Rectangle r = new Square();
            r.setWidth(5);
            r.setHeight(10);
            // user knows that r it's a rectangle.
            // It assumes that he's able to set the
            // width and height as for the base
            // class
            System.out.println(r.getArea());
            // now he's surprised to see that the
            //area is 100 instead of 50.
      }
}
```


public, protected and *private*

- private instance variables and private methods in the base class are NOT inherited by derived classes
  - private instance variables and private methods are inaccessible in all other classes – including its subclasses
- protected instance variables and protected methods in the base class are inherited by derived classes
  - protected instance variables and protected methods are inaccessible in other classes except its subclasses

public, protected and *private*

- private instance variables and private methods exist in subclasses – they are just **invisible**
  - You can call them from public methods in superclasses

```
public class Person {
     private int ID;
     protected int age;
     public int getID(){
          return ID;
     }
}
```

```
public class Student extends Person{
     public void printInfo(){
          System.out.println(age);
          // OK. Age is accessible by Student
          System.out.println(ID);
          // WRONG! ID is invisible to Student;
          System.out.println(this.getID());
          // It is OK. getID() is public
     }
}
```


Using the Keyword *super*

- If your method overrides one of its superclass's methods, you can invoke the overridden method through the use of the keyword *super*

```
public class Animal {
     public void eat() {
          System.out.println("Get anything to eat");
     }
}

public class Bear extends Animal {
     public void eat() {
          super.eat();
          System.out.println("Finding a fish to eat is better");
     }
}
```

Using the Keyword *super*

- *super* can also be used to invoke superclass's constructor. It must be the first line in the subclass constructor

```
public class MountainBike extends Bicycle {
     public MountainBike(int startHeight, int startCadence, int startSpeed,
          int startGear) {
          super(startCadence, startSpeed, startGear);
          seatHeight = startHeight;
}}
```

  - The default constructor super() will be automatically called. If the super class does not have a no-argument constructor, you **must** invoke the superclass constructor with a matching parameter list

Overriding and Overloading

- If a derived class defines a method of the same name, same number and types of parameter as a base class method (in short, the same **signature**), this is ***overriding***
- You can still have another method of the *same name* in the same class, as long as its number or types of parameters are different: ***overloading***

Overriding and Overloading

```
public class BaseClass {
      public void m(int a) {
            System.out.println("Method with one int in BaseClass");
      }

      public void m(int a, int b) {
            System.out.println("Method with two int in BaseClass");
      }
}
```

```
public class DeriveClass extends BaseClass {
      public void m(int a) {
            System.out.println("Method with one int in DeriveClass");
      }
      public static void main(String[] args) {
            BaseClass c = new DeriveClass();
            c.m(0);
      }
}
```

c is a DeriveClass object. The method *m(int)* is defined (overridden) in c

Will print: Method with one int in DeriveClass

Overriding and Overloading

```
public class BaseClass {
      public void m(int a) {
            System.out.println("Method with one int in BaseClass");
      }

      public void m(int a, int b) {
            System.out.println("Method with two int in BaseClass");
      }
}
```

```
public class DeriveClass extends BaseClass {
      public void m(int a) {
            System.out.println("Method with one int in DeriveClass");
      }
      public static void main(String[] args) {
            BaseClass c = new DeriveClass();
            c.m(0,0);
      }
}
```

c is a DeriveClass object. However, the method *m(int, int)* is not defined (overridden) in c. Therefore, it will call the inherited and overloaded method in BaseClass

Will print: Method with two int in BaseClass

Overriding and Overloading

```
public class BaseClass {
      public void m(int a) {
            System.out.println("Method with one int in BaseClass");
      }
}
```

```
public class DeriveClass extends BaseClass {
      public void m(int a) {
            System.out.println("Method with one int in DeriveClass");
      }

      public void m(int a, int b) {
            System.out.println("Method with two int in DeriveClass");
      }

      public static void main(String[] args) {
            BaseClass c = new DeriveClass();
            c.m(0,0);
            // You can declare c as DeriveClass c = new DeriveClass()
      }
}
```

c is in BaseClass type. There is no *m(int, int)* method defined in BaseClass type.

Will cause a syntax error

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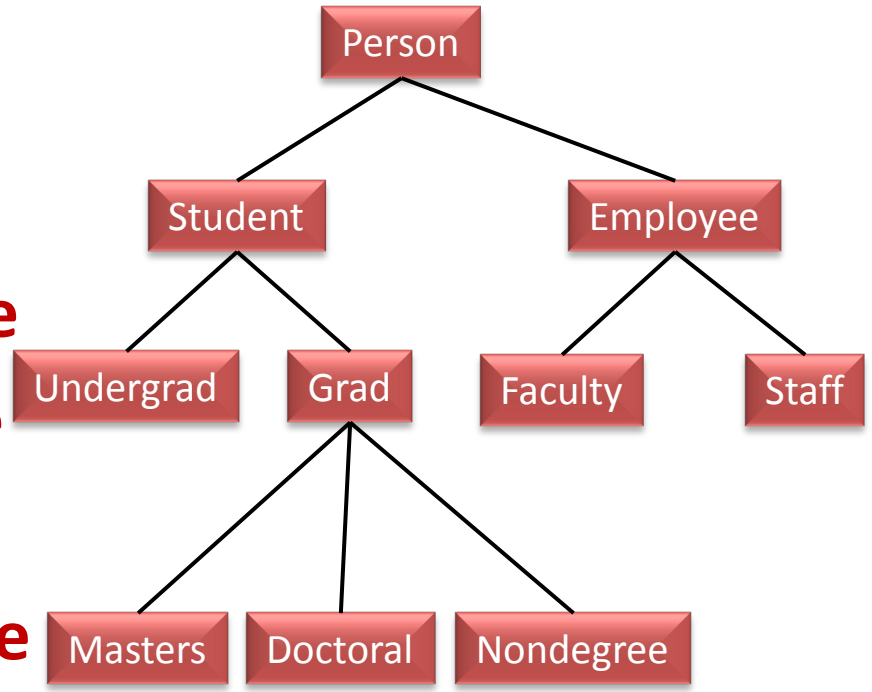
Keyword *instanceof*

- instanceof is very similar to a comparison operator. It returns a boolean value indicating if an object is in a given class type
- The syntax rule: **Variable_of_Object instanceof Class_Name**
  - If the value of the expression is true, it means the variable is (or can be treated as) in the class type

Keyword *instanceof*

- *Person a = new Grad();*
- *Grad b = new Doctoral();*
- *Employee c = new Faculty();*
- *a instanceof Grad* is **true**
- *a instanceof Doctoral* is **false**
- *b instanceof Doctoral* is **true**
- *c instanceof Person* is **true**
- *c instanceof Employee* is **true**



Type Casting

- Similar to primitive types, you can cast a variable to a different type
  - Syntax rule: **(Class_Name) variable_of_object**;
    - *double d = 13.5;*
    - *int a = (int) d;*
    - *Person p = new Student();*
    - *Student s = (Student) p;*
  - A run-time error happens if you can't cast the object
    - *Person p = new Student();*
    - *Student s = (Student) p;*
    - *Doctoral d = (Doctoral) p;* ***// WRONG! p is not in Doctoral type!***

Type Casting

- You can cast the object only if the object is an instance of the class type
  - Therefore, you can always use
    if (objectVariable instanceof ClassName)
    ClassName newVar = (ClassName) objectVariable;
  - The casting can be to a higher level (to superclass) or to a lower level (to subclass). Usually we only use the explict casting if to a lower level
    - *Student s = new Doctoral();*
    - *Person p = s;*
    - *Doctoral d = (Doctoral) s;*

The Class Object

- Every class in Java inherits a base class "Object"
  - You don't have to write "extends" explicitly
  - Every class in Java **is an** object
- Class Object has several methods that can be overridden
  - The most important one is
    public boolean equals (Object obj)
  - This method compares if two Object variables are the same
  - We've used the overridden one in String class

equals() Method

- Read Chapter 8.2 for more details

```
public class Student {

	private String name;
	private int studentNumber;

	public boolean sameName(Student otherStudent) {
		return this.name.equals(otherStudent.name);
	}

	public boolean equals(Object otherObject) {
		boolean isEqual = false;
		if (otherObject instanceof Student) {
			Student otherStudent = (Student) otherObject;
			isEqual = this.sameName(otherStudent)
				&& (this.studentNumber == otherStudent.studentNumber);
		}
		return isEqual;
	}
}
```

Two More Keywords: abstract & final

- If a method is **abstract**, subclasses must override it
- If a method is **final**, subclasses can not override it
- There are more details:
  - A class with at least one abstract method is called an abstract class. You can not create objects in this class. It can only be used as a base class
  - A class can be declared as final. Then you can not inherit this class
  - A variable can also be declared as final. You know that it also means the variable is not changeable

Two More Keywords: abstract & final

```
public abstract class AbstractClass {
      public abstract void m();
      // An abstract method can not have method body
      // Also, you must declare the class as abstract
}

public class ClassWithFinal {
      public final void m() {
            System.out.println("Can't override!");
      }
      public void n() {
            System.out.println("Can override");
      }
}

public final class FinalClass {
      public void m() {
            System.out.println("Can't inheritance!");
      }
}
```

```
public class Class1 extends AbstractClass {
      public void m() {
            System.out.println("Must override!");
      }
}

public class Class2 extends ClassWithFinal {

      // Can not override method m();

      public void n() {
            System.out.println("Override n()!");
      }
}


// A final class can not be inherited
```

Take-Home Message

- A subclass object can be assigned to a superclass type variable
- When you invoke a method, what is called depends on what **object** it is invoked from
- Polymorphism means you can write methods for superclass only, and the behavior depends on detailed subclass implementation

Announcement

- On next lecture, we will start reviewing the important contents, with sample questions from example exams
  - Be sure to attend!
- Read Lab 6 and Lab 7, and review sheets
  - No submission required for new labs. Solutions are given
- Send me an email if you want to attend our tic-tac-toe AI tournament
  - You need (eventually) a version with CPU moves first