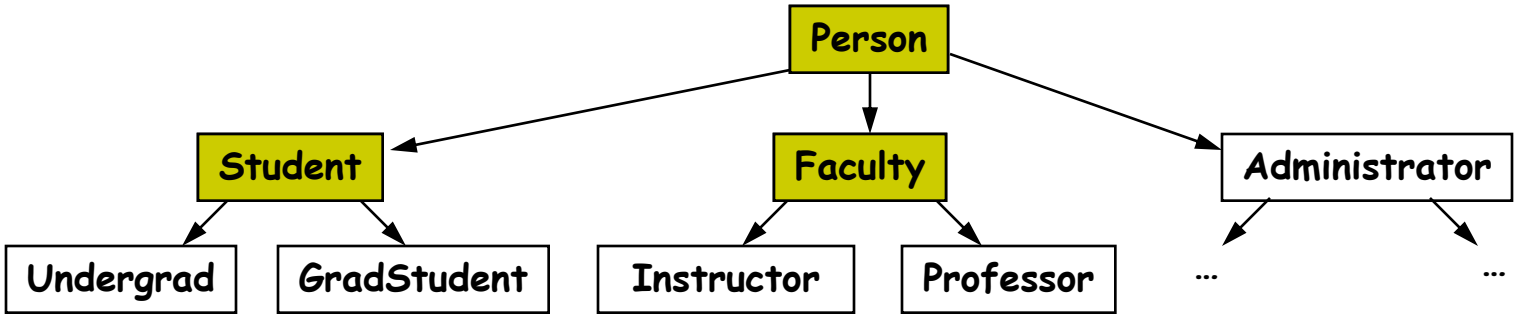
Implements vs. Extends When Defining a Class

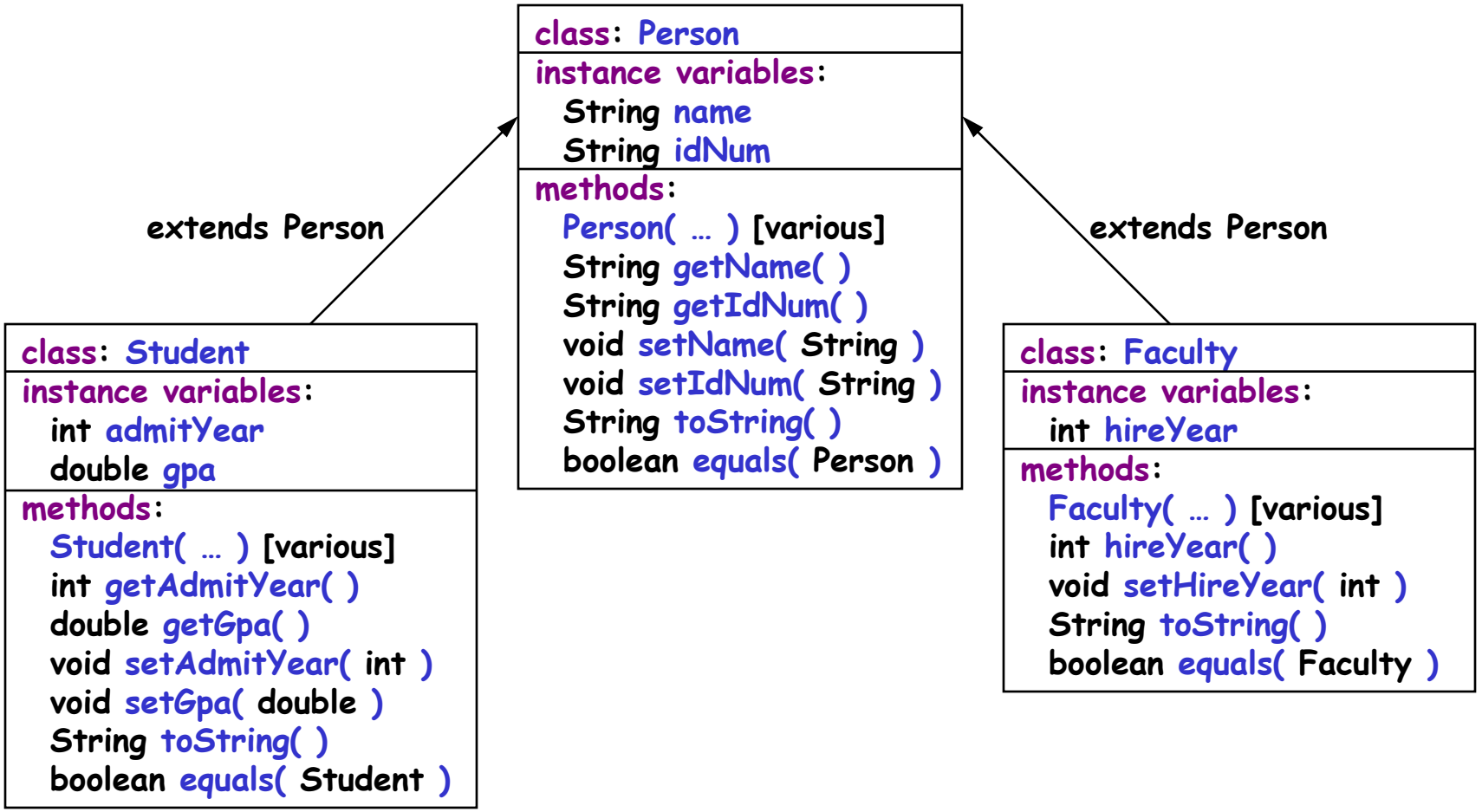
- implements:
  - Keyword followed by the name of an INTERFACE
  - Interfaces only have method PROTOTYPES
  - You CANNOT create on object of an interface type
  - Can have a reference of the interface type point to an object of the class that implements it
- extends:
  - Keyword followed by the name of a CLASS
  - That class contains full method DEFINITIONS
  - You CAN create objects of that base class type
  - Can have reference of the base class type point to an object of the class that extends it

Example: People at University

- Base class: person
- Derived classes: student, faculty, administrator
- Derived from those: undergrad, grad, instructor, professor,…



University Person Example



Overriding vs. Overloading

- Overriding: a derived class defines a method with same name, parameters as base class
- Overloading: two or more methods have the same name, but different parameters
- Example

```
public class Person {
    public void setName( String n ) { name = n; }
    …
}
public class Faculty extends Person {
    public void setName( String n ) {
        super.setName( "The Evil Professor " + n );
    }
    public void setName( String first, String last ) {
        super.setName( first + " " + last );
    }
}
```

Base class setName( )

Overriding

Overloading

Early vs. Late Binding

- Consider:

```
Faculty carol =
  new Faculty("Carol Tuffteacher","999-99-9999", 1995);
Person p = carol;
System.out.println( p.toString() );
```

- Which version of `toString` – `Person` or `Faculty` – is called?
  - Early (static) binding
    - `p` is declared to be of type `Person`
    - Therefore, the `Person` version of `toString` is used
  - Late (dynamic) binding
    - The object to which `p` refers was created as `Faculty` object
    - Therefore, the `Faculty` version of `toString` is used
- Java uses late binding (C++ by default uses early binding)
  - Early binding is more runtime efficient (decisions about method versions can be made at compile time)
  - Late binding respects encapsulation (object defines its operations when it is created)

Polymorphism

- Java's **late binding** makes it possible for a single reference variable to refer to objects of many different types. Such a variable is said to be **polymorphic** (meaning having many forms).
- **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( ) )
```

Output:

```
[Col. Mustard] 000-00-0000
[Ms. Scarlet] 111-11-1111 1998 3.2
[Prof. Plum] 222-22-2222 1981
```

- **What type is list[i]?** It can be a reference to any object that is derived from Person. The appropriate toString will be called.

Public, Protected, Package(default) and Private

- Select which level of visibility

Access Levels				
Access Level/Group	Class	Package	SubClass	World
public	Y	Y	Y	Y
protected(avoid)	Y	Y	Y	N
package (default)	Y	Y	N	N
private	Y	N	N	N

Shadowing

- Can we override instance variables just like methods?
- Yes, but be careful!
  - Overriding instance variable is called shadowing
  - Shadowing hides instance variables of base class (can still access them using `super.varName` in subclass, but not in "outside world")

```
public class Person {
   String name;
   …
}
public class Administrator extends Person {
   String name;  // name refers to Administrator's name
}
```

  - Confusing! Better to pick a new variable name

Example of Overloading/Overriding

```
public class Base {
    public void m (int x) { … }
}

public class Derived extends Base {
    public void m (int x) { … }
    public int m (int x) { … }
    public void m (double d) { … }
}

// The following appears in the same package as above

    Base b = new Base( );
    Base d = new Derived( );
    Derived e = new Derived( );
    b.m (5);
    d.m (6);
    d.m (7.0);
    e.m (8.0);
```

Overriding: with increased visibility

Error! duplicate method declaration

Overloading

calls Base:m(int)

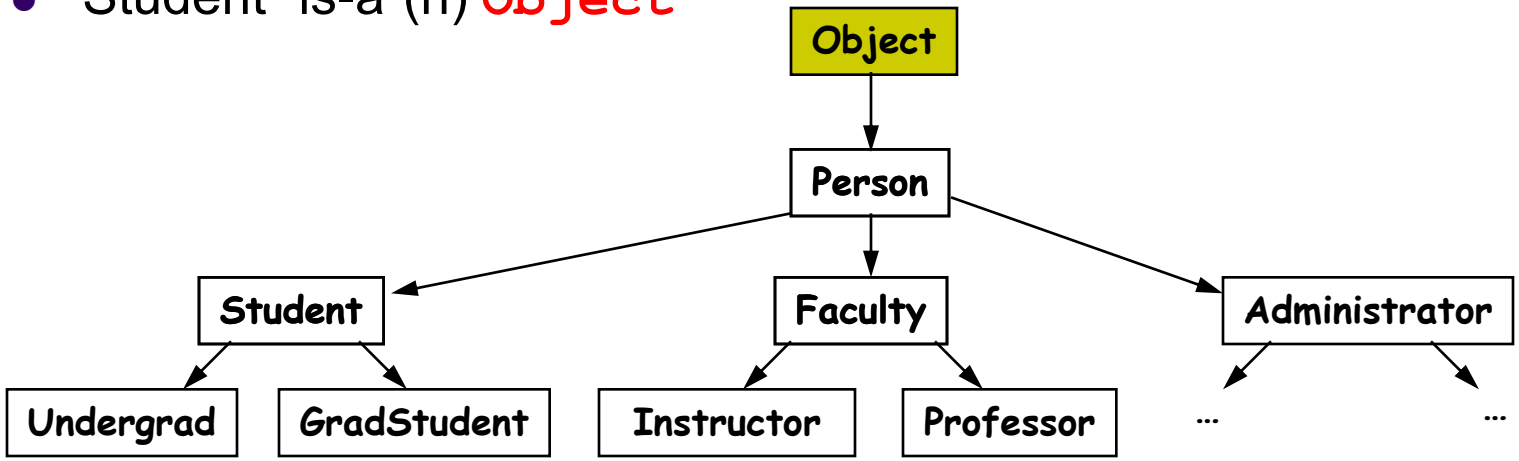
calls Derived:m(int)

Error! Since d is declared Base, the compiler looks for Base:m(double) Doesn't exist! So this does not make it past the compiler, even though Derived:m(double) is defined!

calls Derived:m(double)

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`
- Student "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 vs. Type Information

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

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

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

Accessing Class and 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
  - Widening Conversion
    - Every element in source type is a element in destination type
    - Can be done automatically

```
double x = 3;  // 3 (int) widening conversion to double
```

  - Narrowing Conversion
    - Elements in source type are not necessarily elements in the 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
    - Just ignore the parts that were added by the subclass
  - Downcasting
    - Casting a reference to a derived class
    - Requires explicit casting operator, which checks type info at run-time
    - Can cause runtime error

Safe Downcasting

- Illegal downcasting results in a thrown `ClassCastException` at run-time
- Q: Can we check for the legality of a cast before trying it?
- A: Yes, using `instanceof`
- Example
  - Given: `ArrayList` of university people
  - Want: Print the GPAs of the students
  - Solution approach
    - Iterate through list
    - Print GPAs only of Students

`equals()` Reconsidered

- Recall definition of `equals()`
  - … in Person

```
public boolean equals (Person p) {
     if (p == null){
            return false;
     }
     return name.equals(p.getName()) &&
            idNum.equals(p.getIdNum());
   }
```

  - … in Student

```
public boolean equals( Student s ) {
     if (s == null){
        return false;
      }
     return super.equals(s) &&
            admitYear == s.admitYear &&
            gpa == s.gpa;
    }
```

- What does following do?

```
public static void main (String[] args) {
   Student bob = new Student ("R. Goode", "234-56-7890", 1998, 3.89);
   Faculty bob2 = new Faculty ("R. Goode", "234-56-7890", 2005);
   System.out.println (bob.equals (bob2));
}
```

- `true` is printed!

A Better `equals()`

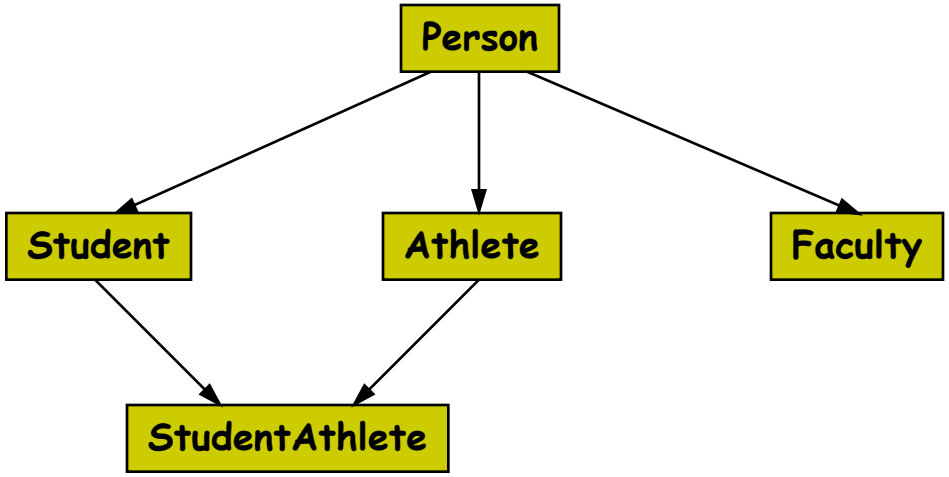
- Take `Object` as parameter
- Check for non-null-ness of parameter
- Check that class type is correct
- Then do other checks
- For example in `Person`:

```
public boolean equals (Object o) {
   if (o == null)
       return false;
   else if (o.getClass() != getClass())
       return false;
   else {
       Person p = (Person)o;
       return name.equals(p.getName()) &&
           idNum.equals(p.getIdNum());
   }
}
```

- Similar improvements can be made to `Student`, `Faculty`
- Now `bob.equals(bob2)` returns `false`

“Multiple Inheritance”?

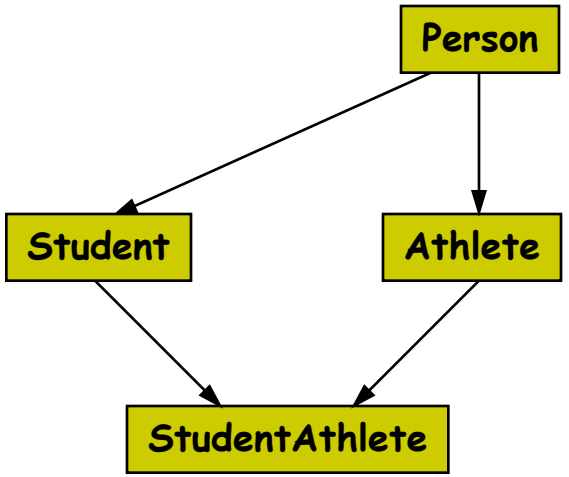
- Intuitively useful to be able to inherit from multiple classes (multiple inheritance)



- But Java does not allow this

Why Does Java Disallow Multiple Inheritance?

- Semantic difficulties!
- Consider `StudentAthlete`
  - Objects would get name field from `Student`
  - Objects would also get name field from `Athlete`
  - Duplicate fields: what to do?
- Some languages (e.g. C++) do allow multiple inheritance



Can We Achieve Some of Benefits of Multiple Inheritance in Java?

- Yes, using interfaces + inheritance
  - Idea: use inheritance for one of inherited classes, interfaces for others
  - Interfaces ensure that relevant methods are implemented
- Example

```
public class Person { … }

public class Student extends  Person { … }

public interface Athlete {
   public String getSport ();
   public void setSport (String sport);
}

public class StudentAthlete extends Student implements Athlete {
   …
}
```

- Objects of type `StudentAthlete` "are" `Student`s
- They also can be wherever objects matching `Athlete` are required

Interfaces and Constants

- Interfaces can also contain `public final static` variables
- Sometimes interfaces are used to provide consistent definitions for constants throughout an application
- Example

```
public interface Months {
    public final static int       JANUARY = 1;
    public final static int       FEBRUARY = 2;
    public final static int       MARCH = 3;
    …
    public final static int       DECEMBER = 12;
}

public class MonthDemo implements Months {

    public static void main( String[ ] args ) {
      System.out.println( "March is month number " + MARCH );
    }
}
```

Because `MonthDemo` implements `Months`, it has access to the constants