Lecture Set #15: Inheritance

Inheritance

- Conceptual
- Is-A relationship compared to contains-a
- Terminology
- Overloading compared to Overriding
- super
- isInstanceOf and getClass()

Inheritance

A crucial feature of object-oriented programming languages

- One class (derived class, subclass, child class) is constructed …
- … by including (extending, inheriting) information …
- … from another (base class, superclass, parent class) …
- … and adding new information / redefining existing

Example

- Base class: Clock
  - setTime
  - getTime
  - tick
- Derived class: Alarm Clock
  - Same methods as Clock plus a few additional ones: setAlarm, ring

Can We Avoid Code Copying and therefore redundancy?

`Alarm Clock` "IS-A" `Clock`

Operations on `Clock` (e.g. `setTime`) should be inherited by `Alarm Clock`

`Alarm Clock` should only have to add information specific to alarm clocks

- setAlarm
- ring

Inheritance provides just this capability

Inheritance

One class (derived class, subclass, child class) is constructed by including (extending, inheriting) information from another (base class, superclass, parent class) then also adding new information and/or redefining existing information

To derive a class D from a base class B, use:

- `public class D extends B { … }`
- `public class AlarmClock extends Clock { … }`

Derived class inherits all instance variables, methods from base class. It can also define new instance variables, methods

Polymorphism: object in derived class can be used anywhere base class is expected (an `AlarmClock` "is a" `Clock`!)

Clock x = new Clock(); //OK

Clock y = new AlarmClock(); //OK

AlarmClock z = new AlarmClock(); //OK

AlarmClock w = new Clock(); //NOT OK

Inheritance vs. Composition

Inheritance: a way to build new classes out of old ones

- Objects in subclass inherit data, methods from superclass
- Object in a subclass "is-a"(n) object in superclass

Association: another way to build new classes out of old ones

- Class definitions may include instance variables which are objects of other class types
- Object in a new class "has-a"(n) object in the original class
- Composition: the strongest form of association – when the lifetime of the enclosed object is completely dependant on the lifetime of the object that contains it

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

Inheritance More Generally

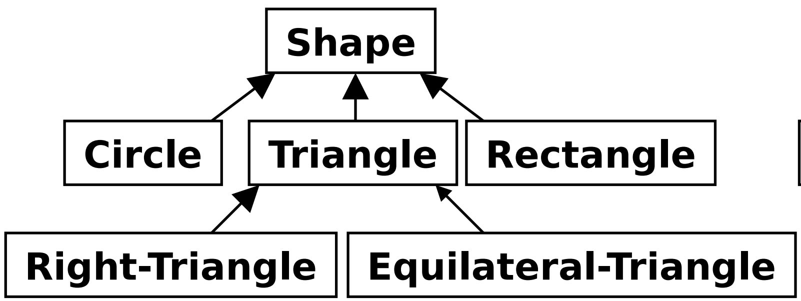
Classes / objects have a natural "is-a" hierarchy
Object-oriented programming provides mechanisms for exploiting this for

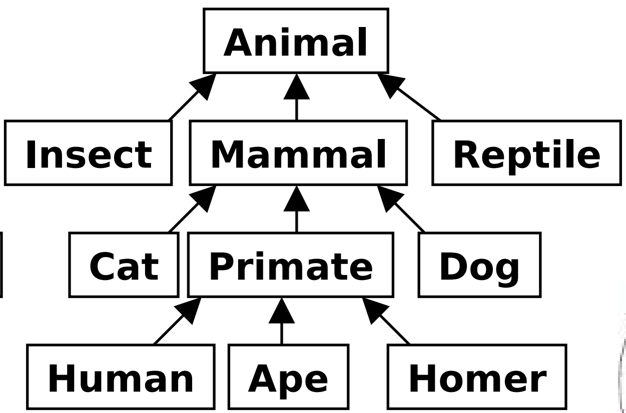
Code re-use

- Common operations implemented in super classes

Polymorphism

- Objects in subclasses can be used wherever superclass objects are needed



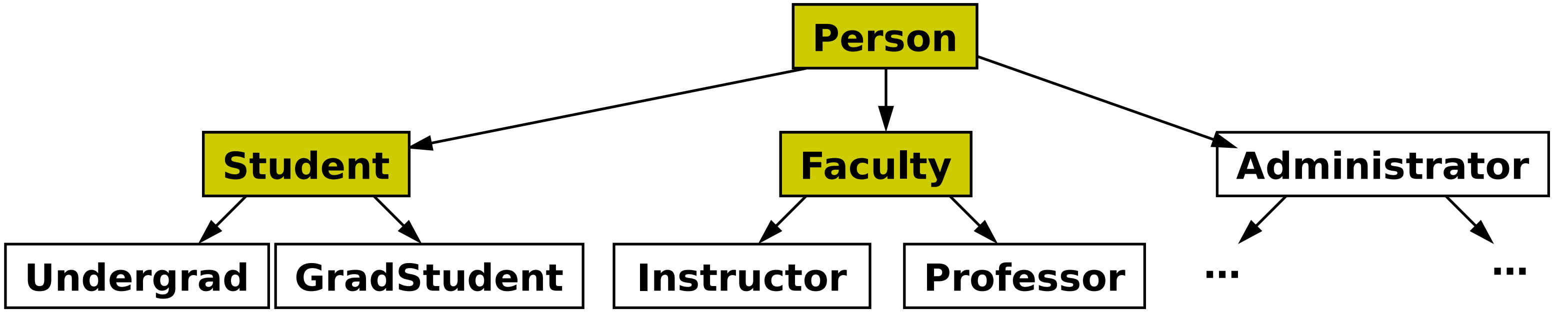


Example: People at University

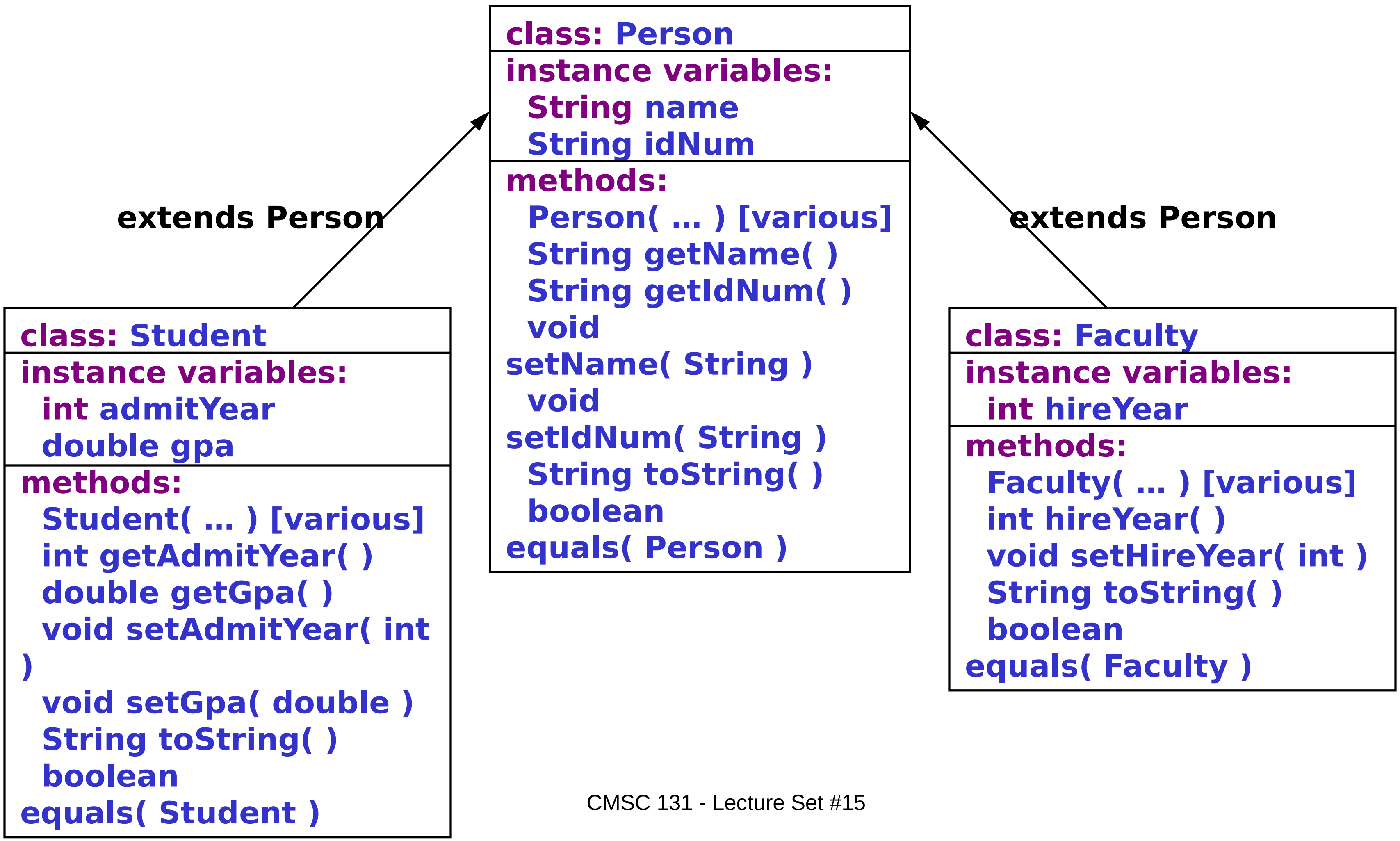
Base class: person

Derived classes: student, faculty, administrator

Derived from those: undergrad, grad, instructor, professor,…



University Person Example



Method Overriding

A derived class can define new instance variables and methods (e.g. `hireYear` and `getHireYear( )`)
A derived class can also redefine (override) existing methods

```
public class Person {
    …
    public String toString( ) { … }
}
public class Student extends Person {
    …
    public String toString( ) { … }
}

Student bob =
    new Student("Bob Goodstudent","123-45-6789",2004,4.0 );
System.out.println( "Bob's info: " + bob.toString( ) );
```

Overrides base-class definition of this method

Since bob is Student, Student toString used

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.

Calling an overridden function

Possible but use sparingly.

Overriding hides methods of the base class (can still access them using `super.methodName()` in subclass, but not in "outside world")

```
public class Person {
    public String toString(){ /*one def here*/}
  …
}
public class Administrator extends Person {
    public String toString(){/*different def here*/}
    public String regPrint(){
       return super.toString(); /* will use Person's def of toString*/
       /*return toString();  will use Administrator's def of toString*/
    }
}
```

Often better to pick a different name rather than overload if you want both.

Derived class: Student

```
package university;
public class Student extends Person {
    private int admitYear;
    private double gpa;

    public Student( ) {
        super( );
        admitYear = -1;
        gpa = 0.0;
    }
    public Student( String n, String id, int yr, double g ) {
        super( n, id );
        admitYear = yr;
        gpa = g;
    }
    public Student( Student s ) {
        super( s );
        admitYear = s.admitYear;
        gpa = s.gpa;
    }
    // …other methods in part 2
}
```

Tells Java that Student is derived from Person

Additional instance variables

Default constructor

This calls the default constructor for base class (superclass), Person, to set name and idNum.

Standard constructor

Calls Person constructor.

Copy constructor

Calls Person copy constructor.

Understanding the Student

`extends` specifies that `Student` is subclass of `Person`:

    public class Student **extends Person**

`super()`

When creating a new Student object, we need to initialize its base-class instance variables (from Person)

This is done by calling `super( … )`. E.g.

`super(name, id)` invokes constructor `Person(name, id)`

`super( … )` must be the first statement of your constructor

If you do not call `super()`, Java will automatically invoke the base class's default constructor

If the base class's default constructor is undefined? Error

You must use `super( … )`, not `Person( … )`

`super` vs. `this`

`super`: refers to the base class

- Can invoke any base class constructor using `super( … )`
- Can access data and methods in base class (`Person`) via `super`
  - E.g., `toString( )`, `equals( )` invoke the corresponding methods from `Person` base class using `super.toString( )` and `super.equals( )`

`this`: refers to current class / object

- Can refer to own data and methods using `this` (usually unnecessary)
- Can invoke any of its own constructors using `this( … )`. Like `super`:
  - Can only be done within a constructor
  - Must be the first statement of the constructor
  - Example

```
public Faculty( Faculty f ) {
    this( f.getName( ), f.getIdNum( ), f.hireYear );
}
```

Inheritance and `private`

`Student` inherits all private data (`name` and `idNum`) from `Person`
However, private members of base class cannot be accessed directly

```
public class Student extends Person {
    …
  public void someMethod( ) {
    name = “Mr. Foobar”;   // Illegal!
  }

  public void someMethod2( ) {
      setName( “Mr. Foobar” ); // OK
    }
```

Why?

Although `Student` inherits from `Person` …

… they are different classes

Public, Protected, Package(default) and Private

Select which level of visibility

Access Level/Group	Class	Package	SubClass	World
public	Y	Y	Y	Y
protected(a void)	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 pa                    ve

    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

calls Derived:m(int)

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

calls Derived:m(double)

Object

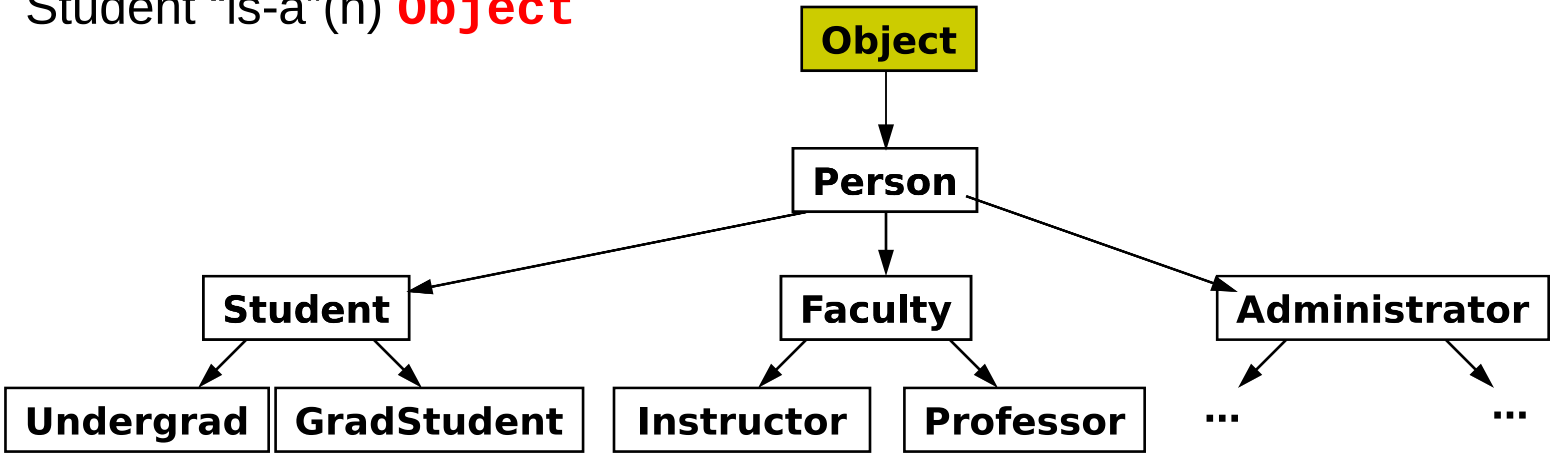
Recall: inheritance induces "is-a" hierarchy on classes

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`

Recall Interfaces

Interfaces contain lists of method prototypes
Example from Lecture #23:

```
public interface UMStudent {

    public void goToClass();

    public void study();

    public void add(int a, int b);

    public String getName();

}
```

Classes can be indicated as implementing interfaces

```
public class CSMajor implements UMStudent {

  …

}
```

To satisfy Java compiler, `CSMajor` must provide implementatons of `goToClass()`, `study()`, etc.

Interfaces can be used as types, and thus to support polymorphism:

```
public void psychoAnalyze(UMStudent student) { … }
```

From last time: interfaces are similar to, but different from, abstract classes

Abstract classes can contain abstract, concrete methods

Classes can implement multiple interfaces, but inherit (directly) from only one class

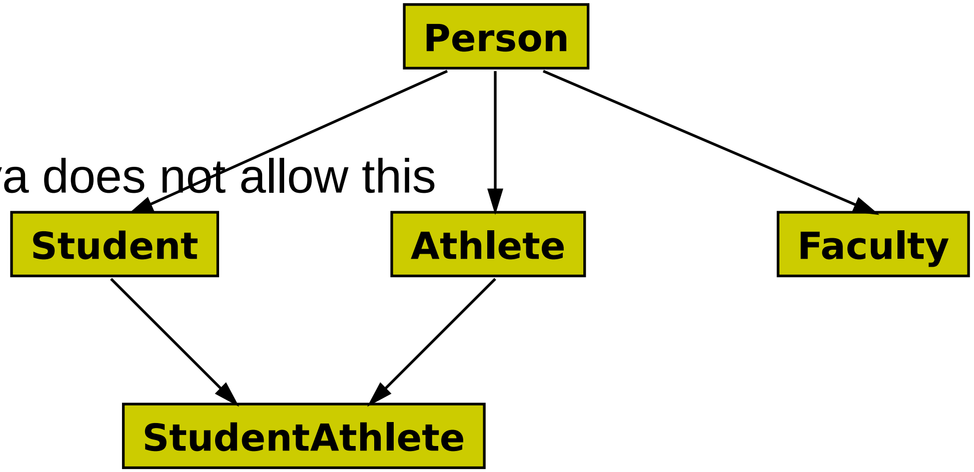
Main Uses of Interfaces

API for classes
Polymorphism
"Faking multiple inheritance"
Specifying sets of symbolic constants

"Multiple Inheritance"?

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

But Java does not allow this



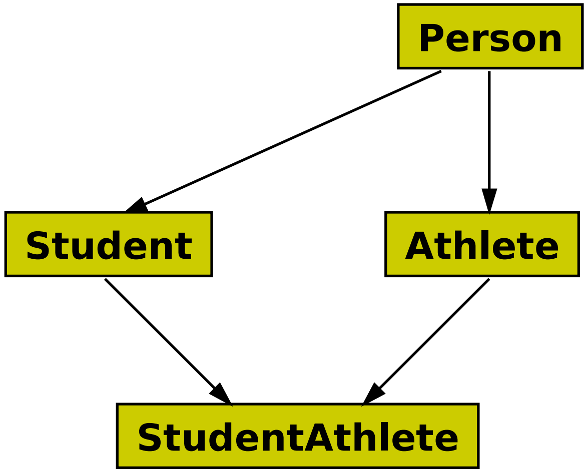
Why Does Java Disallow Multiple Inheritance?

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” `Students`
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

Interface Hierarchies

Inheritance may also be used to build new interfaces from previous ones
A subinterface inherits all method / constant declarations from its base interface
A subinterface may also introduce new methods / constants
E.g. `public interface Level1<T> {`

```
•      boolean x( );
•      T y( );
•      void z( );
•  }
```

We can define a new, interface using inheritance

```
public interface Level2<T> extends Level1<T> {
    boolean a();
    T b();
}
```