Inf1B

Inheritance B

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adapting earlier versions by Perdita Stevens, Ewan Klein, Volker Seeker, et al.

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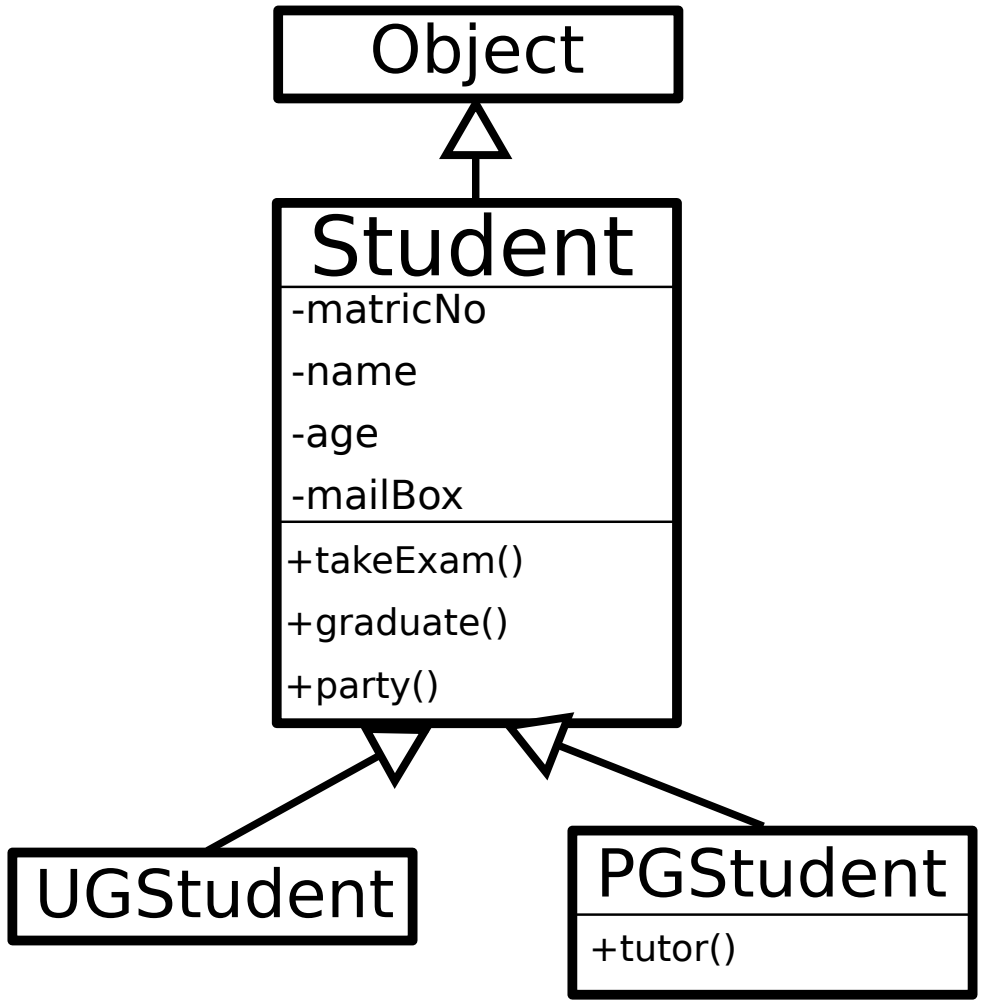
Abstracting Common Stuff

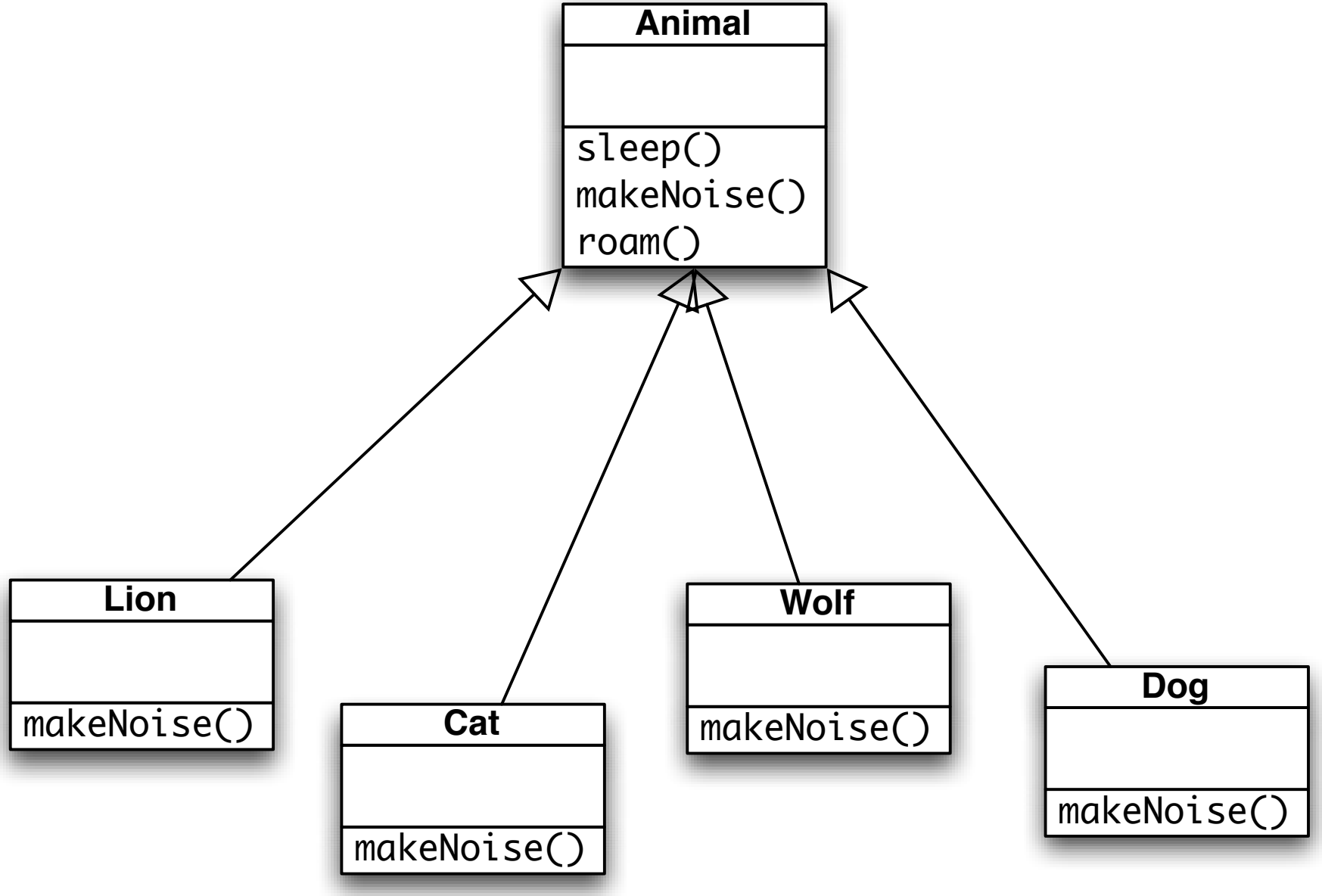
Inheritance hierarchy:

Subclass (`UG`, `PG`) inherit from superclass (`Student`) inherits from superclass (`Object`)



Flat vs. Nested Hierarchies

Flat Animal Hierarchy



Animals Example, 1

Our base class: `Animal`

Animal

```
public class Animal {
    public void sleep() {
        System.out.println("Sleeping: Zzzzz");
    }
    public void makeNoise() {
        System.out.println("Noises...");
    }
    public void roam() {
        System.out.println("Roamin' on the plain.");
    }
}
```

Animals Example, 2

1. `Lion subclass-of Animal`
2. Override the `makeNoise()` method.

Lion

```
public class Lion extends Animal {
    public void makeNoise() {
        System.out.println("Roaring: Rrrrrr!");
    }
}
```

Animals Example, 3

1. `Cat subclass-of Animal`
2. Override the `makeNoise()` method.

Cat

```
public class Cat extends Animal {
    public void makeNoise() {
        System.out.println("Miaowing: Miaooo!");
    }
}
```

Animals Example, 4

1. `Wolf subclass-of Animal`
2. Override the `makeNoise()` method.

Wolf

```
public class Wolf extends Animal {
    public void makeNoise() {
        System.out.println("Howling: Ouoooooo!");
    }
}
```

Animals Example, 5

1. `Dog subclass-of Animal`
2. Override the `makeNoise()` method.

Dog

```
public class Dog extends Animal {
    public void makeNoise() {
        System.out.println("Barking: Woof Woof!");
    }
}
```

Animals Example, 6

The Launcher

```
public class AnimalLauncher {
    public static void main(String[] args) {
        System.out.println("\nWolf\n=====");
        Wolf wolfie = new Wolf();
        wolfie.makeNoise() ; // from Wolf
        wolfie.roam(); // from Animal
        wolfie.sleep(); // from Animal

        System.out.println("\nLion\n=====");
        Lion leo = new Lion();
        leo.makeNoise(); // from Lion
        leo.roam(); // from Animal
        leo.sleep(); // from Animal
    }
}
```

Animals Example, 7

Output

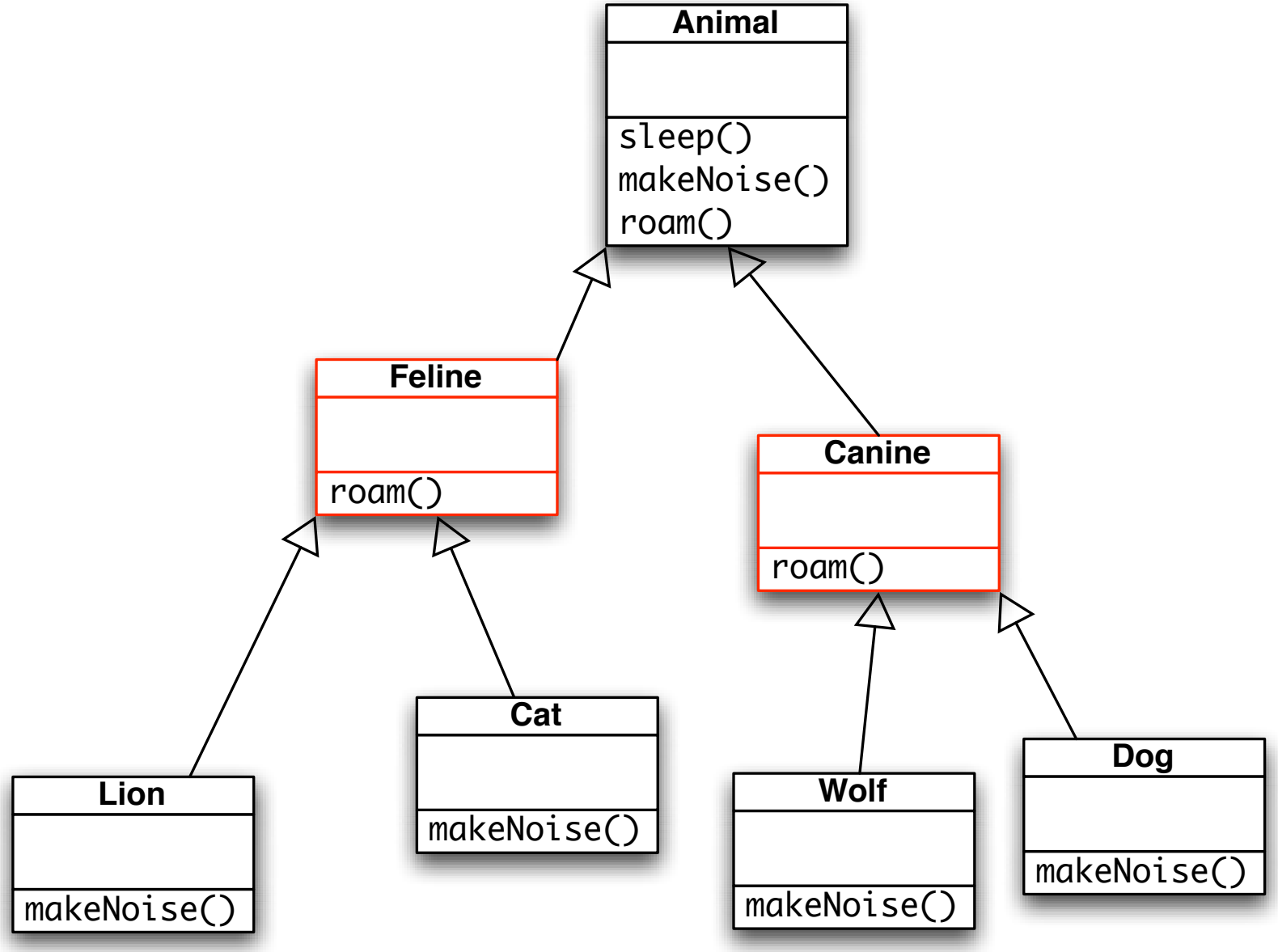
```
Wolf
=====
Howling: Ouoooooo!
Roamin' on the plain.
Sleeping: Zzzzz

Lion
=====
Roaring: Rrrrrr!
Roamin' on the plain.
Sleeping: Zzzzz
```

Nested Animal Hierarchy

- Lions and cats can be grouped together into `Felines`, with common `roam()` behaviours.
- Dogs and wolves can be grouped together into `Canines`, with common `roam()` behaviours.

Nested Animal Hierarchy



Animals Example, 1

Same as before.

Animal

```
public class Animal {
    public void sleep() {
        System.out.println("Sleeping: Zzzzz");
    }
    public void makeNoise() {
        System.out.println("Noises...");
    }
    public void roam() {
        System.out.println("Roamin' on the plain.");
    }
}
```

Animals Example, 2

The new class `Feline`

Feline

```
public class Feline extends Animal {
    public void roam() {
        // Override roam()
        System.out.println("Roaming: I'm roaming alone.");
    }
}
```

Animals Example, 3

The new class `Canine`

Canine

```
public class Canine extends Animal {
    public void roam() {
        // Override roam()
        System.out.println("Roaming: I'm with my pack.");
    }
}
```

Animals Example, 4

1. `Lion subclass-of Feline`
2. Override the `makeNoise()` method.

Lion

```
public class Lion extends Feline {
    public void makeNoise() {
        System.out.println("Roaring: Rrrrrr!");
    }
}
```

- Similarly for `Cat`.

Animals Example, 5

1. `Wolf subclass-of Canine`
2. Override the `makeNoise()` method.

Wolf

```
public class Wolf extends Canine {
    public void makeNoise() {
        System.out.println("Howling: Ouoooooo!");
    }
}
```

- Similarly for `Dog`.

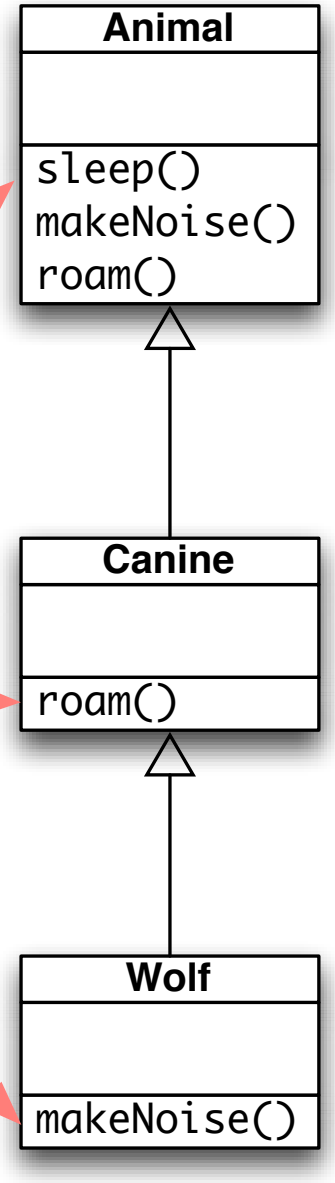
Which method gets called?

```
1. Wolf wolfie = new Wolf();

2. wolfie.makeNoise();

3. wolfie.roam();

4. wolfie.sleep();
```



Animals Example, 6

The Launcher

```
public class AnimalLauncher {
    public static void main(String[] args) {
        System.out.println("\nWolf\n=====");
        Wolf wolfie = new Wolf();
        wolfie.makeNoise(); // from Wolf
        wolfie.roam(); // from Canine
        wolfie.sleep(); // from Animal

        System.out.println("\nLion\n=====");
        Lion leo = new Lion();
        leo.makeNoise(); // from Lion
        leo.roam(); // from Feline
        leo.sleep(); // from Animal
    }
}
```

Animals Example, 7

Output

```
Wolf
=====
Howling: Ouoooooo!
Roaming: I'm with my pack.
Sleeping: Zzzzz

Lion
=====
Roaring: Rrrrrr!
Roaming: I'm roaming alone.
Sleeping: Zzzzz
```

Polymorphism

Typing and Polymorphism

- polymorphism (= 'many shapes'): the same piece of code can be assigned multiple types.
- A class defines a type, roughly the signatures of its methods.
- `S` is a subtype of `T`, written `S <: T`, if a value of type `S` can be used in any context where a value of type `T` is expected.
- The relation `<:` is reflexive: `T <: T`
- The relation `<:` is transitive: if `S <: T` and `T <: U`, then `S <: U`.
- NB: We say `T` is a supertype of `S` if `S` is a subtype of `T`.

Using polymorphism

```
private static void goToBed(Animal tiredAnimal) {
    tiredAnimal.sleep();
}

public static void main(String[] args) {
    Animal myAnimal = new Animal();
    goToBed(myAnimal);
}
```

Polymorphism in Java

- "the same piece of code can be assigned multiple types"
- Especially, an object passed into a method could come from any one of many classes.
- In Java, those classes will be related by inheritance ("OO polymorphism").
- E.g. any method that was written to expect an object of class `Animal` will still work if it is given an object of class `Wolf`.
- (Work? Compile, anyway. The "is-a" check between classes helps to make sure you get sensible rsults...)

Using polymorphism

```
private static void goToBed(Animal tiredAnimal) {
    tiredAnimal.sleep();
}

public static void main(String[] args) {
    Animal myAnimal = new Wolf();
    goToBed(myAnimal);
}
```

The subclass can do **at least** everything the superclass can do.

(maybe a bit different though)

Formal Notation: `Wolf <: Animal` (Wolf is a subtype of Animal)

Polymorphic ArrayList

The Launcher

```
public class AnimalLauncher2 {
   public static void main(String[] args) {
        Wolf wolfie = new Wolf();
        Lion leo = new Lion();
        Cat felix = new Cat();
        Dog rover = new Dog();
        ArrayList< Animal > animals = new ArrayList<Animal>();
        animals.add(wolfie);
        animals.add(leo);
        animals.add(felix);
        animals.add(rover);
        for ( Animal a  : animals) {
             a.makeNoise();
             goToBed(a);
        }
   }
}
```

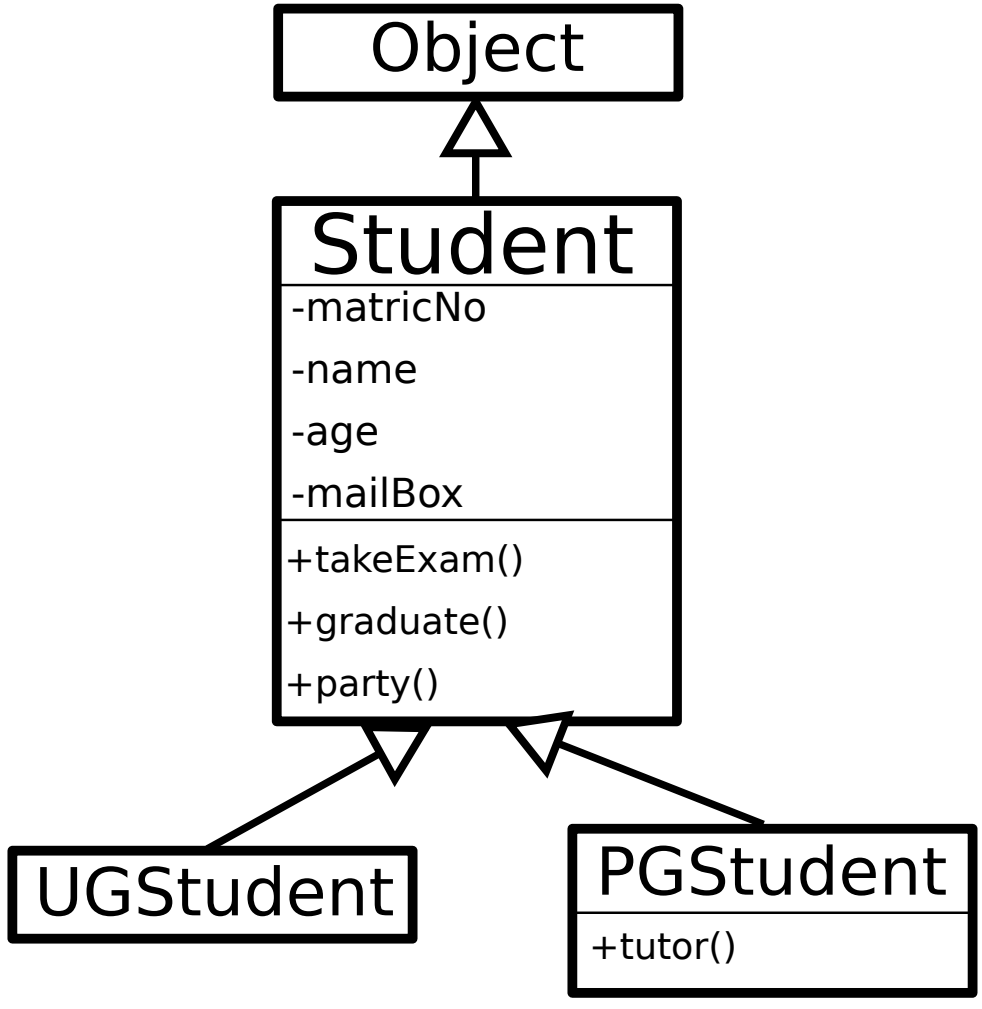
Polymorphic Arrays

`ArrayList<Animal>` is polymorphic.

- `animals.add(wolfie)`
  add an object of type `Wolf`. OK since `Wolf <: Animal`.
- `for (Animal a : animals)`
  for each object a of type `T` such that `T <: Animal` ...
- `a.makeNoise()`
  if a is of type `T`, use `T`'s `makeNoise()` method.
- `goToBed(a)`
  You get at least an Animal, so you can call every method on it an Animal has

Student Hierarchy

Subclass (`UG`, `PG`) inherit from superclass (`Student`) inherits from superclass (`Object`)



Casting Object Types

Does this work?

```
private static void giveTutorial(Student support) {
    support.tutor();
}

public static void main(String[] args) {
    Student support = new PGStudent();
    giveTutorial(support);
}
```

Casting Object Types

Does this work?

```
private static void giveTutorial(Student support) {
    support.tutor();
}

public static void main(String[] args) {
    Student support = new PGStudent();
    giveTutorial(support);
}
```

Compiler Error! Student does not have a `tutor()` method

Casting Object Types

Does this work?

```
private static void giveTutorial(Student support) {
     PGStudent pgsupport = (PGStudent) support;
     pgsupport.tutor();
}

public static void main(String[] args) {
    Student support = new PGStudent();
    giveTutorial(support);
}
```

Casting Object Types

Does this work?

```
private static void giveTutorial(Student support) {
     PGStudent pgsupport = (PGStudent) support;
     pgsupport.tutor();
}

public static void main(String[] args) {
    Student support = new PGStudent();
    giveTutorial(support);
}
```

Yes, I do actually get a PGStudent as argument.

But what if not??

Casting Object Types

Casting Object Types Should be Protected

```
private static void giveTutorial(Student support) {
     if (support instanceof PGStudent) {
         PGStudent pgsupport = (PGStudent) support;
         pgsupport.tutor();
     }
}

public static void main(String[] args) {
    Student support = new UGStudent();
    giveTutorial(support);
}
```

This works and nothing will be printed. But this code smells really bad!

Overriding vs. Overloading

Method Overriding

If a class `C` overrides a method `m` of superclass `D`, ...

For Example

```
public class Animal {
  public Animal findPlaymate() {
     ...
  }
}

public class Wolf extends Animal {

     ???

}
```

Method Overriding

If a class C overrides a method m of superclass D, then:

- Parameter lists must be the same.

```
public class Animal {
  public Animal findPlaymate () {
     ...
  }
}

public class Wolf extends Animal {
  public Animal findPlaymate (int number) { // This is not overriding
    ...
  }
}

public class Wolf extends Animal {
  public Animal findPlaymate () { // This is overriding
    ...
  }
}
```

Method Overriding

If a class C overrides a method m of superclass D, then:

- Parameter lists must be the same.
- The return type must be the same or a subclass of the original.

```
public class Animal {
  public Animal findPlaymate() {
     ...
  }
}

public class Wolf extends Animal {
  public Student findPlaymate() { // This is not overriding
    ...
  }
}

public class Wolf extends Animal {
  public Wolf findPlaymate() { // This is overriding
    ...
  }
}
```

Method Overriding

If a class C overrides a method m of superclass D, then:

- Parameter lists must be the same.
- The return type must be the same or a subclass of the original.
- The overridden method must be at least as accessible as the original.

```
public class Animal {
   protected Animal findPlaymate() {
      ...
   }
}

public class Wolf extends Animal {
   private Animal findPlaymate() { // This is not overriding
    ...
   }
}

public class Wolf extends Animal {
   public Wolf findPlaymate() { // This is overriding
    ...
   }
}
```

Method Overriding

If a class `C` overrides a method `m` of superclass `D`, then:

- Parameter lists must be same and return type must be compatible:
  1. signature of `m` in `C` must be same as signature of `m` in `D`; i.e. same name, same parameter list, and
  2. return type `S` of `m` in `C` must such that `S <: T`, where `T` is return type of `m` in `D`.
- `m` must be at least as accessible in `C` as `m` is in `D`

Most versions I showed that did not override, do in fact compile.

Most versions I showed that did not override, do in fact compile.

But they **overload** the method rather than **override** it.

Method Overloading

Overloading: two methods with same name but different parameter lists.

Overloaded `makeNoise`

```
public void makeNoise() {
...
}
public void makeNoise(int volume) {
...
}
```

Overloaded `println`

```
System.out.println(3); // int
System.out.println(3.0); // double
System.out.println((float) 3.0); // cast to float
System.out.println("3.0"); // String
```

Method Overloading

1. Return types can be different.
2. You can't just change the return type — gets treated as an invalid override.
3. Access levels can be varied up or down.

Incorrect override of `makeNoise`

```
public String makeNoise() {
    String howl = "Ouoooooo!";
    return howl;
}
```

```
Exception in thread "main" java.lang.Error:
Unresolved compilation problem:
        The return type is incompatible with Animal.makeNoise()
```

What does it print?

```
public class Vehicle {
  public void drive() {
    System.out.println("drivedrive");
  }
}
public class Car extends Vehicle {
  public void drive() {
    System.out.println("rollroll");
  }
}
public class Bike extends Vehicle {
  public void drive() {
    System.out.println("pedalpedal");
  }
}
public class Main {
  public static void main(String[] args
      ) {
    Vehicle c = new Car();
    c.drive();
    Vehicle b = new Bike();
    b.drive();
  }
}
```

What does it print?

```
public class Vehicle {
  public void drive() {
    System.out.println("drivedrive");
  }
}
public class Car extends Vehicle {
  public void drive() {
    System.out.println("rollroll");
  }
}
public class Bike extends Vehicle {
  public void drive() {
    System.out.println("pedalpedal");
  }
}
public class Main {
  public static void main(String[] args
      ) {
    Vehicle c = new Car();
    c.drive();
    Vehicle b = new Bike();
    b.drive();
  }
}
```

Prints **rollroll** and **pedalpedal** because polymorphic references c and b contain instances of `Car` and `Bike`.

What does it print?

```
public class Addition{
  public int add(int a, int b){
    int sum = a+b;
    return sum;
  }
  public int add(int a, int b, int c){
    int sum = a+b+c;
    return sum;
  }
  public double add(double a, double b,
        double c){
    double sum = a+b+c;
    return sum;
  }
}
public class Main {
  public static void main (String[]
       args) {
    Addition op = new Addition();
    System.out.println(op.add(1,2));
    System.out.println(op.add(1,2,3);
    System.out.println(op.add
         (1.0,2.0,3.0));
  }
}
```

What does it print?

```
public class Addition{
  public int add(int a, int b){
    int sum = a+b;
    return sum;
  }
  public int add(int a, int b, int c){
    int sum = a+b+c;
    return sum;
  }
  public double add(double a, double b,
        double c){
    double sum = a+b+c;
    return sum;
  }
}
public class Main {
  public static void main (String[]
       args) {
    Addition op = new Addition();
    System.out.println(op.add(1,2));
    System.out.println(op.add(1,2,3);
    System.out.println(op.add
         (1.0,2.0,3.0));
  }
}
```

Prints **3, 6 and 6.00000** because add is overloaded once by using more parameters and once by using different parameter types.

What does it print?

```
public class Birthday {
    public void greet(String name,  int age){
        System.out.println("Happy␣" + age + ".␣birthday,␣" + name + "!")
            ;
    }
    public void greet(int age, String name){
        System.out.println("All␣the␣best␣for␣your␣" +
                           age + ".␣birthday,␣" + name + "!");
    }
}

public class Main {
    public static void main (String[] args) {
      Birthday b = new Birthday();
      b.greet("Jack", 5);
      b.greet(7, "Jill");
    }
}
```

What does it print?

```
public class Birthday {
    public void greet(String name,  int age){
        System.out.println("Happy␣" + age + ".␣birthday,␣" + name + "!")
            ;
    }
    public void greet(int age, String name){
        System.out.println("All␣the␣best␣for␣your␣" +
                           age + ".␣birthday,␣" + name + "!");
    }
}

public class Main {
    public static void main (String[] args) {
      Birthday b = new Birthday();
      b.greet("Jack", 5);
      b.greet(7, "Jill");
    }
}
```

Prints **Happy 5. birthday, Jack!** and **All the best for your 7. birthday, Jill!** because `greet` is overloaded by swapping parameter types around. This smells.

What does it print?

```
public class Addition{
    public int add(int a, int b){
        int sum = a+b;
        return sum;
    }
    public double add(int a, int b){
        int sum = a+b;
        return sum;
    }
}

public class Main {
    public static void main (String[] args) {
        Addition ob = new Addition();
        System.out.println(ob.add(1,2));
        System.out.println(ob.add(1,2));
    }
}
```

What does it print?

```
public class Addition{
    public int add(int a, int b){
        int sum = a+b;
        return sum;
    }
    public double add(int a, int b){
        int sum = a+b;
        return sum;
    }
}

public class Main {
    public static void main (String[] args) {
        Addition ob = new Addition();
        System.out.println(ob.add(1,2));
        System.out.println(ob.add(1,2));
    }
}
```

Does not compile because changing only the return type when overloading is not enough.

Summary

- Inheritance structures can be long and nested.
- But that's not a good thing – OO beginners tend to use inheritance too much!
- Polymorphism is when code can be given several types. E.g.
  - you can collect objects of various subtypes in a collection that is defined at the common supertype
  - you can use the same client code on objects of different subtypes of the type the code is written for
- Overriding needs to follow three rules (parameter list, return type, access).
- Otherwise it is likely overloading.
- Overloading across a class hierarchy can be confusing: usually, best avoided.

Reading

Objects First

Chapter 10.7 *SubTyping*
Chapter 11 *More About Inheritance*