# More OO Fundamentals

CSCI 4448/5448: Object-Oriented Analysis & Design
Lecture 4 — 09/11/2012

# Goals of the Lecture

- Continue a review of fundamental object-oriented concepts

# Overview of OO Fundamentals

- **Delegation**
  - HAS-A
- **More on Inheritance**
  - IS-A
- **More on Polymorphism**
  - message passing
  - polymorphic arguments and return types
- **Interfaces**
  - Abstract Classes
- **Object Identity**

# Delegation (I)

- When designing a class, there are four ways to handle an incoming message
  - Handle message by **implementing code in a method**
  - Let the **class's superclass** handle the request **via inheritance**
  - **Pass the request to another object** (delegation)
  - some combination of the previous three

# Delegation (II)

- Delegation is employed when **some other class already exists to handle a request** that might be made on the class being designed
  - The host class **simply creates a private instance of the helper class** and **sends messages to it when appropriate**
  - As such, delegation is often referred to as a “**HAS-A**” relationship
    - A Car object HAS-A Engine object

```java
import java.util.List;
import java.util.LinkedList;

public class GroceryList {

   private List<String> items;

   public GroceryList() {
      items = new LinkedList<String>();
   }

   public void addItem(String item) {
      items.add(item);
   }

   public void removeItem(String item) {
      items.remove(item);
   }

   public String toString() {
      String result = "Grocery List\n------------\n\n";
      int index = 1;
      for (String item: items) {
          result += String.format("%3d. %s", index++, item) + "\n";
      }
      return result;
   }

}
```

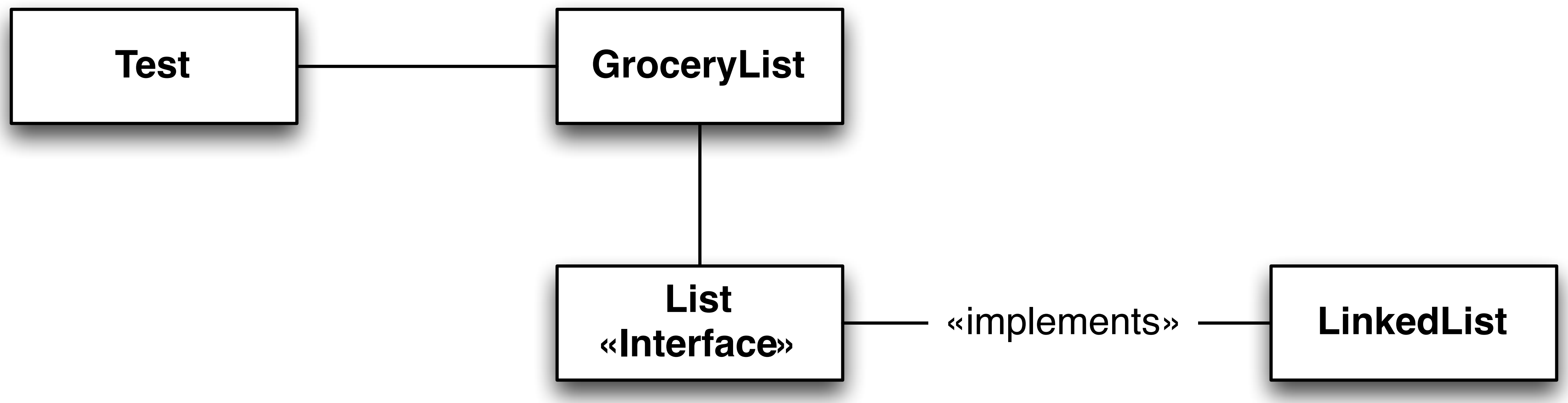
GroceryList delegates all of its work to Java's LinkedList class (which it accesses via the List interface).

```java
public class Test {

    public static void main(String[] args) {
        GroceryList g = new GroceryList();
        g.addItem("Granola");
        g.addItem("Milk");
        g.addItem("Eggs");
        System.out.println("" + g);
        g.removeItem("Milk");
        System.out.println("" + g);
    }

}
```

With the delegation, I get a nice abstraction in my client code. I can create grocery lists, add and remove items and get a printout of the current state of the list.

**DEMO**

# UML for GroceryList with Delegation




GroceryList needs “list like” functionality. So, internally, it uses a LinkedList (via a List interface). This is hidden from Test which just sees a “grocery list” with a nice abstraction.

```java
import java.util.List;
import java.util.LinkedList;

public class TestWithout {

    public static void printList(List<String> items) {
       System.out.println("Grocery List");
       System.out.println("------------\n");
       int index = 1;
       for (String item : items) {
           System.out.println(String.format("%3d. %s", index++, item));
       }
       System.out.println();
    }

    public static void main(String[] args) {
        List<String> g = new LinkedList<String>();
        g.add("Granola");
        g.add("Milk");
        g.add("Eggs");
        printList(g);
        g.remove("Milk");
        printList(g);
    }

}
```

Without delegation, I get less abstraction. I’m using the List interface directly with its method names and I have to create a static method to handle the printing of the list rather than using toString().

**DEMO**

# UML for GroceryList with no Delegation


Test needs “grocery list” functionality which the Developer decides is “close enough” to “list like” functionality. Test simply makes use of a List directly, even though the names of the List class (it’s methods, class name, attributes, etc.) do not provide a good abstraction for “grocery list”

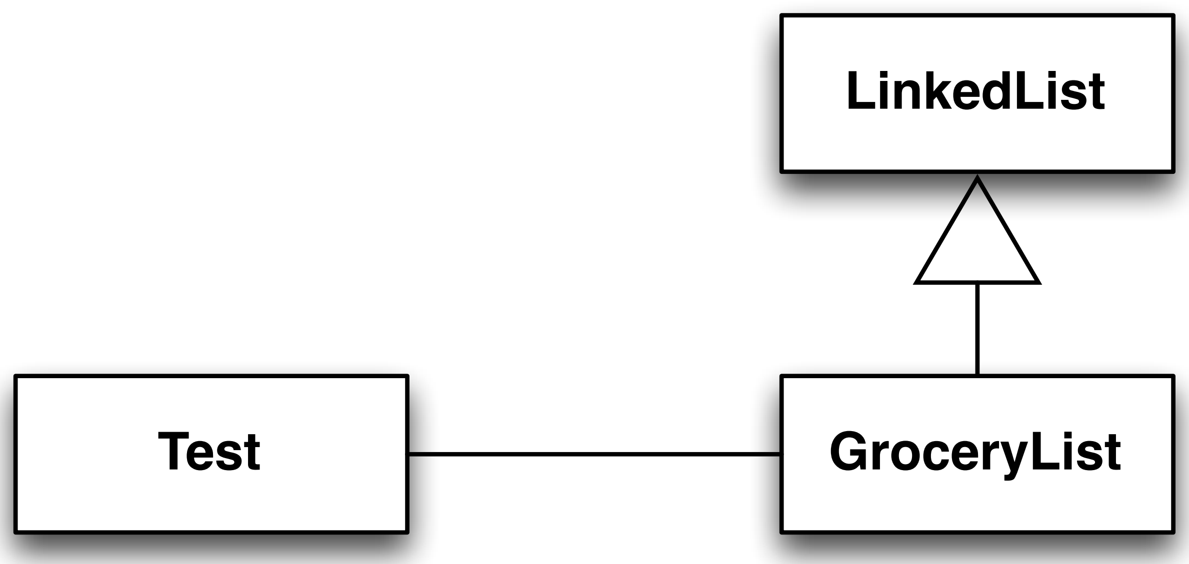
# Delegation (III)

- Now, the two programs (with delegation and without delegation) produce exactly the same output
  - So, do we care which method we use?
  - Yes!
    - (But see the fantastic blog "programming in the twenty-first century" for a counterpoint to this answer)

# Delegation (IV)

- Benefits of Delegation
  - **Better abstraction**
  - **Less code** in classes we write ourselves
  - We can **change delegation relationships at runtime**!
    - Unlike inheritance relationships
    - Imagine if we had created GroceryList as a subclass of LinkedList (*shudder*)
      - Why? Because GroceryList **IS-NOT-A** LinkedList

# UML for GroceryList with Inheritance




In this hypothetical version of GroceryList, inheritance would **pin us down in ways that are unpleasant**; we would be **unable to hide LinkedList's public API** from Test; those methods would be visible to Test, even if GroceryList added it's own methods.

Plus, we would be **unable to switch the data structure** used by GroceryList **at run time**, if that ever became needed

# Delegation (V)

- Changing delegation relationships at run-time
  - A class can use a set at run-time
    - `Set<String> items = new HashSet<String>();`
  - If the class suddenly needs to be sorted, it can do this
    - `items = new TreeSet<String>(items);`
  - We have changed the delegation to an entirely new object at run-time and now the items are sorted
    - In both cases, the type of items is Set<String> and we get the correct behavior via polymorphism

# Delegation (VI)

- Summary
  - **Don’t re-invent the wheel… delegate!**
  - Delegation is **dynamic** (not static)
    - delegation relationships can **change at run-time**
  - **Not tied to inheritance**
    - indeed, considered much more flexible; In languages that support only single inheritance this is important!

# Delegation (VII)

- Delegation, as a design pattern, is used throughout the iOS and Cocoa frameworks
  - Basic pattern involving two objects
    - Host and delegate; use delegate to customize host
    - Define an interface that a delegate will implement
      - some methods are required; the rest are optional
    - Host will invoke methods on delegate as needed to influence its behavior

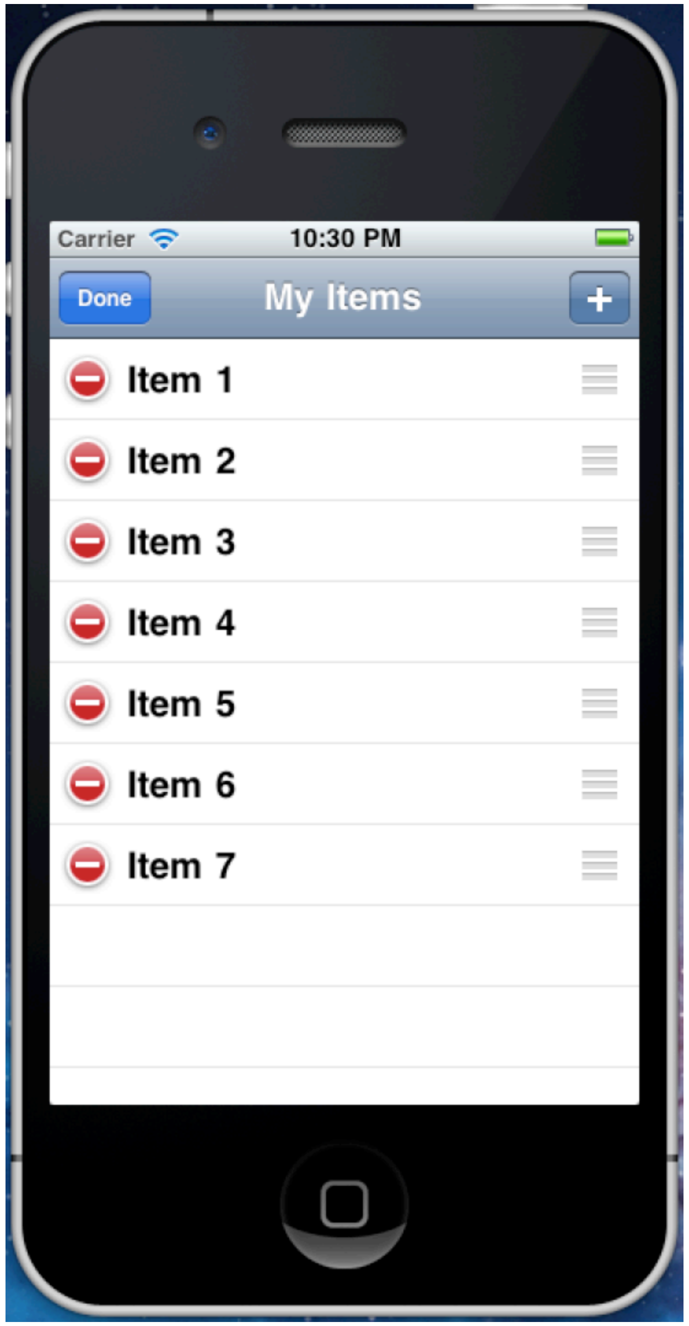
# iOS Delegation Example (I)

- UITableView displays a single-column table of rows
  - It requires two delegates
    - UITableViewDelegate
    - UITableViewDataSource
  - The first contains methods about how the table should look, how it should respond to selections, etc.
  - The second contains methods that populate the table and allow it to be edited

# iOS Delegation Example (II)

- iOS app with a UITableViewController
  - by default acts as both the
    - delegate and the
    - data source
  - Some cleverness
    - Move handles do not appear unless a delegate method is implemented

**Demo**



# Inheritance (I)

- Inheritance is a mechanism for **sharing (public/protected) features between classes**
- Subclasses have an “**IS-A**” relationship with their superclass
  - A Hippo IS-A Animal **makes sense** while the reverse does not
  - IS-A relationships are **transitive**
    - If D is a subclass of C and C is a subclass of B, then D IS-A B is true

# Inheritance (II)

- Good OO design strives to make sure that **all** IS-A relationships in a software system “make sense”
    - Consider Dog IS-A Canine vs. Dog IS-A Window
        - The latter might actually be tried by an inexperienced designer who wants to display each Dog object in its own separate window
            - This is known as **implementation inheritance**; it is considered poor design and something to be avoided

# Inheritance (III)

- Inheritance enables **significant code reuse** since subclasses gain access to the code defined in their ancestors
- The next two slides show two ways of creating a set of classes modeling various types of Animals
  - The first uses no inheritance and likely contains a lot of duplicated code
  - The second uses inheritance and requires less code
    - even though it has more classes than the former

# Animals (No Inheritance)

**Lion**
makeNoise()
roam()
sleep()

**Hippo**
makeNoise()
roam()
sleep()

**Dog**
makeNoise()
roam()
sleep()

**Cat**
makeNoise()
roam()
sleep()

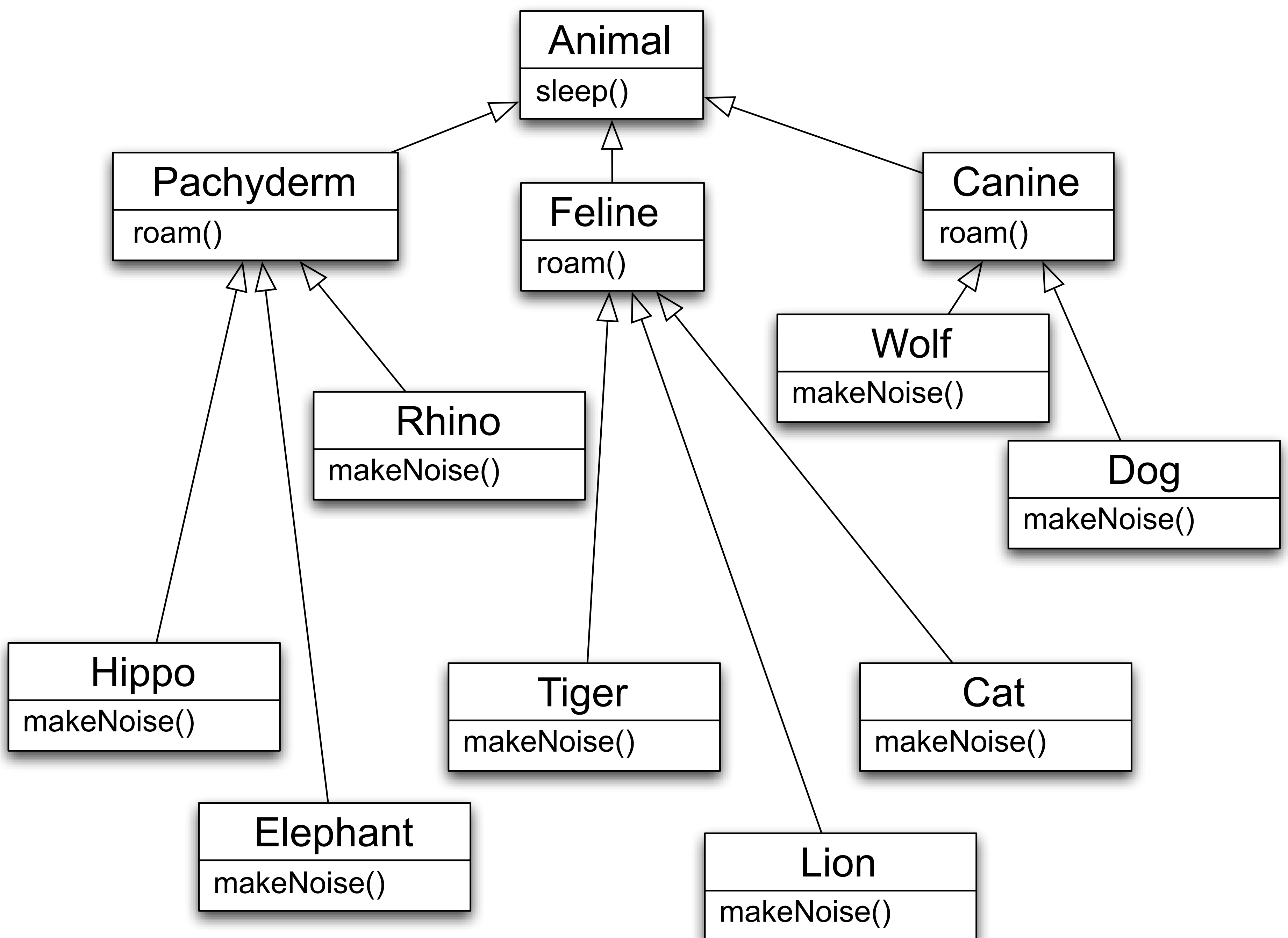
**Elephant**
makeNoise()
roam()
sleep()

**Wolf**
makeNoise()
roam()
sleep()

**Tiger**
makeNoise()
roam()
sleep()

**Rhino**
makeNoise()
roam()
sleep()

# Animals (With Inheritance)



# Code Metrics

- Indeed, I coded these two examples and discovered
  - without inheritance: 9 files, 200 lines of code
  - with inheritance: 13 files, 167 lines of code
  - approximately a 15% savings, even for this simple example

# Inheritance (IV)

- An important aspect of inheritance is **substitutability**
  - Since a subclass **exhibits all of the behavior of its superclass**, it can be **used anywhere an instance of its superclass is used**
    - The textbook describes this as **polymorphism**

# Inheritance (VI)

- Furthermore, subclasses **can add additional behaviors** that make sense for it and **override behaviors** provided by the superclass, altering them to suit its needs
  - This is both powerful **AND** dangerous
    - Why? Stay tuned for the answer…

# Polymorphism (I)

- OO programming languages support polymorphism ("many forms")
  - In practice, this allows code
    - to be written **with respect to the root of an inheritance hierarchy**
    - and **function correctly when applied to the root's subclasses**

# Polymorphism (II)

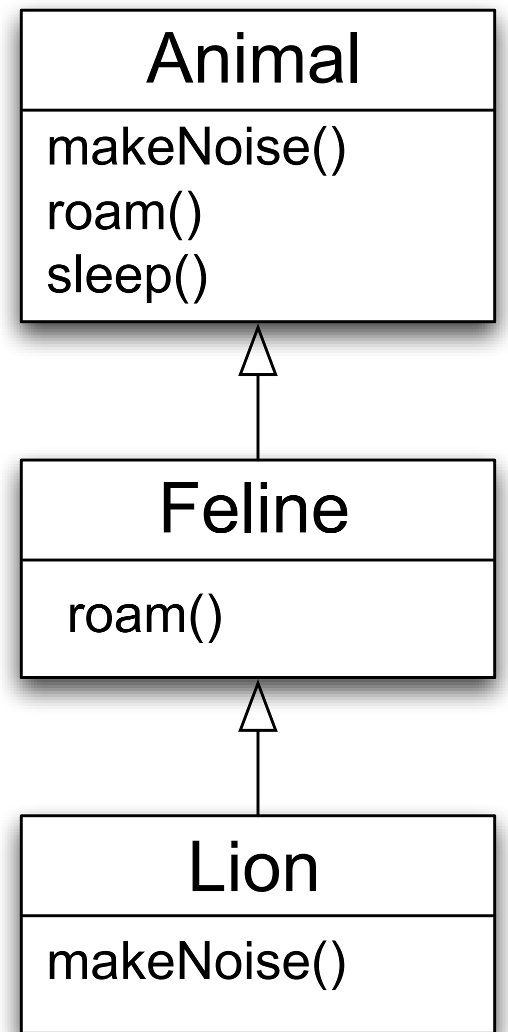
- Message Passing vs. Method Invocation
  - With polymorphism, a message ostensibly sent to a superclass, may be handled by a subclass
    - as discussed in lecture 3

# Polymorphism (III)

- Compare this
  - `Animal a = new Animal();`
  - `a.sleep(); // sleep() in Animal called`
- with this
  - `Animal a = new Lion();`
  - `a.sleep(); // sleep() in Lion called`

# Polymorphism Example

- Without polymorphism, the code on the right only calls methods in Animal
  - Think C++ non-virtual method invocations
- With polymorphism
  - a.roam() invokes Feline.roam()
  - a.makeNoise() invokes Lion.makeNoise()
- A message sent to Animal travels down the hierarchy looking for the "most specific" method body
  - In actuality, method lookup starts with Lion and goes up




```
Animal a = new Lion()
a.makeNoise();
a.roam();
a.sleep();
```

# Why is this important?

- Polymorphism allows us to write very abstract code that is robust with respect to the creation of new subclasses
- For instance

```
public void goToSleep(Animal[] zoo) {
    for (int i = 0; i < zoo.length; i++) {
        zoo[i].sleep();
    }
}
```

# Importance (II)

- In the previous code
    - we don’t care what type of animals are contained in the array
    - we just call sleep() and get the correct behavior for each type of animal

# Importance (III)

- Indeed, if a new subclass of animal is created
  - the above code still functions correctly AND
  - it doesn't need to be recompiled
  - with dynamic class loading, if the above code was running in a server, you wouldn't even need to "stop the server"; you could simply load a new subclass and "keep on trucking" ☺

**DEMO**

- It only cares about Animal, not its subclasses
  - as long as Animal doesn't change, the addition/removal of Animal subclasses has no impact

# Importance (IV)

- We can view a class's public methods as **establishing a contract** that it and its subclasses promise to keep
  - if we code to the (root) contract, as we did in the previous example, we can create very robust and easy to maintain software systems
  - This perspective is known as **design by contract**

# Importance (IV)

- Earlier, we referred to method overloading as “powerful **AND** dangerous”
  - The danger comes from the possibility that a subclass may **change the behavior of a method** such that it **no longer follows the contract** established by a superclass
    - such a change **will break previously abstract and robust code**

# Importance (V)

- Consider what would happen if an Animal subclass overrides the sleep() method to make its instances flee from a predator or eat a meal
  - Our goToSleep() method would no longer succeed in putting all of the Zoo's animals to sleep
- If we could not change the offending subclass, we would have to modify the goToSleep() method to contain special case code to handle it
  - this would **break abstraction** and **seriously degrade the maintainability** of that code

# Polymorphism (IV)

- Finally, **polymorphism** is supported in **arguments to methods** and **method return types**
  - In our goToSleep() method, we passed in a **polymorphic argument**, namely an **array of Animals**
    - The code **doesn’t care** if the array **contains Animal instances** or **any of its subclasses**

# Polymorphism (IV)

- In addition, we can create methods that **return polymorphic return values**. For example

```
public Animal createRandomAnimal() {
    // code that randomly creates and
    // returns one of Animal's subclasses
}
```

- When using the createRandomAnimal() method, we don’t know ahead of time which instance of an Animal subclass will be returned
    - That’s okay as long as we are happy to interact with it via the API provided by the Animal superclass

# Abstract Classes (I)

- There are times when you want to make the “design by contract” principle explicit
  - **Abstract classes and Interfaces let you do this**
- An abstract class is **simply one which cannot be directly instantiated**
  - It is **designed** from the start **to be subclassed**
  - It does this by declaring a number of method signatures **without** providing method implementations for them
    - this sets a contract that each subclass must meet

# Abstract Classes (II)

- Abstract classes are useful since
  - they allow you to **provide code for some methods** (enabling code reuse)
  - while still **defining an abstract interface** that **subclasses must implement**

# Abstract Classes (III)

- Zoo example
  - `Animal a = new Lion(); // manipulate Lion via Animal interface`
  - `Animal a = new Animal(); // what Animal is this?`
- Animal, Feline, Pachyderm, and Canine are good candidates for being abstract classes

# Interfaces

- Interfaces go one step further and only allow the declaration of abstract methods
  - you cannot provide method implementations for any of the methods declared by an interface (in the interface itself)
- Interfaces are useful when you want to define a role in your software system that could be played by any number of classes

# Interface Example (I)

- Consider modifying the Animal hierarchy to provide operations related to pets (e.g. play() or takeForWalk())
  - We have several options, all with pros and cons
    - add Pet-related methods to Animal
    - add abstract Pet methods to Animal
    - add Pet methods only in the classes they belong (no explicit contract)

# Interface Example (II)

- Options continued…
  - make a separate Pet superclass and have pets inherit from both Pet and Animal
  - make a Pet interface and have only pets implement it
    - This often makes the most sense although it hinders code reuse
    - Variation: create Pet interface, but then create Pet helper class that is then composed internally and Pet's delegate if they want the default behavior

# Object Identity

- In OO programming languages, **all objects have a unique id**
  - This id might be its memory location or a unique integer assigned to it when it was created
- This id is used to enable a comparison of two variables **to see if they point at the same object**
  - See example next slide

```
public class identity {

    public static void compare(String a, String b) {
        if (a == b) {
            System.out.println("(" + a + ", " + b + "): identical");
        } else if (a.equals(b)) {
            System.out.println("(" + a + ", " + b + "): equal");
        } else {
            System.out.println("(" + a + ", " + b + "): not equal");
        }
    }

    public static void main(String[] args) {
        String ken = "Ken Anderson";
        String max = "Max Anderson";
        compare(ken, max);
        ken = max;
        compare(ken, max);
        max = new String("Max Anderson");
        compare(ken, max);
    }

}
```

**Not Equal**

**Identical**

**Equal**

# Identity in OO A&D (I)

- **Identity** is also important in **analysis and design**
  - We **do not want to create a class** for objects that **do not have unique identity in our problem domain**
    - Consider people in an elevator
      - Does the elevator care who pushes its buttons?

# Identity in OO A&D (II)

- Examples, continued
  - Consider a cargo tracking application
    - Does the system need to monitor every carrot that exists inside a bag? How about each bag of carrots in a crate?
  - Consider a flight between Denver and Chicago
    - What uniquely identifies that flight? The plane? The flight number? The cities? What?

# Identity in OO A&D (III)

- When doing analysis, you will confront similar issues
  - you will be searching for uniquely identifiable objects that help you solve your problem

# Coming Up Next

- Homework 2 will be assigned this week, along with the first quiz!
- Lecture 5: Example problem domain and initial OO solution (from book)
    - Read Chapters 3 and 4 of the Textbook
- Lecture 6: Introduction to Design Patterns
    - Read Chapter 5 of the Textbook