Lecture 9 (Inheritance 2)

Subtype Polymorphism, Comparators, Comparable

CS61B, Fall 2024 @ UC Berkeley

Slides credit: Josh Hug

Bonus Content: DMS and Type Checking Puzzle

Online Video Only

Lecture 9, CS61B, Fall 2024

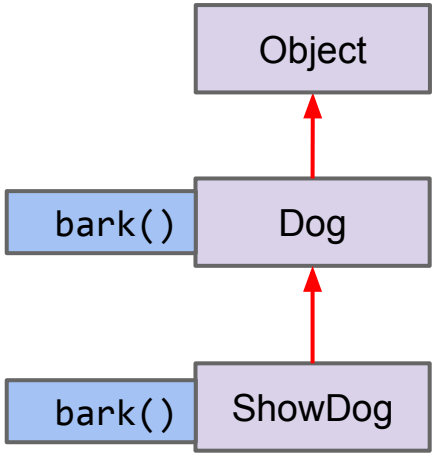
A Typing Puzzle

Suppose we have two classes:

- Dog: Implements bark() method.
- ShowDog: Extends Dog, overrides bark method.

Summarizing is-a relationships, we have:

- Every ShowDog is-a Dog
- Every Dog is-an Object.
  - All types in Java are a subtype of Object.



A Typing Puzzle

For each assignment, decide if it causes a compile error.

For each call to bark, decide whether: 1. Dog.bark() is called, 2. ShowDog.bark() is called, or 3. A syntax error results.

```
Object o2 = new ShowDog("Mortimer", "Corgi", 25, 512.2);

ShowDog sdx = ((ShowDog) o2);
sdx.bark();

Dog dx = ((Dog) o2);
dx.bark();

((Dog) o2).bark();

Object o3 = (Dog) o2;
o3.bark();
```

The rules:

- Compiler allows memory box to hold any subtype.
- Compiler allows calls based on static type.
- **Overridden non-static methods are selected at run time based on dynamic type**.
  - **Everything else is based on static type**, including overloaded methods. Note: No overloaded methods for problem at left.

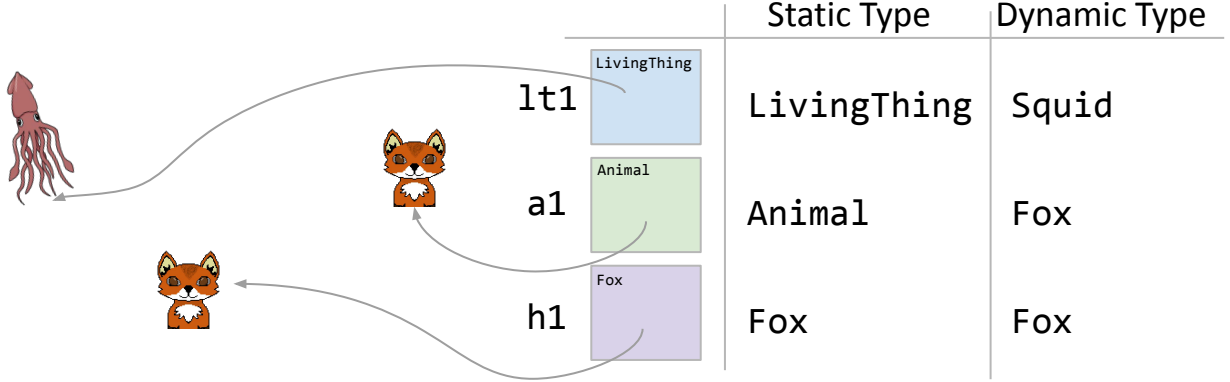
Static Type vs. Dynamic Type

Every variable in Java has a “compile-time type”, a.k.a. “static type”.

- This is the type specified at **declaration**. Never changes!

Variables also have a “run-time type”, a.k.a. “dynamic type”.

- This is the type specified at **instantiation** (e.g. when using `new`).
- Equal to the type of the object being pointed at.



Static Methods, Variables, and Inheritance

You may find questions on old 61B exams, worksheets, etc. that consider:

- What if a subclass has variables with the same name as a superclass?
- What if subclass has a static method with the same signature as a superclass method?
  - For static methods, we do not use the term overriding for this.
- What if a subclass has methods that overload superclass methods?

These practices are generally not a good idea.

- It is bad style.
- There is almost no good reason to ever do this.
- The rules for resolving the conflict are a bit confusing to learn.
- I've pushed 61B away from learning these rules.
- But if you want to learn them, see https://docs.oracle.com/javase/tutorial/java/IandI/override.html

Subtype Polymorphism vs. Explicit Higher Order Functions

Lecture 9, CS61B, Fall 2024

Subtype Polymorphism vs. Explicit Higher Order Functions

Building a General Max Function

- The Naive Approach
- OurComparable
- Compilation Error Puzzle
- Comparable

Comparators

Some Miscellaneous Java Syntax

Subtype Polymorphism

The biggest idea of the last couple of lectures: ***Subtype Polymorphism***

- Polymorphism: “providing a single interface to entities of different types”

a.k.a. compile-time type

Consider a variable `deque` of static type `Deque`:

- When you call `deque.addFirst()`, the actual behavior is based on the dynamic type. ← a.k.a. run-time type
- Java automatically selects the right behavior using what is sometimes called “dynamic method selection”.

Curious about alternatives to subtype polymorphism? See wiki or CS164.

http://www.stroustrup.com/glossary.html#Gpolymorphism

Subtype Polymorphism vs. Explicit Higher Order Functions

Suppose we want to write a program that prints a string representation of the larger of two objects.

Sometimes called a “callback”.

Explicit HoF Approach

```
def print_larger(x, y, compare, stringify):
    if compare(x, y):
        return stringify(x)
    return stringify(y)
```

Subtype Polymorphism Approach

```
def print_larger(x, y):
    if x.largerThan(y):
        return x.str()
    return y.str()
```

Not to be confused with the fascinating Dr. Ernest Kaulbach, who taught my Old English class.

The Naive Approach

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Subtype Polymorphism vs. Explicit Higher Order Functions

Building a General Max Function

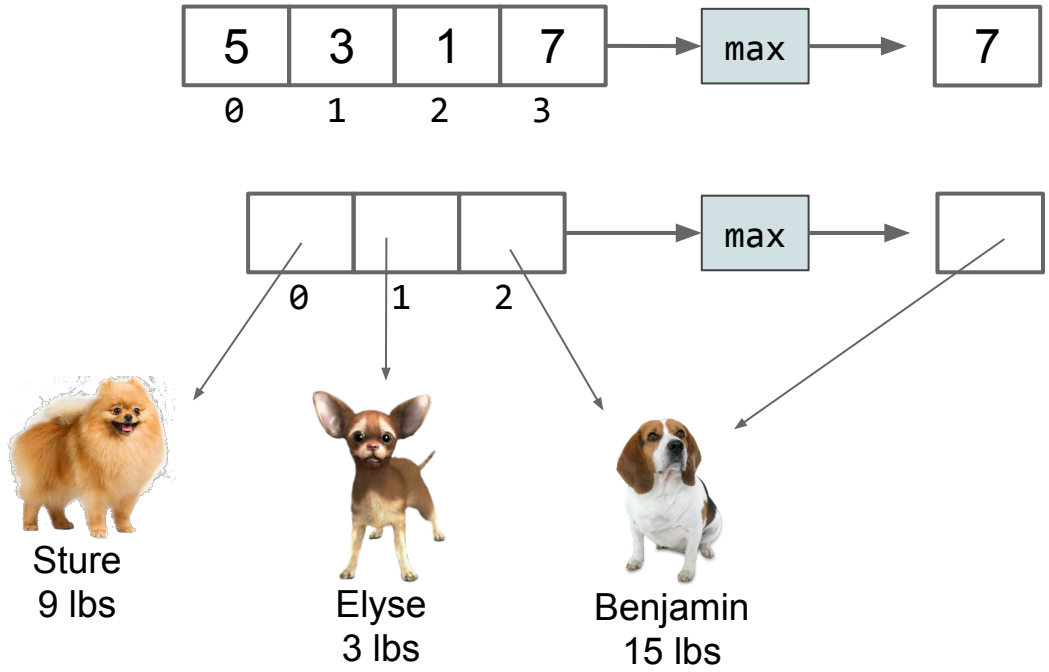
- **The Naive Approach**
- OurComparable
- Compilation Error Puzzle
- Comparable

Comparators

Some Miscellaneous Java Syntax

Goal: The One True Max Function

Suppose we want to write a function `max()` that returns the max of any array, regardless of type.



Compilation Error Challenge

Suppose we want to write a function `max()` that returns the max of any array, regardless of type. How many compilation errors are there in the code shown?

A. 0
B. 1
C. 2
D. 3

Maximizer.java

```
public static Object max(Object[] items) {
   int maxDex = 0;
   for (int i = 0; i < items.length; i += 1) {
       if (items[i] > items[maxDex]) {
           maxDex = i;                }}
   return items[maxDex];
}
```

DogLauncher.java

```
public static void main(String[] args) {
   Dog[] dogs = {new Dog("Elyse", 3), new Dog("Sture", 9),
                 new Dog("Benjamin", 15)};
   Dog maxDog = (Dog) Maximizer.max(dogs);
   maxDog.bark();
}
```

Writing a General Max Function

Objects cannot be compared to other objects with >

- One (bad) way to fix this: Write a max method in the Dog class.

Maximizer.java

```
public static Object max(Object[] items) {
   int maxDex = 0;
   for (int i = 0; i < items.length; i += 1) {
       if (items[i] > items[maxDex]) {
           maxDex = i;                }}
   return items[maxDex];
}
```

DogLauncher.java

```
public static void main(String[] args) {
   Dog[] dogs = {new Dog("Elyse", 3), new Dog("Sture", 9),
                 new Dog("Benjamin", 15)};
   Dog maxDog = (Dog) Maximizer.max(dogs);
   maxDog.bark();
}
```

Dog.maxDog

One approach to maximizing a Dog array: Leave it to the Dog class.

- What is the disadvantage of this?

```
/** Returns maximum of dogs. */
public static Dog maxDog(Dog[] dogs) {
    if (dogs == null || dogs.length == 0) {
        return null; }
    Dog maxDog = dogs[0];
    for (Dog d : dogs) {
        if (d.size > maxDog.size) {
            maxDog = d;           }}
    return maxDog;
}
```

```
Dog[] dogs = new Dog[]{d1, d2, d3};
Dog largest = Dog.maxDog(dogs);
```

The Fundamental Problem

Objects cannot be compared to other objects with >

- How could we fix our Maximizer class using inheritance / HoFs?

Maximizer.java

```
public static Object max(Object[] items) {
   int maxDex = 0;
   for (int i = 0; i < items.length; i += 1) {
       if (items[i] > items[maxDex]) {
           maxDex = i;                }}
   return items[maxDex];
}
```

DogLauncher.java

```
public static void main(String[] args) {
   Dog[] dogs = {new Dog("Elyse", 3), new Dog("Sture", 9),
                 new Dog("Benjamin", 15)};
   Dog maxDog = (Dog) Maximizer.max(dogs);
   maxDog.bark();
}
```

OurComparable

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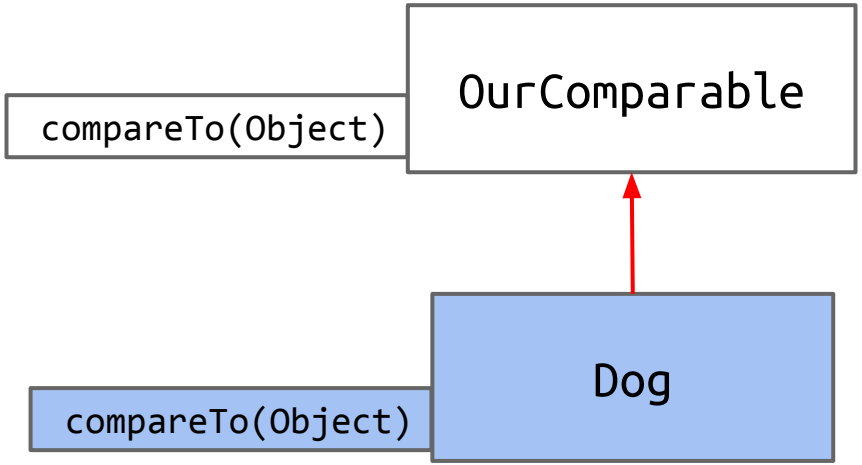
Solution

Create an interface that guarantees a comparison method.

- Have Dog implement this interface.
- Write Maximizer class in terms of this interface.

Interface inheritance says **what** a class can do, in this case compare.

```
public static OurComparable max(OurComparable[] items) { ...
```



Coding Demo: OurComparable

Maximizer.java

```
public class Maximizer {
   public static Object max(Object[] items) {
      int maxDex = 0;
      for (int i = 0; i < items.length; i += 1) {
         if (items[i] > items[maxDex]) {
            maxDex = i;
         }
      }
      return items[maxDex];
   }

   public static void main(String[] args) {
      Dog[] dogs = {new Dog("Elyse", 3), new Dog("Sture", 9),
                    new Dog("Benjamin", 15)};
      Dog maxDog = (Dog) Maximizer.max(dogs);
      maxDog.bark();
   }
}
```

This doesn't compile because you can't compare objects with the > operator.

Coding Demo: OurComparable

OurComparable.java

```
public interface OurComparable {



}
```

Coding Demo: OurComparable

OurComparable.java

```
public interface OurComparable {



   public int compareTo(Object o);
}
```

Coding Demo: OurComparable

OurComparable.java

```
public interface OurComparable {
   /** Return -1 if this < o.
    *  Return 0 if this equals o.
    *  Return 1 if this > o.
    */
   public int compareTo(Object o);
}
```

Coding Demo: OurComparable

Dog.java

```
public class Dog {
   private String name;
   private int size;









}
```

Coding Demo: OurComparable

Dog.java

```
public class Dog implements OurComparable {
   private String name;
   private int size;









}
```

Coding Demo: OurComparable

Dog.java

```
public class Dog implements OurComparable {
   private String name;
   private int size;


   public int compareTo(Object o) {









   }
}
```

Coding Demo: OurComparable

Dog.java

```
public class Dog implements OurComparable {
   private String name;
   private int size;

   /** Returns -1 if this dog is less than the dog pointed at by o, and so forth. */
   public int compareTo(Object o) {









   }
}
```

Coding Demo: OurComparable

Dog.java

```
public class Dog implements OurComparable {
   private String name;
   private int size;

   /** Returns -1 if this dog is less than the dog pointed at by o, and so forth. */
   public int compareTo(Object o) {


       if (this.size < o.size) {
           return -1;
       }









   }
}
```

Coding Demo: OurComparable

Dog.java

```
public class Dog implements OurComparable {
   private String name;
   private int size;

   /** Returns -1 if this dog is less than the dog pointed at by o, and so forth. */
   public int compareTo(Object o) {


       if (this.size < o.size) {
           return -1;
       } else if (this.size == o.size) {
           return 0;
       }




   }
}
```

Coding Demo: OurComparable

Dog.java

```
public class Dog implements OurComparable {
   private String name;
   private int size;

   /** Returns -1 if this dog is less than the dog pointed at by o, and so forth. */
   public int compareTo(Object o) {


       if (this.size < o.size) {
           return -1;
       } else if (this.size == o.size) {
           return 0;
       }
       return 1;




   }
}
```

Coding Demo: OurComparable

Dog.java

```
public class Dog implements OurComparable {
   private String name;
   private int size;

   /** Returns -1 if this dog is less than the dog pointed at by o, and so forth. */
   public int compareTo(Object o) {
       Dog uddaDog = (Dog) o;

       if (this.size < uddaDog.size) {
           return -1;
       } else if (this.size == uddaDog.size) {
           return 0;
       }
       return 1;




   }
}
```

Coding Demo: OurComparable

Maximizer.java

```
public class Maximizer {
   public static Object max(Object[] items) {
      int maxDex = 0;
      for (int i = 0; i < items.length; i += 1) {

         if (items[i] > items[maxDex]) {
            maxDex = i;
         }
      }
      return items[maxDex];
   }

   public static void main(String[] args) {
      Dog[] dogs = {new Dog("Elyse", 3), new Dog("Sture", 9),
                    new Dog("Benjamin", 15)};
      Dog maxDog = (Dog) Maximizer.max(dogs);
      maxDog.bark();
   }
}
```

Coding Demo: OurComparable

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```
public class Maximizer {
   public static OurComparable max(OurComparable[] items) {
      int maxDex = 0;
      for (int i = 0; i < items.length; i += 1) {

         if (items[i] > items[maxDex]) {
            maxDex = i;
         }
      }
      return items[maxDex];
   }

   public static void main(String[] args) {
      Dog[] dogs = {new Dog("Elyse", 3), new Dog("Sture", 9),
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      Dog maxDog = (Dog) Maximizer.max(dogs);
      maxDog.bark();
   }
}
```

Coding Demo: OurComparable

Maximizer.java

```
public class Maximizer {
   public static OurComparable max(OurComparable[] items) {
      int maxDex = 0;
      for (int i = 0; i < items.length; i += 1) {
         int cmp = items[i].compareTo(items[maxDex]);
         if (items[i] > items[maxDex]) {
            maxDex = i;
         }
      }
      return items[maxDex];
   }

   public static void main(String[] args) {
      Dog[] dogs = {new Dog("Elyse", 3), new Dog("Sture", 9),
                    new Dog("Benjamin", 15)};
      Dog maxDog = (Dog) Maximizer.max(dogs);
      maxDog.bark();
   }
}
```

Coding Demo: OurComparable

Maximizer.java

```
public class Maximizer {
   public static OurComparable max(OurComparable[] items) {
      int maxDex = 0;
      for (int i = 0; i < items.length; i += 1) {
         int cmp = items[i].compareTo(items[maxDex]);
         if (cmp > 0) {
            maxDex = i;
         }
      }
      return items[maxDex];
   }

   public static void main(String[] args) {
      Dog[] dogs = {new Dog("Elyse", 3), new Dog("Sture", 9),
                    new Dog("Benjamin", 15)};
      Dog maxDog = (Dog) Maximizer.max(dogs);
      maxDog.bark();
   }
}
```

Coding Demo: OurComparable

Dog.java

```
public class Dog implements OurComparable {
   private String name;
   private int size;

   /** Returns -1 if this dog is less than the dog pointed at by o, and so forth. */
   public int compareTo(Object o) {
       Dog uddaDog = (Dog) o;

       if (this.size < uddaDog.size) {
           return -1;
       } else if (this.size == uddaDog.size) {
           return 0;
       }
       return 1;
   }
}
```

This code is kind of long. We can simplify it with the following trick.

Coding Demo: OurComparable

Dog.java

```
public class Dog implements OurComparable {
   private String name;
   private int size;

   /** Returns <0 if this dog is less than the dog pointed at by o, and so forth. */
   public int compareTo(Object o) {
       Dog uddaDog = (Dog) o;

       return this.size - uddaDog.size;









   }
}
```

This code is kind of long. We can simplify it with the following trick.

Coding Demo: OurComparable

OurComparable.java

```
public interface OurComparable {
   /** Return -1 if this < o.
    *  Return 0 if this equals o.
    *  Return 1 if this > o.
    */
   public int compareTo(Object o);
}
```

We need to modify our interface specification accordingly.

Coding Demo: OurComparable

OurComparable.java

```
public interface OurComparable {
   /** Return negative number if this < o.
    *  Return 0 if this equals o.
    *  Return positive number if this > o.
    */
   public int compareTo(Object o);
}
```

We need to modify our interface specification accordingly.

The OurComparable Interface

```
public interface OurComparable {
    int compareTo(Object o);
}
```

Could have also been OurComparable. No meaningful difference.

Specification, returns:

- Negative number if ***this*** is less than obj.
- 0 if ***this*** is equal to object.
- Positive number if ***this*** is greater than obj.

General Maximization Function Through Inheritance

the origin of uddaDog

```
public interface OurComparable {
   int compareTo(Object o);
}
```

```
public class Dog implements OurComparable {
   public int compareTo(Object obj) {
       /** Warning, cast can cause runtime error! */
       Dog uddaDog = (Dog) obj;
       return this.size - uddaDog.size;
   } ...
```

```
public class Maximizer {
   public static OurComparable max(OurComparable[] a) {
   ...
   }
```

```
Dog[] dogs = new Dog[]{d1, d2, d3};
Dog largest = (Dog) Maximizer.max(dogs);
```

General Maximization Function Through Inheritance

Benefits of this approach:

- No need for array maximization code in every custom type (i.e. no `Dog.maxDog(Dog[])` function required).
- Code that operates on multiple types (mostly) gracefully, e.g.

```
OurComparable[] objs = getItems("somefile.txt");
return Maximizer.max(objs);
```

Compilation Error Puzzle

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Interfaces Quiz #1

```
public class DogLauncher {
  public static void main(String[] args) {
    ...
    Dog[] dogs = new Dog[]{d1, d2, d3};
    System.out.println(Maximizer.max(dogs));
   }
}
```

```
public class Dog
implements OurComparable {
  ...
  public int compareTo(Object o) {
      Dog uddaDog = (Dog) o;
      return this.size
             - uddaDog.size;
  } ...
```

Q: If we omit `compareTo()`, which file will fail to **compile**?

A. DogLauncher.java
B. Dog.java
C. Maximizer.java
D. OurComparable.java

```
public class Maximizer {
  public static OurComparable max(
          OurComparable[] items) {
    ...
    int cmp = items[i].
      compareTo(items[maxDex]);
    ...
  } ...
```

Interfaces Quiz #2: yellkey.com

```
public class DogLauncher {
  public static void main(String[] args) {
    ...
    Dog[] dogs = new Dog[]{d1, d2, d3};
    System.out.println(Maximizer.max(dogs));
   }
}
```

```
public class Dog
implements OurComparable {
  ...
  public int compareTo(Object o) {
     Dog uddaDog = (Dog) o;
     return this.size
             - uddaDog.size;
  } ...
```

Q: If we omit `implements OurComparable`, which file will fail to **compile**?

A. DogLauncher.java
B. Dog.java
C. Maximizer.java
D. OurComparable.java

```
public class Maximizer {
  public static OurComparable max(
          OurComparable[] items) {
    ...
    int cmp = items[i].
      compareTo(items[maxDex]);
    ...
  } ...
```

Answers to Quiz

Problem 1: Dog will fail to compile because it does not implement all abstract methods required by OurComparable interface. (And I suppose DogLauncher will fail as well since Dog.class doesn't exist)

Problem 2: DogLauncher will fail, because it tries to pass things that are not OurComparables, and Maximizer expects OurComparables.

Comparable

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Subtype Polymorphism vs. Explicit Higher Order Functions

Building a General Max Function

- The Naive Approach
- OurComparable
- Compilation Error Puzzle
- **Comparable**

Comparators

Some Miscellaneous Java Syntax

The Issues With OurComparable

Two issues:

- Awkward casting to/from Objects.
- We made it up.
  - No existing classes implement OurComparable (e.g. String, etc).
  - No existing classes use OurComparable (e.g. no built-in max function that uses OurComparable)

```
public class Dog implements OurComparable {
    public int compareTo(Object obj) {
        /** Warning, cast can cause runtime error! */
        Dog uddaDog = (Dog) obj;
        return this.size - uddaDog.size;
    } ...
```

```
Dog[] dogs = new Dog[]{d1, d2, d3};
Dog largest = (Dog) Maximizer.max(dogs);
```

The Issues With OurComparable

Two issues:

- Awkward casting to/from Objects.
- We made it up.
  - No existing classes implement OurComparable (e.g. String, etc).
  - No existing classes use OurComparable (e.g. no built-in max function that uses OurComparable)

The industrial strength approach: Use the built-in Comparable interface.

- Already defined and used by tons of libraries. Uses generics.

```
public interface Comparable<T> {
   public int compareTo(T obj);
}
```

```
public interface OurComparable {
   public int compareTo(Object obj);
}
```

Coding Demo: Comparable

Dog.java

```
public class Dog implements OurComparable {
   private String name;
   private int size;

   /** Returns <0 if this dog is less than the dog pointed at by o, and so forth. */
   public int compareTo(Object o) {
       Dog uddaDog = (Dog) o;

       return this.size - uddaDog.size;
   }
}
```

```
public interface Comparable<T> {
   public int compareTo(T obj);
}
```

Replacing OurComparable with the built-in Comparable interface.

Coding Demo: Comparable

Dog.java

```
public class Dog implements Comparable<Dog> {
   private String name;
   private int size;

   /** Returns <0 if this dog is less than the dog pointed at by o, and so forth. */
   public int compareTo(Object o) {
       Dog uddaDog = (Dog) o;

       return this.size - uddaDog.size;
   }
}
```

```
public interface Comparable<T> {
   public int compareTo(T obj);
}
```

Replacing OurComparable with the built-in Comparable interface.

Coding Demo: Comparable

Dog.java

```
public class Dog implements Comparable<Dog> {
   private String name;
   private int size;

   /** Returns <0 if this dog is less than the dog pointed at by o, and so forth. */
   public int compareTo(Dog uddaDog) {


       return this.size - uddaDog.size;
   }
}
```

```
public interface Comparable<T> {
   public int compareTo(T obj);
}
```

Replacing OurComparable with the built-in Comparable interface.

Coding Demo: OurComparable

Maximizer.java

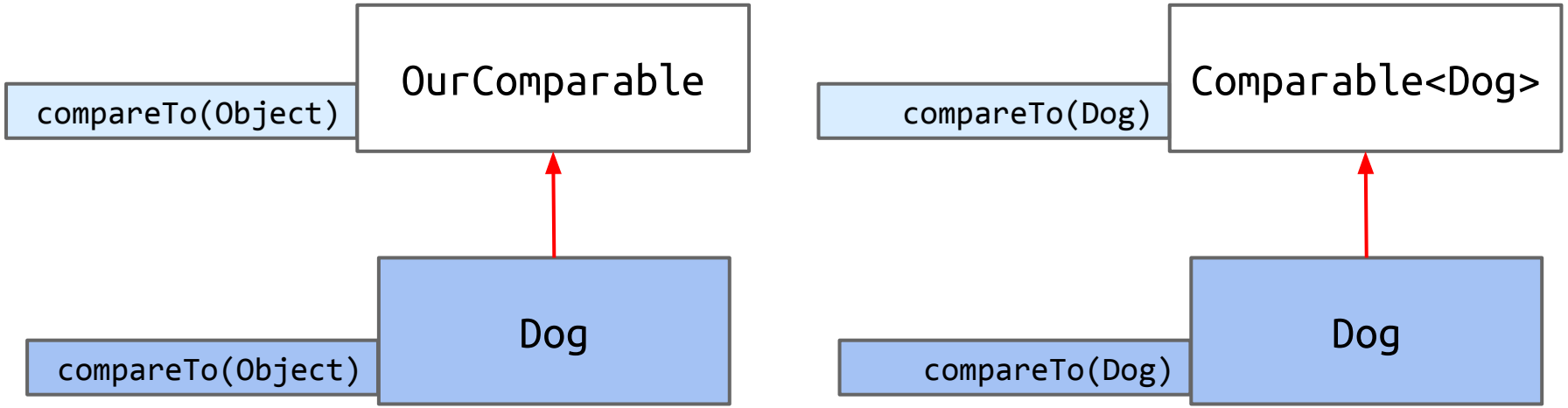
```java
public class Maximizer {
   public static OurComparable max(OurComparable[] items) {
      int maxDex = 0;
      for (int i = 0; i < items.length; i += 1) {
         int cmp = items[i].compareTo(items[maxDex]);
         if (cmp > 0) {
            maxDex = i;
         }
      }
      return items[maxDex];
   }
}
```

Coding Demo: OurComparable

Maximizer.java

```
public class Maximizer {
   public static Comparable max(Comparable[] items) {
      int maxDex = 0;
      for (int i = 0; i < items.length; i += 1) {
         int cmp = items[i].compareTo(items[maxDex]);
         if (cmp > 0) {
            maxDex = i;
         }
      }
      return items[maxDex];
   }
}
```

Comparable vs. OurComparable



Comparable Advantages

- Lots of built in classes implement Comparable (e.g. String).
- Lots of libraries use the Comparable interface (e.g. Arrays.sort)
- Avoids need for casts.

```
public class Dog implements Comparable<Dog> {
    public int compareTo(Dog uddaDog) {
        return this.size - uddaDog.size;
    }
```

← Much better!

```
public class Dog implements OurComparable {
    public int compareTo(Object obj) {
        Dog uddaDog = (Dog) obj;
        return this.size - uddaDog.size;
    } ...
```

Implementing Comparable allows library functions to compare custom types (e.g. finding max).

```
Dog[] dogs = new Dog[]{d1, d2, d3};
Dog largest = Collections.max(Arrays.asList(dogs));
```

Comparators

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Natural Order

The term “Natural Order” is sometimes used to refer to the ordering implied by a `Comparable`’s `compareTo` method.

- Example: Dog objects (as we’ve defined them) have a natural order given by their size.

“Doge”, size: 5

“Grigometh”, size: 200

“Clifford”, size: 9000

Natural Order

May wish to order objects in a different way.

- Example: By Name.

“Clifford”, size: 9000

“Doge”, size: 5

“Grigometh”, size: 200

Subtype Polymorphism vs. Explicit Higher Order Functions

Suppose we want to write a program that prints a string representation of the larger of two objects according to some specific comparison function.

Explicit HoF Approach

```
def print_larger(x, y, compare, stringify):
    if compare(x, y):
        return stringify(x)
    return stringify(y)
```

Can simply pass a different compare function.

Subtype Polymorphism Approach??

```
def print_larger(T x, T y):
    if x.largerThan(y):
        return x.str()
    return y.str()
```

Subtype Polymorphism vs. Explicit Higher Order Functions

Suppose we want to write a program that prints a string representation of the larger of two objects according to some specific comparison function.

Explicit HoF Approach

```
def print_larger(x, y, compare, stringify):
    if compare(x, y):
        return stringify(x)
    return stringify(y)
```

Can simply pass a different compare function.

Some possible designs (not the best):

- Add more functions `compareTo2`, `compareTo3`, `compareTo4`, etc.
- Add an extra argument to specify which comparison you want:
  `public int compareTo(Dog uddaDog, String whichCompare)`

Subtype Polymorphism vs. Explicit Higher Order Functions

Suppose we want to write a program that prints a string representation of the larger of two objects according to some specific comparison function.

Explicit HoF Approach

```
def print_larger(x, y, compare, stringify):
    if compare(x, y):
        return stringify(x)
    return stringify(y)
```

Subtype Polymorphism Approach

```
def print_larger(T x, T y, comparator<T> c):
   if c.compare(x, y):
       return x.str()
   return y.str()
```

Can simply pass a different compare function.

Coding Demo: Comparator

Dog.java

```
public class Dog implements Comparable<Dog> {
   private String name;
   private int size;

   /** Returns <0 if this dog is less than the dog pointed at by o, and so forth. */
   public int compareTo(Dog uddaDog) {
       return this.size - uddaDog.size;
   }




}
```

Coding Demo: Comparator

Dog.java

```
public class Dog implements Comparable<Dog> {
   private String name;
   private int size;

   /** Returns <0 if this dog is less than the dog pointed at by o, and so forth. */
   public int compareTo(Dog uddaDog) {
       return this.size - uddaDog.size;
   }

   public class NameComparator implements Comparator<Dog> {



   }
}
```

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```
import java.util.Comparator;

public class Dog implements Comparable<Dog> {
   private String name;
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   /** Returns <0 if this dog is less than the dog pointed at by o, and so forth. */
   public int compareTo(Dog uddaDog) {
       return this.size - uddaDog.size;
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Coding Demo: Comparator

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   /** Returns <0 if this dog is less than the dog pointed at by o, and so forth. */
   public int compareTo(Dog uddaDog) {
       return this.size - uddaDog.size;
   }

   public class NameComparator implements Comparator<Dog> {
       public int compare(Dog a, Dog b) {

       }
   }
}
```

Coding Demo: Comparator

Dog.java

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import java.util.Comparator;

public class Dog implements Comparable<Dog> {
   private String name;
   private int size;

   /** Returns <0 if this dog is less than the dog pointed at by o, and so forth. */
   public int compareTo(Dog uddaDog) {
       return this.size - uddaDog.size;
   }

   public class NameComparator implements Comparator<Dog> {
       public int compare(Dog a, Dog b) {
           return a.name.compareTo(b.name);
       }
   }
}
```

Coding Demo: Comparator

Dog.java

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import java.util.Comparator;

public class Dog implements Comparable<Dog> {
   private String name;
   private int size;

   /** Returns <0 if this dog is less than the dog pointed at by o, and so forth. */
   public int compareTo(Dog uddaDog) {
       return this.size - uddaDog.size;
   }

   public static class NameComparator implements Comparator<Dog> {
       public int compare(Dog a, Dog b) {
           return a.name.compareTo(b.name);
       }
   }
}
```

Coding Demo: Comparator

DogLauncher.java

```
public class DogLauncher {
   public static void main(String[] args) {
       Dog d1 = new Dog("Elyse", 3);
       Dog d2 = new Dog("Sture", 9);
       Dog d3 = new Dog("Benjamin", 15);
       Dog[] dogs = new Dog[]{d1, d2, d3};









   }
}
```

Coding Demo: Comparator

DogLauncher.java

```
public class DogLauncher {
   public static void main(String[] args) {
       Dog d1 = new Dog("Elyse", 3);
       Dog d2 = new Dog("Sture", 9);
       Dog d3 = new Dog("Benjamin", 15);
       Dog[] dogs = new Dog[]{d1, d2, d3};




       Dog.NameComparator nc = new Dog.NameComparator();









   }
}
```

Coding Demo: Comparator

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public class DogLauncher {
   public static void main(String[] args) {
       Dog d1 = new Dog("Elyse", 3);
       Dog d2 = new Dog("Sture", 9);
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       Dog[] dogs = new Dog[]{d1, d2, d3};




       Dog.NameComparator nc = new Dog.NameComparator();
       if (nc.compare(d1, d3) > 0) { // if d1 comes later than d3 in the alphabet

       }




   }
}
```

Coding Demo: Comparator

DogLauncher.java

```
public class DogLauncher {
   public static void main(String[] args) {
       Dog d1 = new Dog("Elyse", 3);
       Dog d2 = new Dog("Sture", 9);
       Dog d3 = new Dog("Benjamin", 15);
       Dog[] dogs = new Dog[]{d1, d2, d3};




       Dog.NameComparator nc = new Dog.NameComparator();
       if (nc.compare(d1, d3) > 0) { // if d1 comes later than d3 in the alphabet
           d1.bark();
       }




   }
}
```

Coding Demo: Comparator

DogLauncher.java

```
public class DogLauncher {
   public static void main(String[] args) {
       Dog d1 = new Dog("Elyse", 3);
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       if (nc.compare(d1, d3) > 0) { // if d1 comes later than d3 in the alphabet
           d1.bark();
       } else {
           d3.bark();
       }


   }
}
```

Coding Demo: Comparator

Dog.java

Slight change to reflect Java convention.

```
import java.util.Comparator;
public class Dog implements Comparable<Dog> {
   private String name;
   private int size;

   /** Returns <0 if this dog is less than the dog pointed at by o, and so forth. */
   public int compareTo(Dog uddaDog) {
       return this.size - uddaDog.size;
   }

   public static class NameComparator implements Comparator<Dog> {
       public int compare(Dog a, Dog b) {
           return a.name.compareTo(b.name);
       }
   }




}
```

Coding Demo: Comparator

Slight change to reflect Java convention.

Dog.java

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public class Dog implements Comparable<Dog> {
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           return a.name.compareTo(b.name);
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}
```

Coding Demo: Comparator

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   /** Returns <0 if this dog is less than the dog pointed at by o, and so forth. */
   public int compareTo(Dog uddaDog) {
       return this.size - uddaDog.size;
   }

   private static class NameComparator implements Comparator<Dog> {
       public int compare(Dog a, Dog b) {
           return a.name.compareTo(b.name);
       }
   }

   public static Comparator<Dog> getNameComparator() {

   }
}
```

Coding Demo: Comparator

Dog.java

Slight change to reflect Java convention.

```
import java.util.Comparator;
public class Dog implements Comparable<Dog> {
   private String name;
   private int size;

   /** Returns <0 if this dog is less than the dog pointed at by o, and so forth. */
   public int compareTo(Dog uddaDog) {
       return this.size - uddaDog.size;
   }

   private static class NameComparator implements Comparator<Dog> {
       public int compare(Dog a, Dog b) {
           return a.name.compareTo(b.name);
       }
   }

   public static Comparator<Dog> getNameComparator() {
       return new NameComparator();
   }
}
```

Coding Demo: Comparator

DogLauncher.java

Slight change to reflect Java convention.

```
public class DogLauncher {
   public static void main(String[] args) {
       Dog d1 = new Dog("Elyse", 3);
       Dog d2 = new Dog("Sture", 9);
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       Dog[] dogs = new Dog[]{d1, d2, d3};




       Dog.NameComparator nc = new Dog.NameComparator();
       if (nc.compare(d1, d3) > 0) { // if d1 comes later than d3 in the alphabet
           d1.bark();
       } else {
           d3.bark();
       }

   }
}
```

Coding Demo: Comparator

DogLauncher.java

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       Dog.NameComparator nc = Dog.getNameComparator();
       if (nc.compare(d1, d3) > 0) { // if d1 comes later than d3 in the alphabet
           d1.bark();
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           d3.bark();
       }

   }
}
```

Coding Demo: Comparator

DogLauncher.java

Slight change to reflect Java convention.

```
public class DogLauncher {
   public static void main(String[] args) {
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       Dog[] dogs = new Dog[]{d1, d2, d3};




       Comparator<Dog> nc = Dog.getNameComparator();
       if (nc.compare(d1, d3) > 0) { // if d1 comes later than d3 in the alphabet
           d1.bark();
       } else {
           d3.bark();
       }

   }
}
```

Coding Demo: Comparator

DogLauncher.java

Slight change to reflect Java convention.

```
import java.util.Comparator;
public class DogLauncher {
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       Comparator<Dog> nc = Dog.getNameComparator();
       if (nc.compare(d1, d3) > 0) { // if d1 comes later than d3 in the alphabet
           d1.bark();
       } else {
           d3.bark();
       }

   }
}
```

Additional Orders in Java

In some languages, we'd write two comparison functions and simply pass the one we want :

- sizeCompare()
- nameCompare()

The standard Java approach: Create `SizeComparator` and `NameComparator` classes that implement the `Comparator` interface.

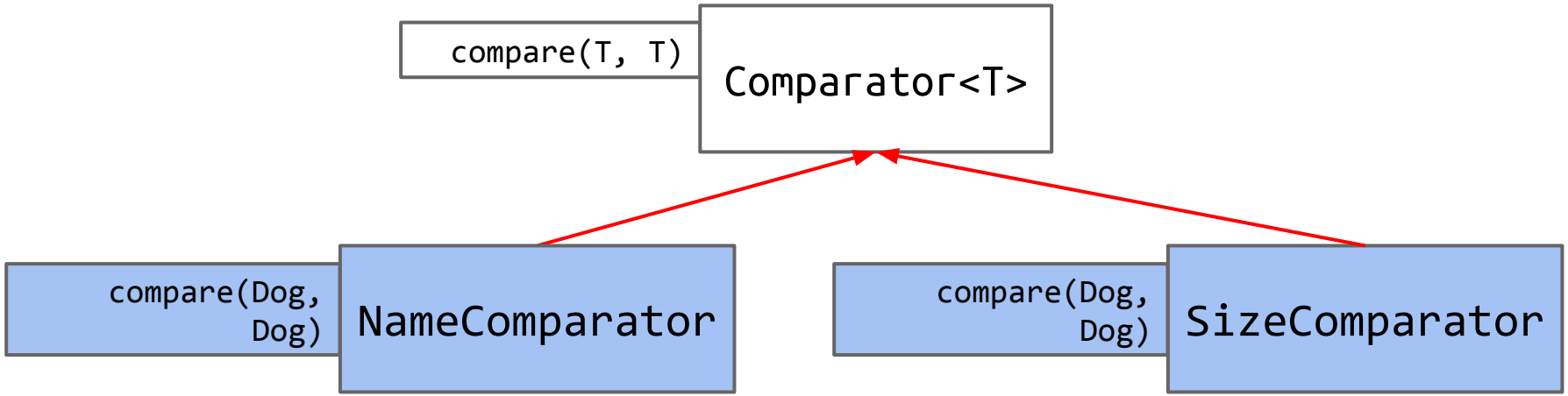
- Requires methods that also take Comparator arguments (see project 1C).

```
public interface Comparator<T> {
   int compare(T o1, T o2);
}
```

Dogs and Comparators

```
public interface Comparator<T> {
    int compare(T o1, T o2);
}
```

Dog not related by inheritance to any of the classes below.



Example: NameComparator

```
public class Dog implements Comparable<Dog> {
  private String name;
  private int size;

  public static class NameComparator implements Comparator<Dog> {
      public int compare(Dog d1, Dog d2) {
          return d1.name.compareTo(d2.name);
      }
  }
  ...
}
```

```
Comparator<Dog> cd = new Dog.NameComparator();
if (cd.compare(d1, d3) > 0) {
    d1.bark();
} else {
    d3.bark();
}
```

Result: If d1 has a name that comes later in the alphabet than d3, d1 barks.

Some Miscellaneous Java Syntax

Lecture 9, CS61B, Fall 2024

Java Access Modifiers

Java philosophy:

- When declaring variables, *minimize* the set of operations permitted on them.
- If you're only planning to use an SLList as a List61B, declare it as a List61B.
- This way, the compiler prevents you from using SLList-specific methods.

Why?

- Greater flexibility when you go back and change code.
  - Can swap SLList with any other List61B class easily.
- Enforces abstraction barriers.
  - Less for you to think about when building on top of that code.
- Communicates to future readers of your code your intended use for that variable.

```
SLList<Integer> L = new SLList<>();
```

Bad.

```
List61B<Integer> L = new SLList<>();
```

Good.

Final

If you declare a variable with `final`, you can only assign it a value *once*.

- Reassigning a `final` variable is not allowed.
- If you try, you'll get a compiler error.

```
final int x = 0;
x = 1;
```

Will not compile!
You can't reassign a final variable.

Protected

So far, we've seen:

- `public`: The instance variable is accessible by other classes.
- `private`: The instance variable is only accessible in the current class.
  - Not even accessible by subclasses!

```
public class SLList {
  private int size;
  ...
}
```

```
public class VengefulSLList extends SLList {
    public int removeLast() {
        size -= 1;
        ...
    }
    ...
}
```

Will not compile!
Subclass cannot access parent's private variables.

Protected

So far, we've seen:

- `public`: The instance variable is accessible by other classes.
- `private`: The instance variable is only accessible in the current class.
  - Not even accessible by subclasses!

Another access modifier you can use:

- `protected`: The instance variable is accessible in **the current class, and its subclasses**.

```
public class SLList {
  protected int size;
  ...
}
```

```
public class VengefulSLList extends SLList {
    public int removeLast() {
        size -= 1;
        ...
    }
    ...
}
```

Now, this will compile. Subclass can access parent's protected variables.