Programming Languages and Techniques (CIS1200)

Lecture 27

Java Collections, Overriding and Equality

Chapter 25

Announcements

- HW07: PennPals
  - Programming with Java Collections
  - Due Tuesday, April 8th at 11.59pm

The Java Collections Library

A case study in subtyping and generics...

that is also very useful...

(But many pitfalls and Java idiosyncrasies!)

Java Packages

- Java code can be organized into *packages* that provide namespace management.
  - Somewhat like OCaml's modules
  - Packages contain groups of related classes and interfaces.
  - Packages are organized hierarchically in a way that mimics the file system's directory structure.
- A Java source file can *import* (parts of) packages that it needs access to:

```
import org.junit.Test;     // just the JUnit Test class
import java.util.*;        // everything in java.util
```

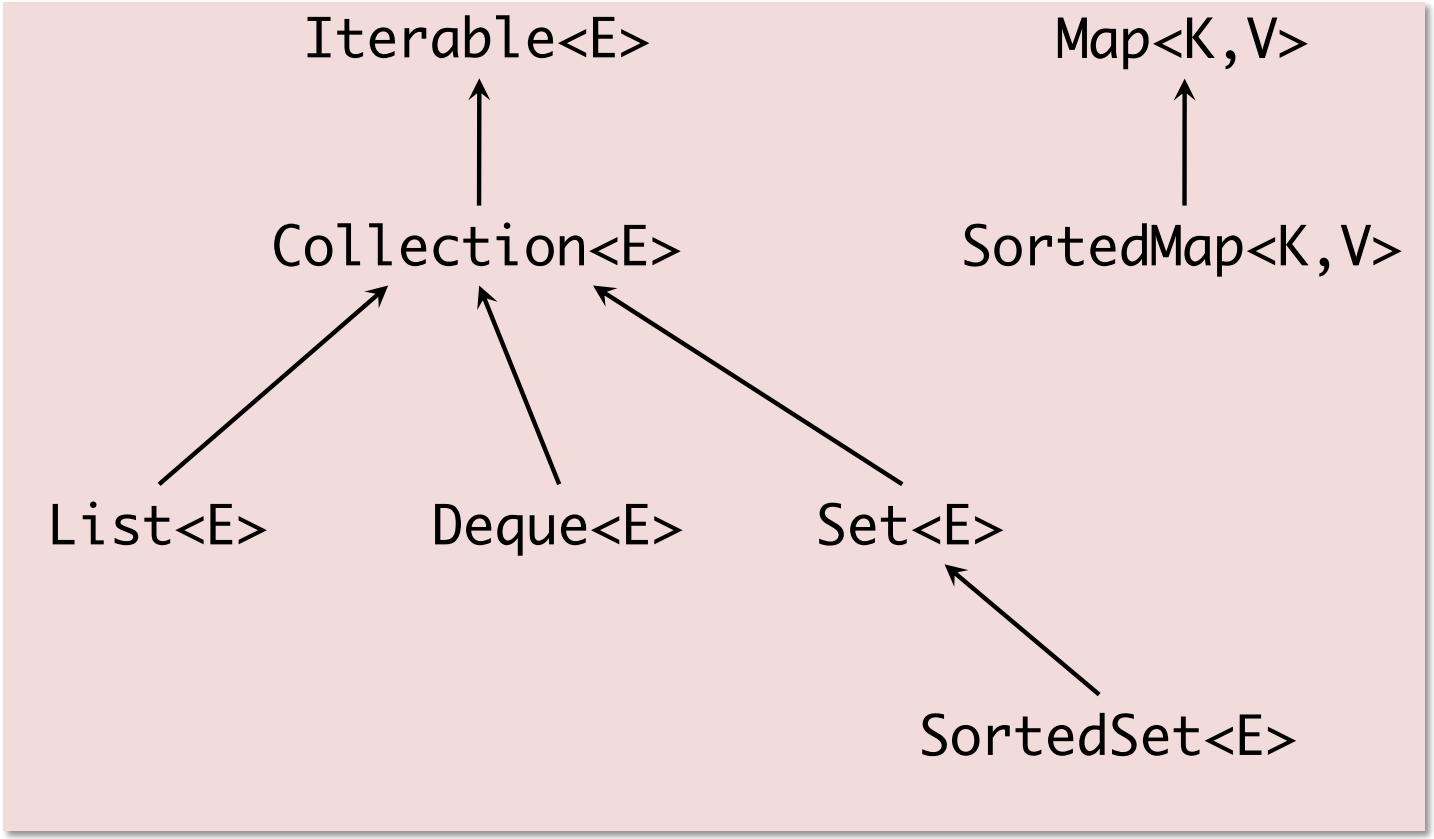
- Important packages
  - java.lang, java.io, **java.util**, java.math, org.junit
- See documentation at http://docs.oracle.com/javase/17/docs/api/
- You should refer to this documentation when working on HW 7

Reading Java Docs

java.util

https://docs.oracle.com/en/java/javase/17/docs/api/java.base/java/util/package-summary.html

Interfaces* of the Collections Library



*not all of them!

Collection<E> Interface (excerpt)

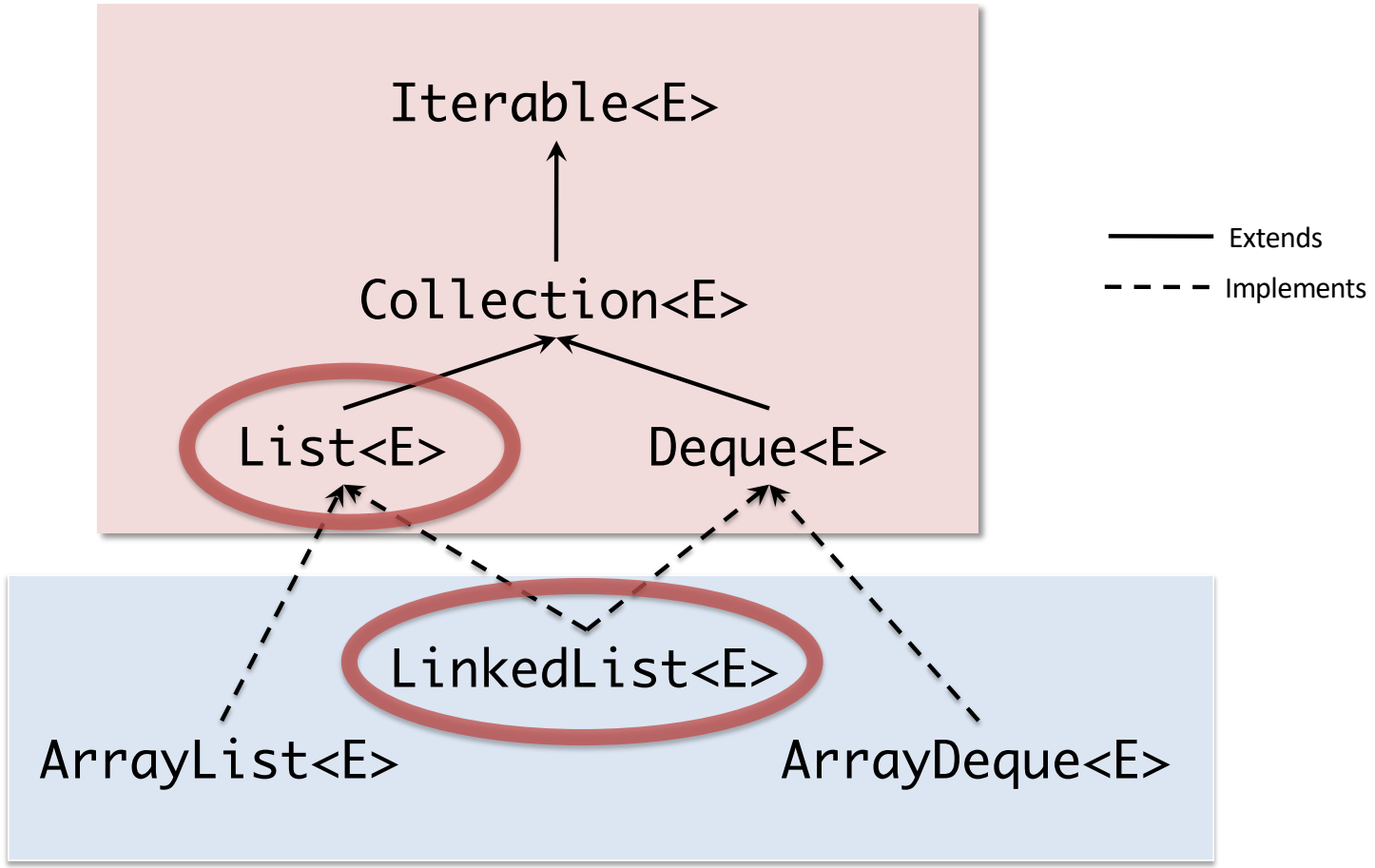
```
interface Collection<E> extends Iterable<E> {
  // basic operations
  int size();
  boolean isEmpty();
  boolean add(E o);
  boolean remove(Object o);      // why not E?*
  boolean contains(Object o);

  // bulk operations
  …
}
```

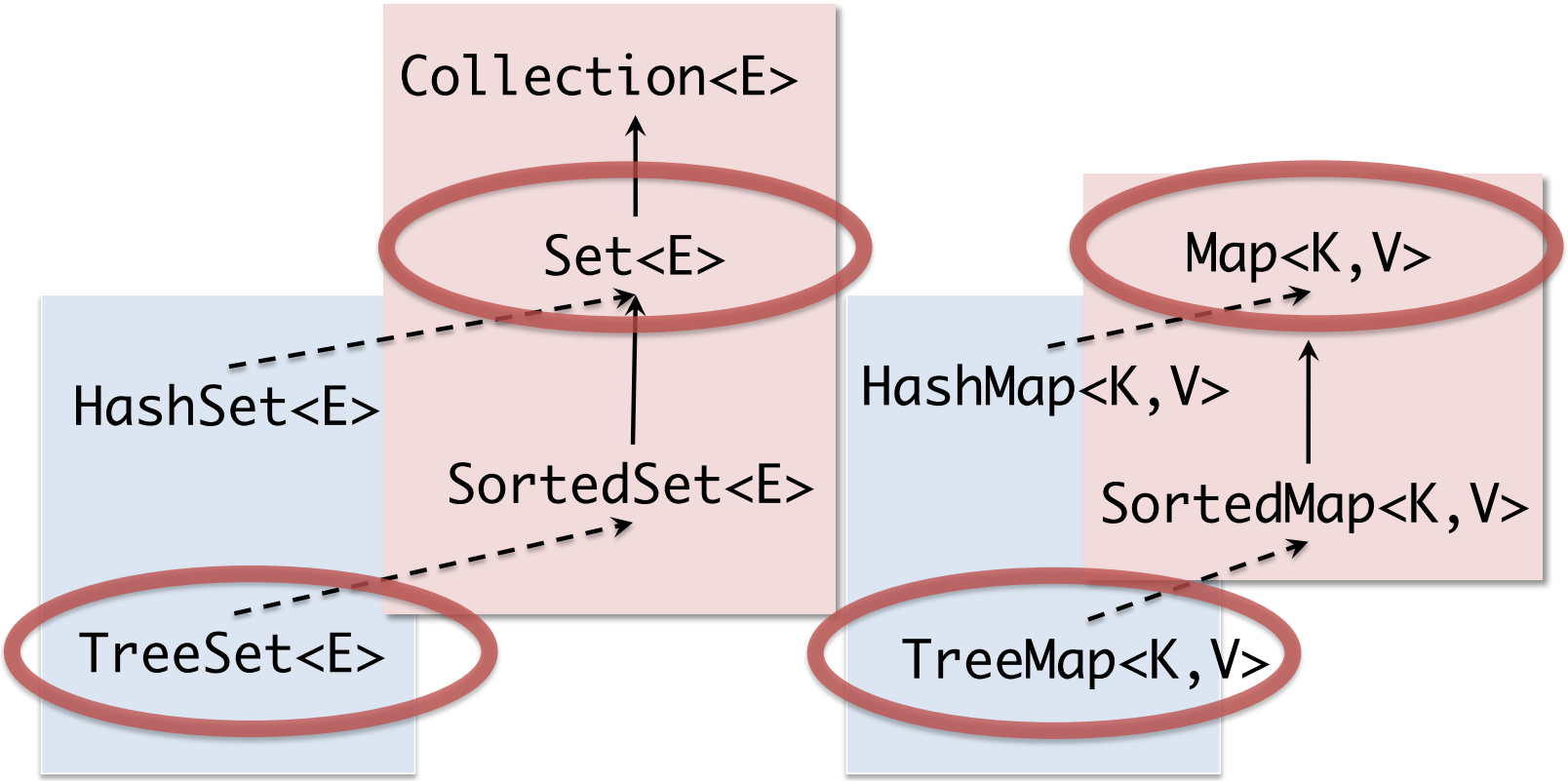
- We've already seen a similar interface in the OCaml part of the course
- Most collections are designed to be *mutable* (like queues and deques)

* Why not E? Internally, collections use the `equals` method to check for equality – membership is determined by o.equals, which does not have to be false for objects of different types. Most applications only store and remove one type of element in a collection, in which case this subtlety never becomes an issue.

Sequences


Iterable<E>
Collection<E>
List<E>
Deque<E>
LinkedList<E>
ArrayList<E>
ArrayDeque<E>
Extends
Implements

Sets and Maps*



*Read javadocs before instantiating these classes! There are some important details to be aware of to use them correctly.

TreeSet Demo

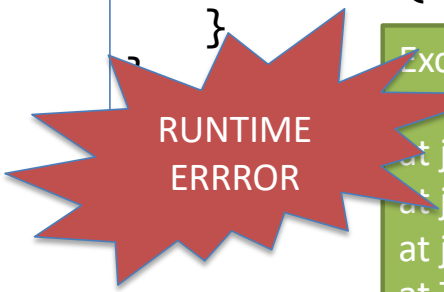
implement Comparable when using SortedSets and Sorted Maps

Buggy Use of TreeSet implementation

```
import java.util.*;

class Point {
    private final int x, y;
    public Point(int x0, int y0) { x = x0; y = y0; }
    public int getX(){ return x; }
    public int getY(){ return y; }
}

public class TreeSetDemo {
    public static void main(String[] args) {
        Set<Point> s = new TreeSet<>();
        s.add(new Point(1,1));
    }
}
```




```
Exception in thread "main" java.lang.ClassCastException:
                        Point cannot be cast to java.base/java.lang.Comparable
at java.base/java.util.TreeMap.compare(TreeMap.java:1291)
at java.base/java.util.TreeMap.put(TreeMap.java:536)
at java.base/java.util.TreeSet.add(TreeSet.java:255)
at TreeSetDemo.main(TreeSetDemo.java:14)
```

A Crucial Detail of `TreeSet`

Constructor Detail

TreeSet

public TreeSet()

Constructs a new, empty tree set, sorted according to the natural ordering of its elements. All elements inserted into the set must implement the `Comparable` interface. Furthermore, all such elements must be mutually comparable: `e1.compareTo(e2)` must not throw a `ClassCastException` for any elements `e1` and `e2` in the set. ...

The Interface Comparable

public interface Comparable<T>

This interface imposes a total ordering on the objects of each class that implements it. This ordering is referred to as the class's *natural ordering*, and the class's compareTo method is referred to as its *natural comparison method*. ...

Methods of Comparable

Method Summary

All Methods	Instance Methods	Abstract Methods

Modifier and Type	Method and Description
int	`compareTo(T o)` Compares this object with the specified object for order.

Method Detail

compareTo

```
int compareTo(T o)
```

Compares this object with the specified object for order. Returns a negative integer, zero, or a positive integer as this object is less than, equal to, or greater than the specified object.

The implementor must ensure `sgn(x.compareTo(y)) == -sgn(y.compareTo(x))` for all `x` and `y`. (This implies that `x.compareTo(y)` must throw an exception iff `y.compareTo(x)` throws an exception.)

The implementor must also ensure that the relation is transitive: (x.compareTo(y)>0 &&

Adding Comparable to Point

```
import java.util.*;

class Point implements Comparable<Point> {
    private final int x, y;
    public Point(int x0, int y0) { x = x0; y = y0; }
    public int getX(){ return x; }
    public int getY(){ return y; }

    public int compareTo(Point o) {
        if (this.x < o.x) {
            return -1;
        } else if (this.x > o.x) {
            return 1;
        } else if (this.y < o.y) {
            return -1;
        } else if (this.y > o.y) {
            return 1;
        }
        return 0;
    }
}
```

```
Point p1 = new Point(0,1);
Point p2 = new Point(0,2);
p1.compareTo(p2);  // -1
p2.compareTo(p1);  // 1
p1.compareTo(p1);  // 0
```

Digging Deeper into Comparable

It is strongly recommended (though not required) that natural orderings be consistent with equals. This is so because sorted sets (and sorted maps) without explicit comparators behave "strangely" when they are used with elements (or keys) whose natural ordering is inconsistent with equals. *In particular, such a sorted set (or sorted map) violates the general contract for set (or map), which is defined in terms of the equals method.*

How do we change the definition of equals?

Method Overriding

When a subclass replaces an inherited method with its own re-definition…

28: What gets printed to the console?

0

I'm a C

0%

I'm a D

0%

NullPointerException

0%

NoSuchMethodException

0%

A Subclass can *Override* its Parent

```
class C {
  public void printName() { System.out.println("I'm a C"); }
}

class D extends C {
  public void printName() { System.out.println("I'm a D"); }
}

// somewhere in main
C c = new D();
c.printName();
```

What gets printed to the console?

1. I'm a C
2. I'm a D
3. NullPointerException
4. NoSuchMethodException

Answer: I'm a D

A Subclass can *Override* its Parent

```
class C {
  public void printName() { System.out.println("I'm a C"); }
}

class D extends C {
  public void printName() { System.out.println("I'm a D"); }
}

// somewhere in main
C c = new D();
c.printName();
```

- Our ASM model for dynamic dispatch already explains what will happen when we run this code.
- Useful for changing the default behavior of classes.
- But… can be confusing and difficult to reason about if not used carefully.

Overriding Example

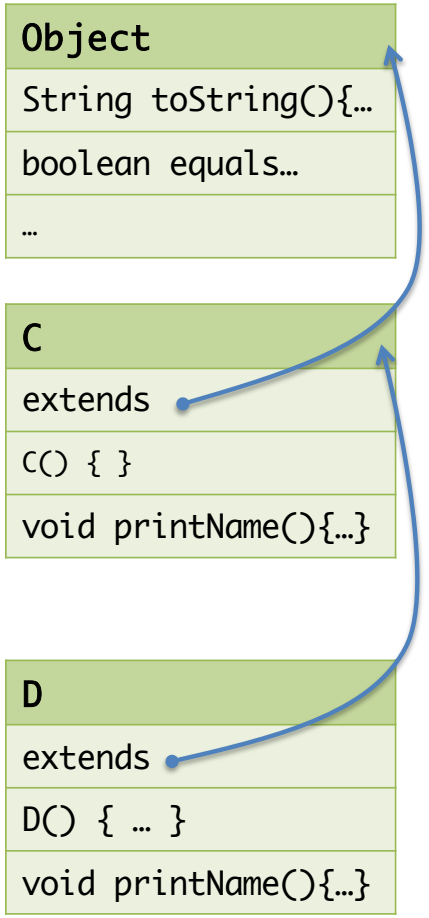
Workspace

```
C c = new D();
c.printName();›
```

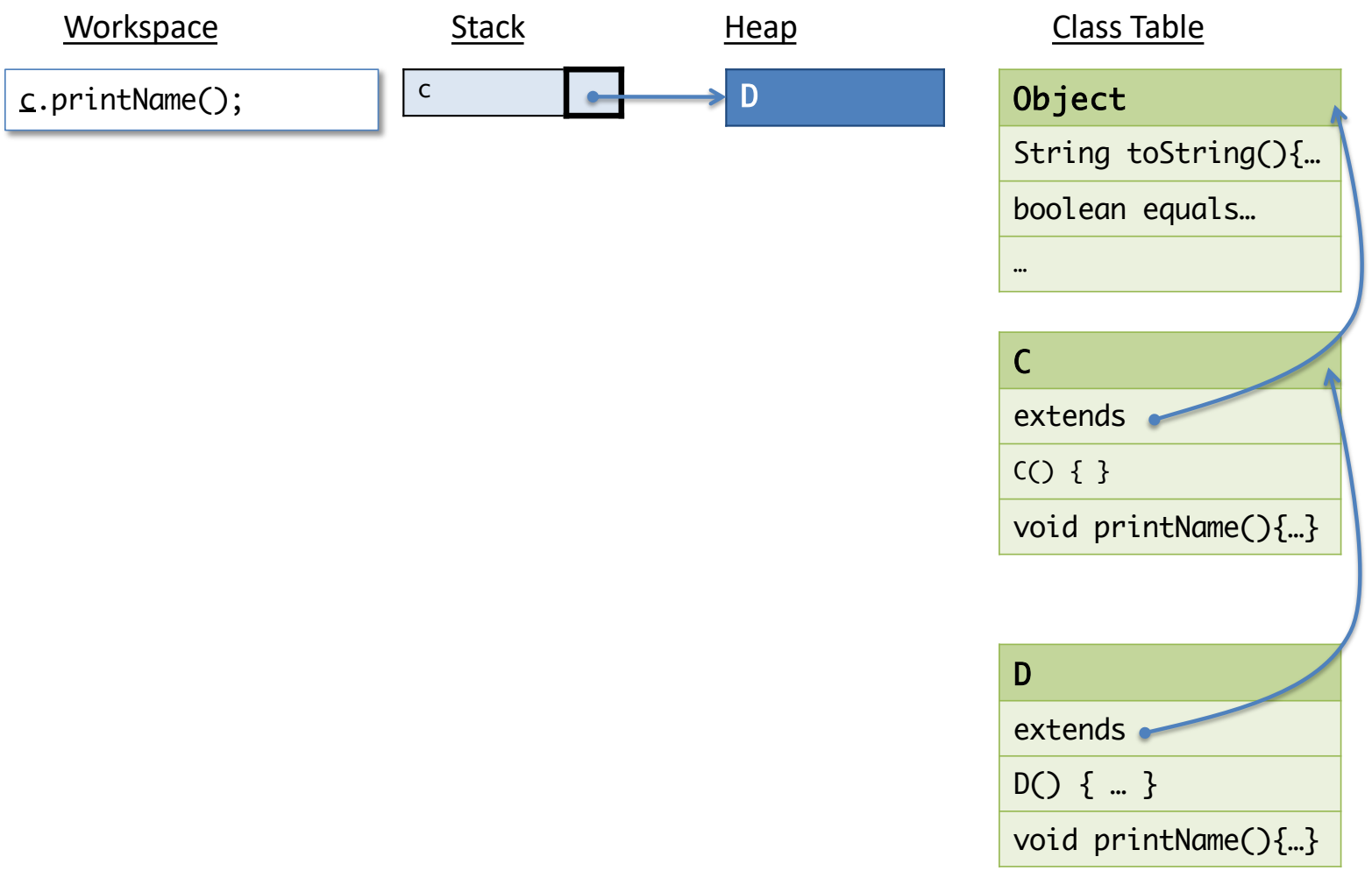
Stack

Heap

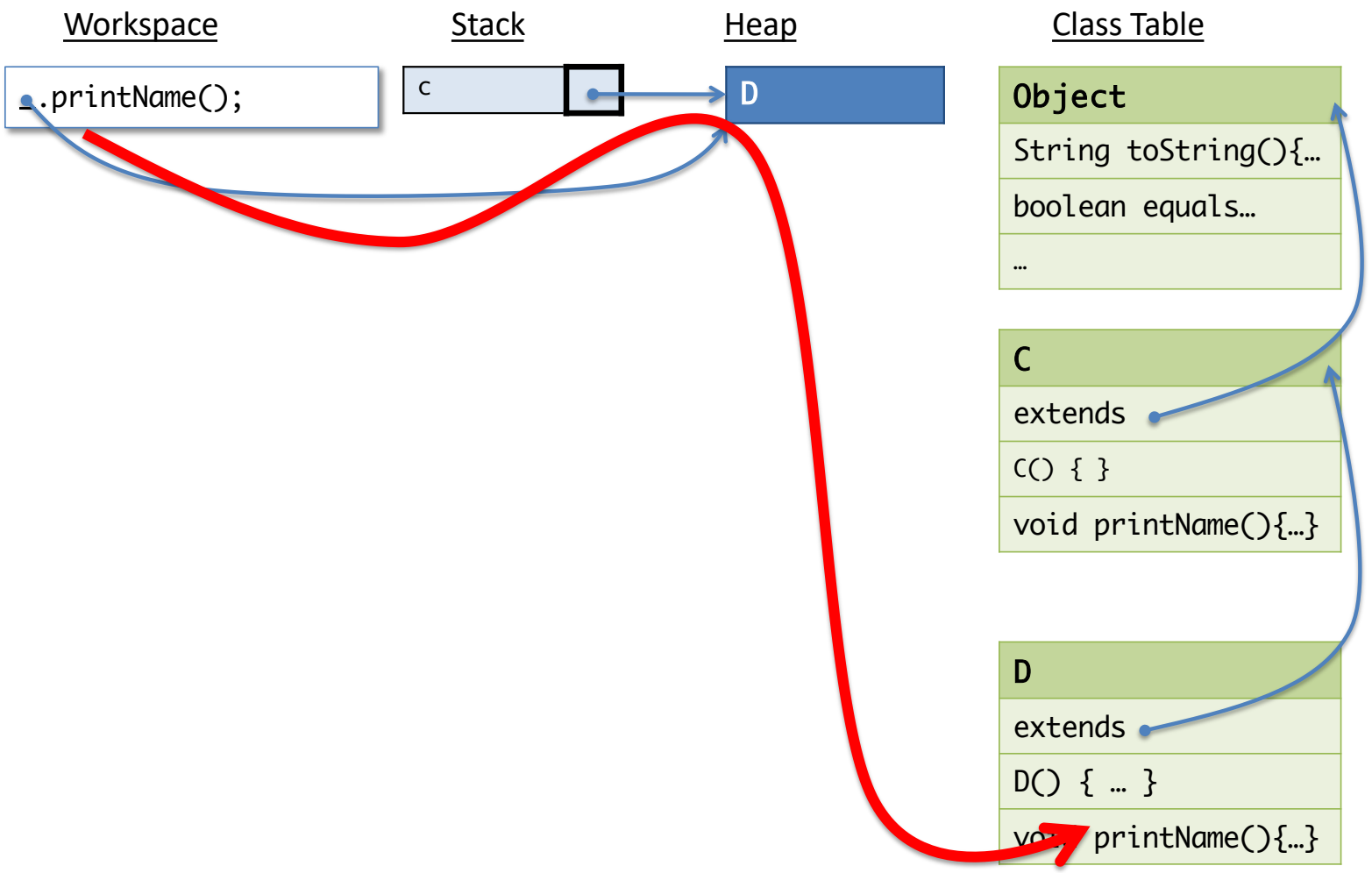
Class Table



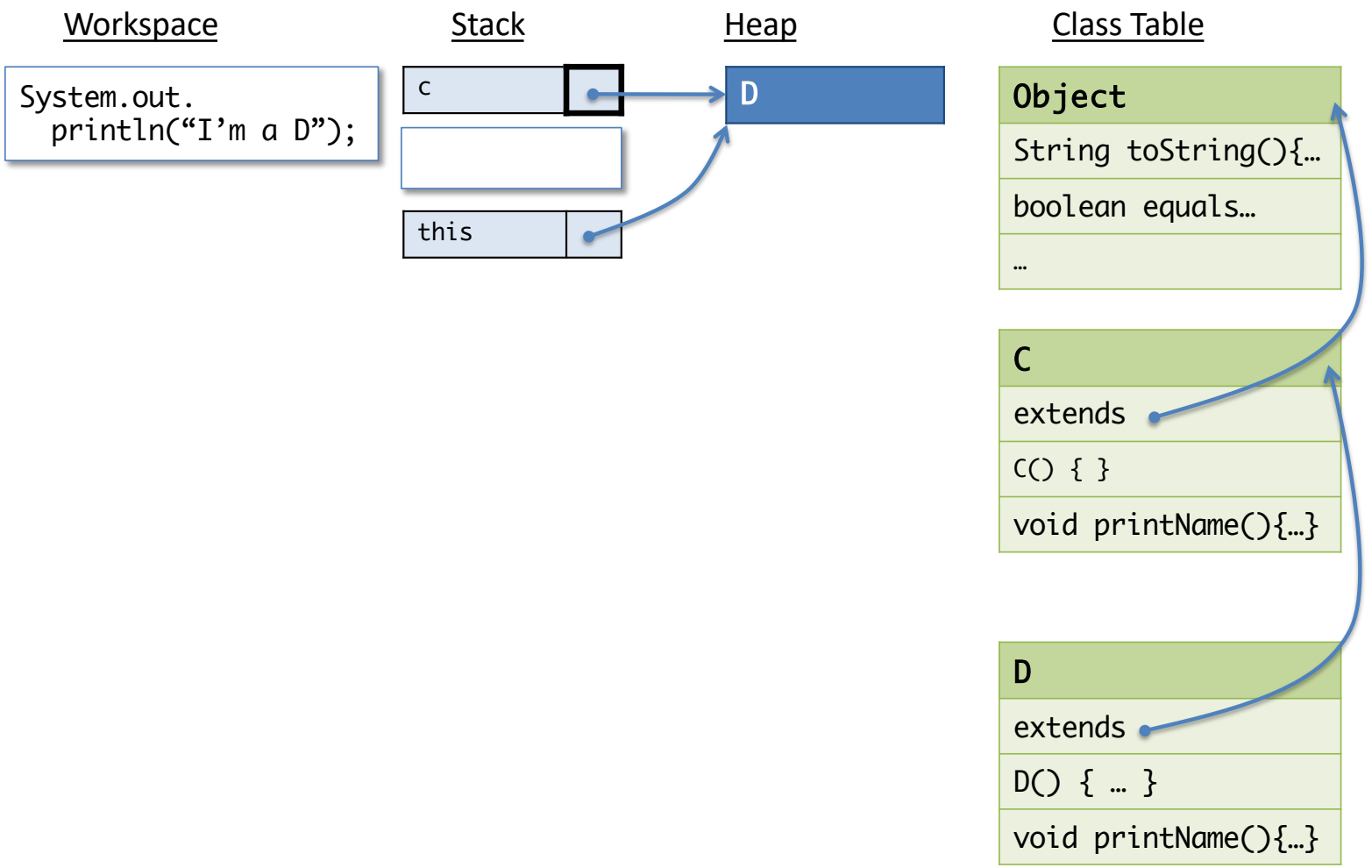
Overriding Example



Overriding Example



Overriding Example



28: What gets printed to the console?

0

```
class C {

  public void printName() {
    System.out.println("I'm a " + getName());
  }

  public String getName() {
    return "C";
  }
}

class E extends C {

  public String getName() {
    return "E";
  }
}

// in main
C c = new E();
c.printName();
```

I'm a C

0%

I'm a E

0%

NullPointerException

0%

Difficulty with Overriding

```
class C {

  public void printName() {
    System.out.println("I'm a " + getName());
  }

  public String getName() {
    return "C";
  }
}

class E extends C {

  public String getName() {
    return "E";
  }
}

// in main
C c = new E();
c.printName();
```

What gets printed to the console?

1. I'm a C
2. I'm a E
3. NullPointerException

Answer: I'm a E

Difficulty with Overriding

```
class C {

  public void printName() {
    System.out.println("I'm a " + getName());
  }

  public String getName() {
    return "C";
  }
}

class E extends C {

  public String getName() {
    return "E";
  }
}

// in main
C c = new E();
c.printName();
```

The C class might be in another package, or a library...

Whoever writes E might not be aware of the implications of changing `getName`.

Overriding the `getName` method causes the behavior of `printName` to change!

- Overriding can break invariants/abstractions relied upon by the superclass.

Overriding case study: Equality

29: What gets printed to the console?

0

True

0%

False

0%

Consider this example

```
public class Point {
    private final int x;
    private final int y;
    public Point(int x, int y) { this.x = x; this.y = y;
}
    public int getX() { return x; }
    public int getY() { return y; }
}

// somewhere in main…
List<Point> l = new LinkedList<Point>();
l.add(new Point(1,2));
System.out.println(l.contains(new Point(1,2)));
```

What gets printed to the console?

1. true
2. false

Why?

Answer: 2