Programming Languages and Techniques (CIS120)

Lecture 27

March 23rd, 2016

Generics and Collections

Chapter 25

Announcements

- HW #6 due Tuesday

- I will be away all next week (FP workshop in Germany)
  - Monday's lecture: Yaron Minsky, Jane Street
  - My office hours are cancelled on Monday
  - Guest lecturers Wednesday & Friday, bring clickers!

Java Generics

Subtype Polymorphism*

- Main idea:

Anywhere an object of type A is needed, an object that is a subtype of A can be provided.

```
// in class C
public static void times2(Counter c) {
    c.incBy(c.get());
 }
// somewhere else, Decr extends Counter
C.times2(new Decr(3));
```

- If B is a subtype of A, it provides all of A's (public) methods.

*polymorphism = many shapes

Is subtyping good enough?

Subtype Polymorphism

vs.

Parametric Polymorphism

Mutable Queue ML Interface

```
module type QUEUE =
sig
  (* type of the data structure *)
  type 'a queue

  (* Make a new, empty queue *)
  val create : unit -> 'a queue

  (* Add a value to the end of the queue *)
  val enq : 'a -> 'a queue -> unit

  (* Remove the front value and return it (if any) *)
  val deq : 'a queue -> ‘a

  (* Determine if the queue is empty *)
  val is_empty : ‘a queue -> bool

end
```

How can we translate this interface to Java?

Java Interface

```
module type QUEUE =
sig

  type 'a queue

  val create : unit -> 'a queue

  val enq : 'a -> 'a queue ->
   unit

  val deq : 'a queue -> ‘a

  val is_empty : ‘a queue -> bool

end
```

```
interface ObjQueue {



   // no constructors
   // in an interface


    public void enq(Object elt);

    public Object deq();

    public boolean isEmpty();

}
```

Subtype Polymorphism

```
interface ObjQueue {
    public void enq(Object elt);
    public Object deq();
    public boolean isEmpty();
}
```

```
ObjQueue q = …;

q.enq(" CIS 120 ");
__A__  x = q.deq();
```

What type for A?

1. String
2. Object
3. ObjQueue
4. None of the above

Subtype Polymorphism

```
interface ObjQueue {
    public void enq(Object elt);
    public Object deq();
    public boolean isEmpty();
}
```

```
ObjQueue q = …;

q.enq(" CIS 120 ");
Object  x = q.deq();
System.out.println(x.trim());
```

← Does this line type check

1. Yes
2. No
3. It depends

Subtype Polymorphism

```
interface ObjQueue {
    public void enq(Object elt);
    public Object deq();
    public boolean isEmpty();
}
```

```
ObjQueue q = …;

q.enq(" CIS 120 ");
Object  x = q.deq();
//System.out.println(x.trim());
q.enq(new Point(0.0,0.0));
___B___  y = q.deq();
```

What type for B?

1. Point
2. Object
3. ObjQueue
4. None of the above

Parametric Polymorphism (a.k.a. Generics)

- Big idea:

Parameterize a type (i.e. interface or class) by another type.

```
public interface Queue<E> {
  public void enq(E o);
  public E deq();
  public boolean isEmpty();

}
```

- The implementations of a parametric polymorphic interface can not depend on the implementation details of the parameter.
  - e.g. the implementation of enq should not invoke methods on ‘o’

Generics (Parametric Polymorphism)

```
public interface Queue<E> {
  public void enq(E o);
  public E deq();
  public boolean isEmpty();
  …
}
```

```
Queue<String> q = …;

q.enq(" CIS 120 ");
String x = q.deq();               // What type of x?    String
System.out.println(x.trim());     // Is this valid?     Yes!
q.enq(new Point(0.0,0.0));        // Is this valid?     No!
```

Subtyping and Generics

Subtyping and Generics*

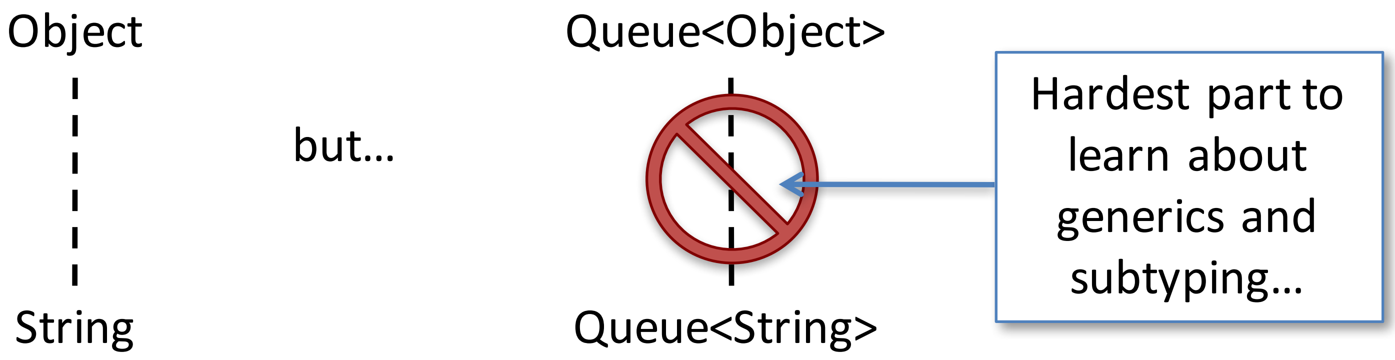
```
Queue<String>  qs = new QueueImpl<String>();
Queue<Object>  qo = qs;

qo.enq(new Object());
String s = qs.deq();
```

Ok? Sure!
Ok? Let's see…

Ok? I guess
Ok? Noooo!

- Java generics are *invariant*:
  - Subtyping of *arguments* to generic types does not imply subtyping between the instantiations:



* Subtyping and generics interact in other ways too. Java supports "bounded" polymorphism and wildcard types, but those are beyond the scope of CIS 120.

Subtyping and Generics

Which of these are true, assuming that class QueueImpl<E> implements interface Queue<E>?

1. QueueImpl<Queue<String>> is a subtype of Queue<Queue<String>>
2. Queue<QueueImpl<String>> is a subtype of Queue<Queue<String>>
3. Both
4. Neither

The Java Collections Library

A case study in subtyping and generics

(Also very useful!)

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 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
```

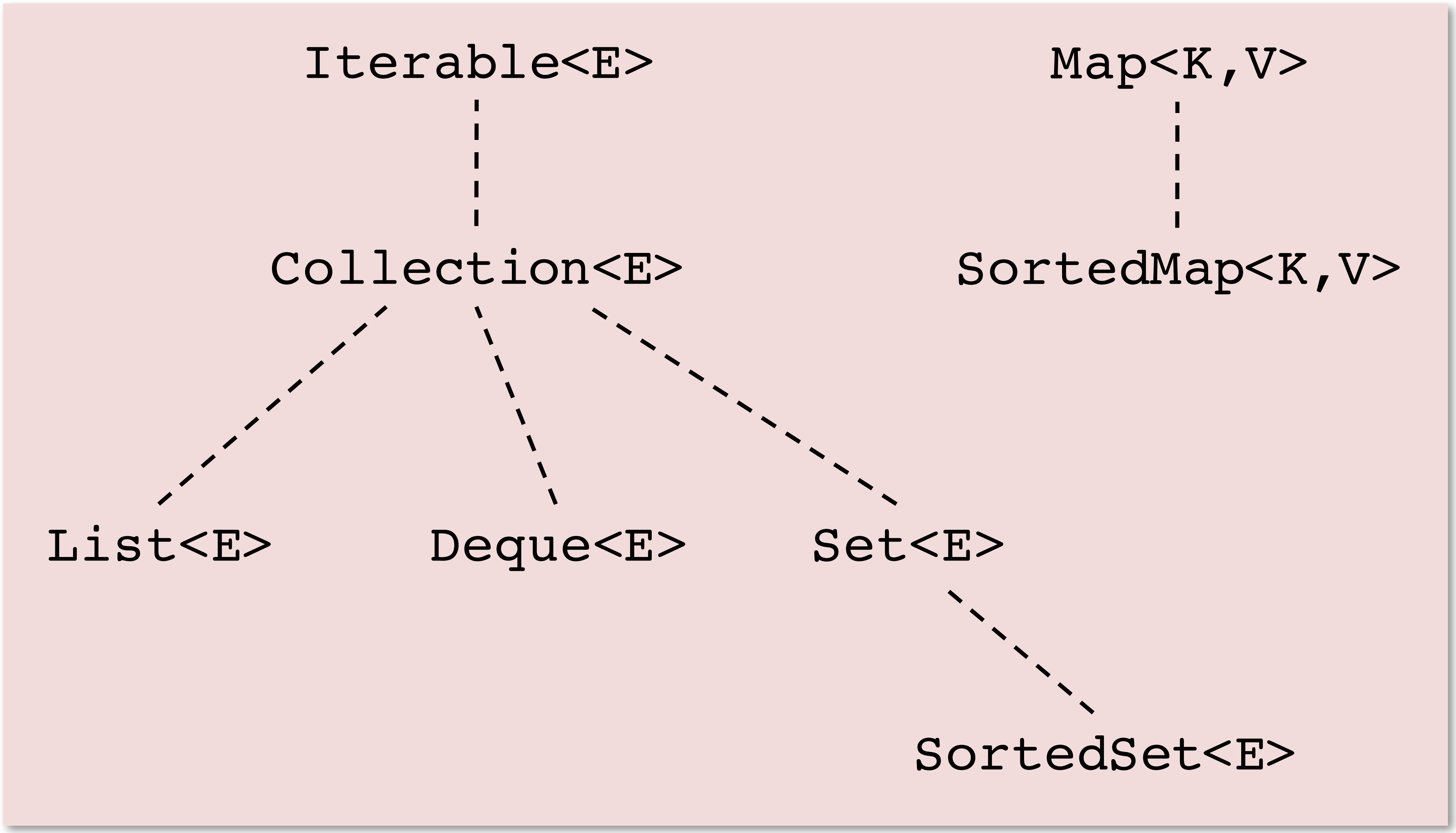
- Important packages:
  - java.lang, java.io, java.util, java.math, org.junit
- See documentation at: http://docs.oracle.com/javase/7/docs/api/

Reading Java Docs

java.util

https://docs.oracle.com/javase/7/docs/api/java/util/package-summary.html

Interfaces* of the Collections Library



*not all of them!

Collection<E> Interface (Excerpt)

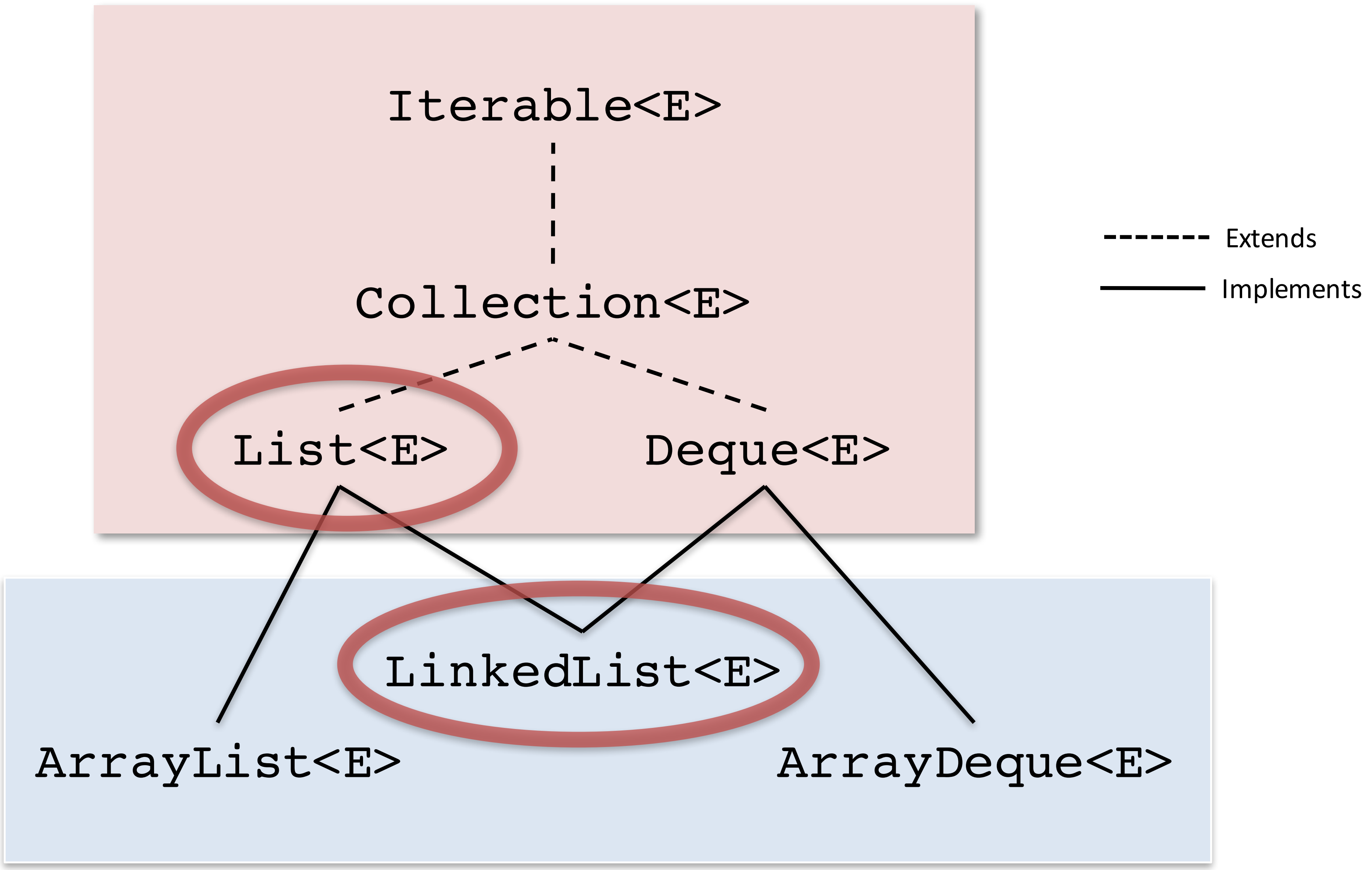
```
public interface Collection<E> extends Iterable<E> {
  // basic operations
  int size();
  boolean isEmpty();
  boolean add(E o);
  boolean remove(Object o);      // why not E?*
  boolean contains(Object o);

  // bulk operations
  …
}
```

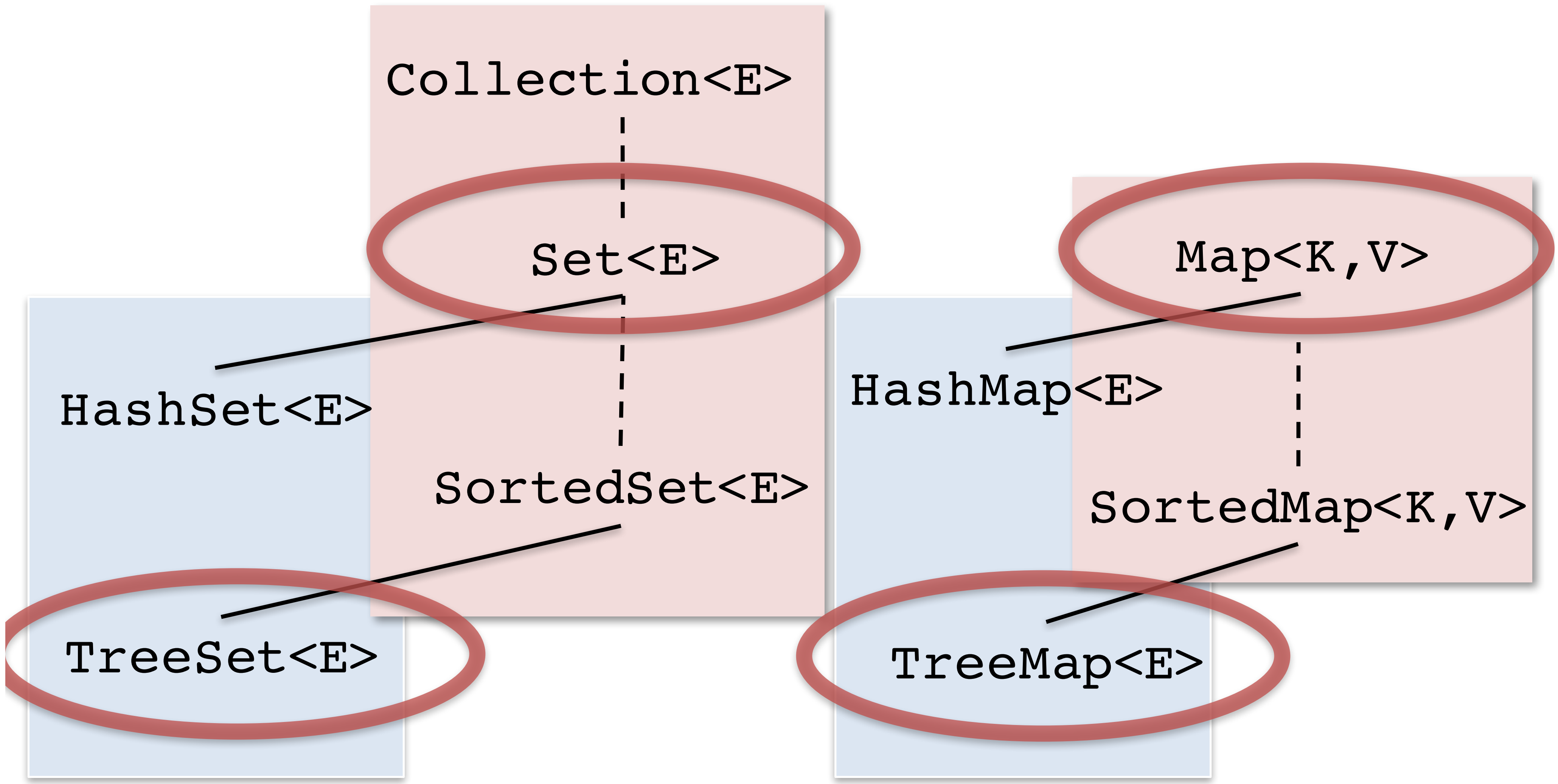
- We've already seen this interface in the OCaml part of the course.
- Most collections are designed to be *mutable* (like queues)

* 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