

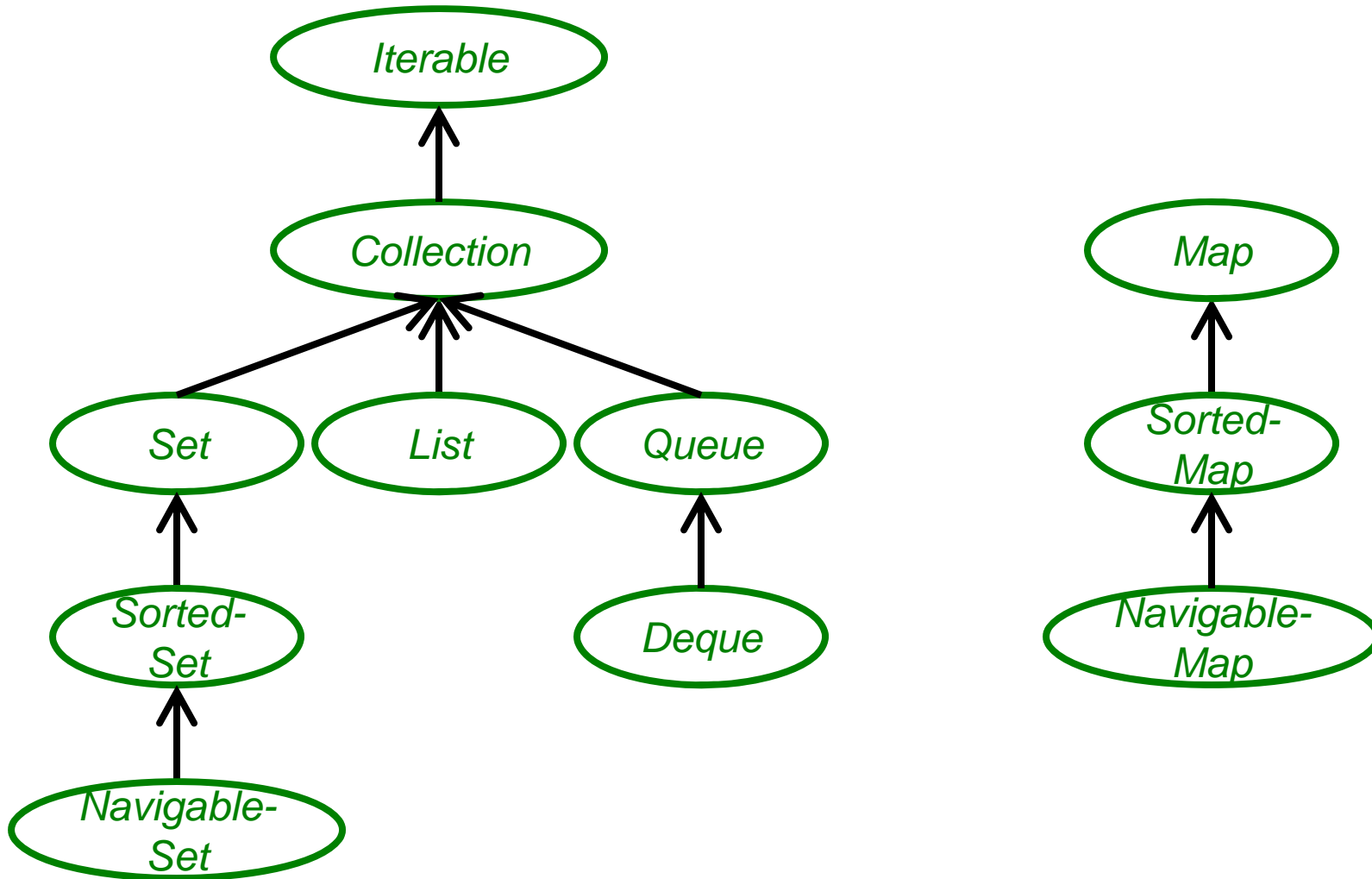
Java Collections Framework



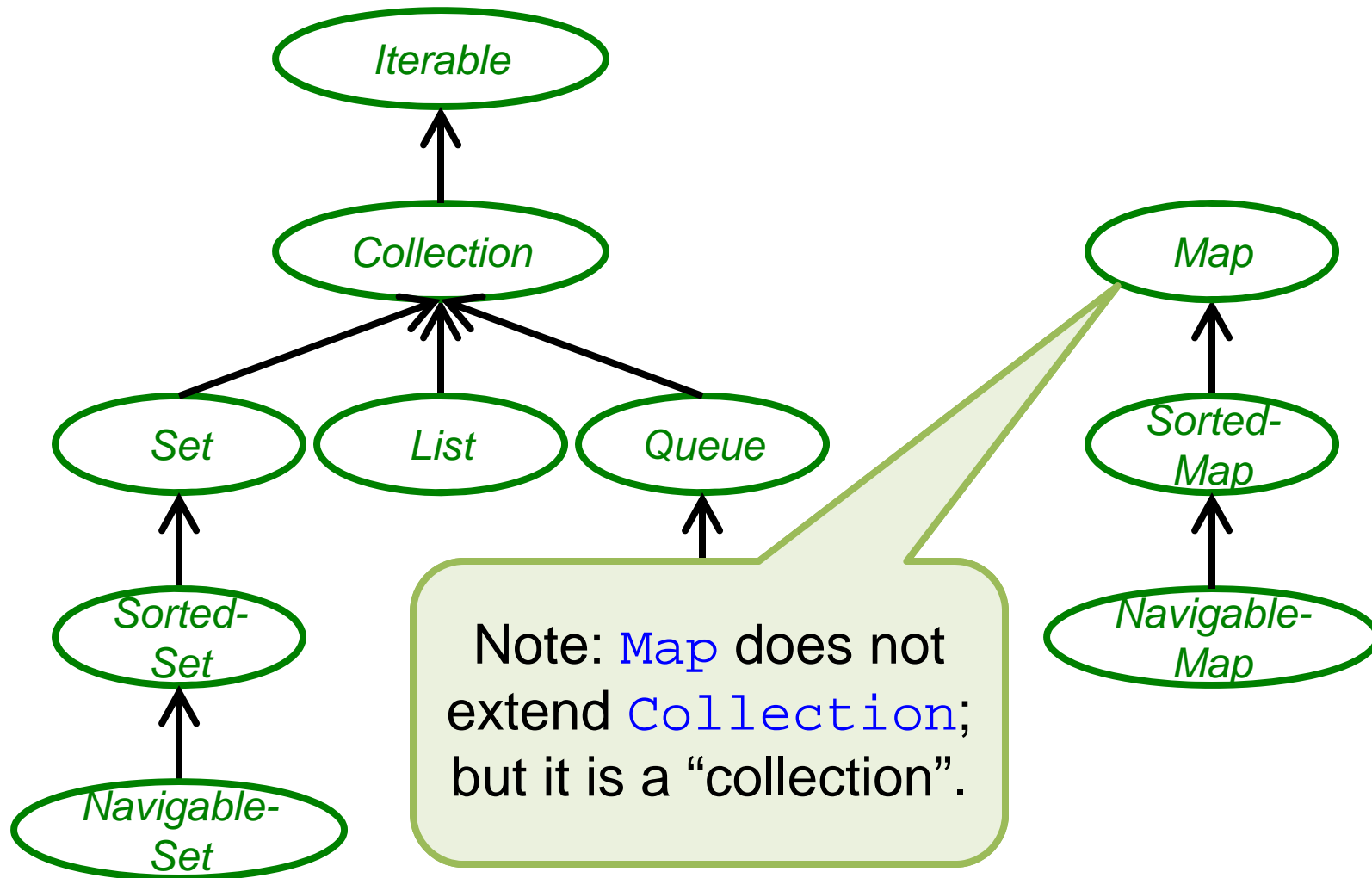
Overview

- The ***Java Collections Framework (JCF)*** is a group of interfaces and classes similar to the OSU CSE components
 - The similarities will become clearly evident from examples
 - See Java libraries package `java.util`
- There are some important differences, too, however, that deserve mention (at the end)

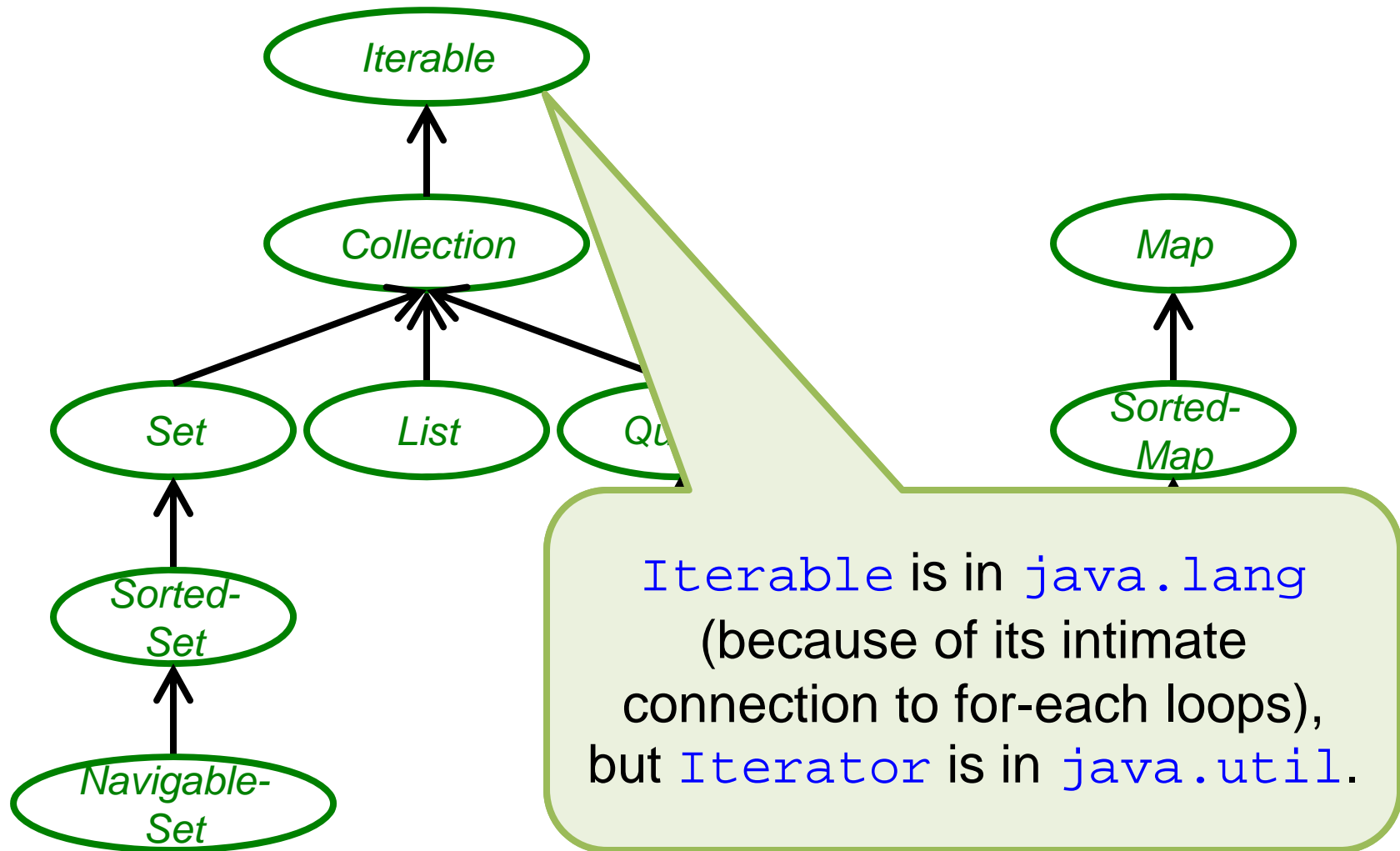
Overview of Interfaces



Overview of Interfaces

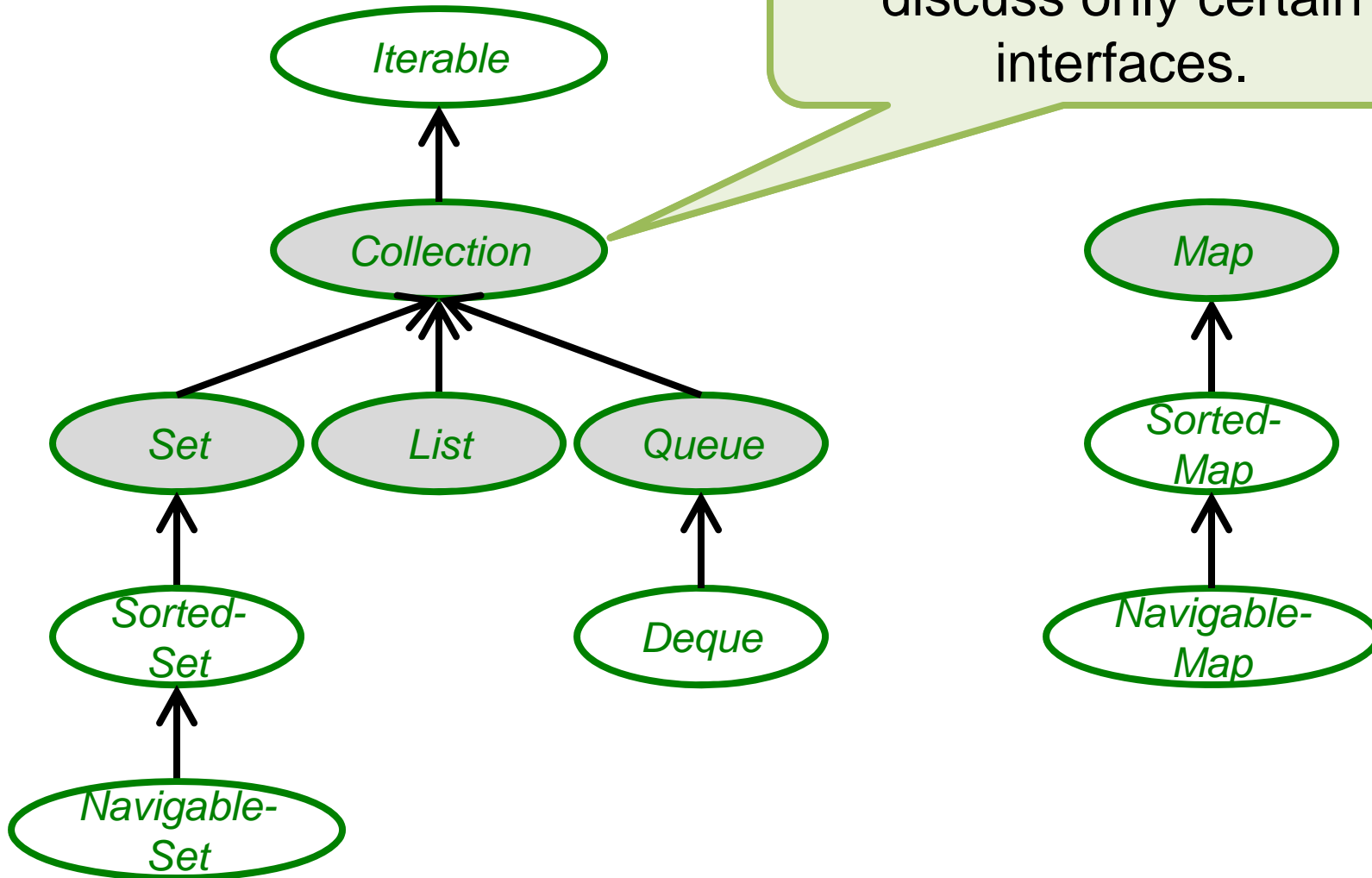


Overview of Interfaces



Overview of

Subsequent slides discuss only certain interfaces.



The `Collection<E>` Interface

- Essentially a *finite multiset of E*
- No direct/efficient way to ask how many “copies” of a given element there are
- Two interesting methods to create arrays of the elements
- Many methods (including `add`, `remove`, `clear`) are “optional”

The `Set<E>` Interface

- Essentially a *finite set of E*
- No `removeAny` or similar method, so you must use `iterator` to iterate over a `Set`
 - Recall (from `Iterator`): “The behavior of an iterator is unspecified if the underlying collection is modified while the iteration is in progress [except using `Iterator.remove`].”
- Many methods (including `add`, `remove`, `clear`) are “optional”

The `List<E>` Interface

- Essentially a *string of E*
- Access by position (similar to `Sequence` from OSU CSE components)
- Many methods (including `add`, `remove`, `clear`) are “optional”
- Two interesting additional features:
 - Sublist “views” of a `List`
 - A special two-way `ListIterator`

The `List<E>` Interface

- Essentially a *string of E*
- Access by position from OSU CSE components
- Many methods (including `clear`) are “optional”
- Two interesting additional features:
 - Sublist “views” of a `List`
 - A special two-way `ListIterator`

How do you move forward and backward through a `List` from OSU CSE components?

The `Queue<E>` Interface

- Essentially a *string of E*
- Access at ends (similar to `Queue` from OSU CSE components)
- Here, `add` and `remove` are *not* “optional”
 - `add` is similar to `enqueue` for OSU CSE components’ `Queue`
 - `remove` is similar to `dequeue`
- Curious names for other methods, e.g., `offer`, `peek`, `poll`

The `Map<K, V>` Interface

- Essentially a *finite set of (K, V)* with the function property
- No `removeAny` or similar method, so you must use `iterator` (somewhat indirectly) to iterate over a `Map`
- Many methods (including `put`, `remove`, `clear`) are “optional”
- Like `List`, a `Map` supports “views” of its elements

Views in the JCF

- A **view** is a “subcollection” of a collection
 - Not a *copy* of some of the elements, but rather “a collection within a collection” that is manipulated “in place”
- Views for `Map`:
 - Keys: `Set<K> keySet()`
 - Values: `Collection<V> values()`
 - Pairs: `Set<Map.Entry<K,V>> entrySet()`

Views in the JCF

- A **view** is a “subcollection” of a collection

- Not a *copy* of so
“a collection with
manipulated “in

`Map.Entry<K, V>` in the JCF is very similar to `Map.Pair<K, V>` in the OSU CSE components.

- Views for `Map`:

- Keys: `Set<K> keys()`

- Values: `Collection<V> values()`

- Pairs: `Set<Map.Entry<K, V>> entrySet()`

Example: `Map<String, Integer> m`

Code	State
	$m = \{ ("PB", 99), ("BK", 42), ("SA", 42) \}$
<code>Set<String> s = m.keySet();</code>	
	$m = \{ ("PB", 99), ("BK", 42), ("SA", 42) \}$ $s = \{ "SA", "BK", "PB" \}$

Example: `Map<String, Integer> m`

Note all the aliases here!
There is no problem in this case because `String` is immutable, but consider the potential problems if it were not.

```
Set<String> s =  
    m.keySet();
```

State

```
m = { ("PB", 99),  
      ("BK", 42),  
      ("SA", 42) }
```

```
m = { ("PB", 99),  
      ("BK", 42),  
      ("SA", 42) }  
s = { "SA", "BK",  
      "PB" }
```


Example: `Map<String, Integer> m`

Code	State
	$m = \{ ("PB", 99), ("BK", 42), ("SA", 42) \}$
<code>Collection<Integer> c = m.values();</code>	
	$m = \{ ("PB", 99), ("BK", 42), ("SA", 42) \}$ $c = \{ 42, 99, 42 \}$

Example: `Map<String, Integer> m`

Code	State
	$m = \{ ("PB", 99), ("BK", 42) \}$
<pre>Set<Map.Entry<String, Integer>> s = m.entrySet();</pre>	
	$m = \{ ("PB", 99), ("BK", 42) \}$ $s = \{ ("BK", 42), ("PB", 99) \}$

View “Backed By” Collection

- A view is ***backed by*** the underlying collection, which means that if the view is modified then the underlying (“backing”) collection is also modified, and vice versa
 - See Javadoc for supported modifications
 - Be especially careful when iterating over a view of a collection and trying to modify it

Example: `List<Integer> s`

Code	State
	<code>s = <10, 7, 4, -2></code>
<code>s.subList(1,3).clear();</code>	
	<code>s = <10, -2></code>

Example: `Map<String, Integer> m`

Code	State
	$m = \{ ("PB", 99), ("BK", 42), ("SA", 42) \}$
<code>m.values().remove(42);</code>	
	$m = \{ ("PB", 99), ("SA", 42) \}$

Example: `Map<String, Integer> m`

Because `remove` for `Collection` (assuming it is available for `m.values`!) removes one copy, we do not know which pair remains in `m`.

State

```
m = { ("PB", 99),  
      ("BK", 42),  
      ("SA", 42) }
```

```
m.values().remove(42);
```

```
m = { ("PB", 99),  
      ("SA", 42) }
```

Could `remove` Cause Trouble?

- The ***object (dynamic) type*** of `m.values()` in the above code might be an implementation of `List` or of `Queue`
 - But not of `Set`; why not?
- The `remove` being called is “optional” if the object type of `m.values()` is a `List` implementation, but not if it is a `Queue`
 - How can the client know what interface it implements?

Could `remove` Cause Trouble?

The informal Javadoc for the `values` method says:
“The collection supports element removal, which removes the corresponding mapping from the map, via the `Iterator.remove`, `Collection.remove`, `removeAll`, `retainAll` and `clear` operations. It does not support the `add` or `addAll` operations.”

- The `remove` being called “`removeAll`” if the object type of `m.values()` is a `List` implementation, but not if it is `Queue`
 - How can the client know what interface it implements?

Could `remove` Cause Trouble?

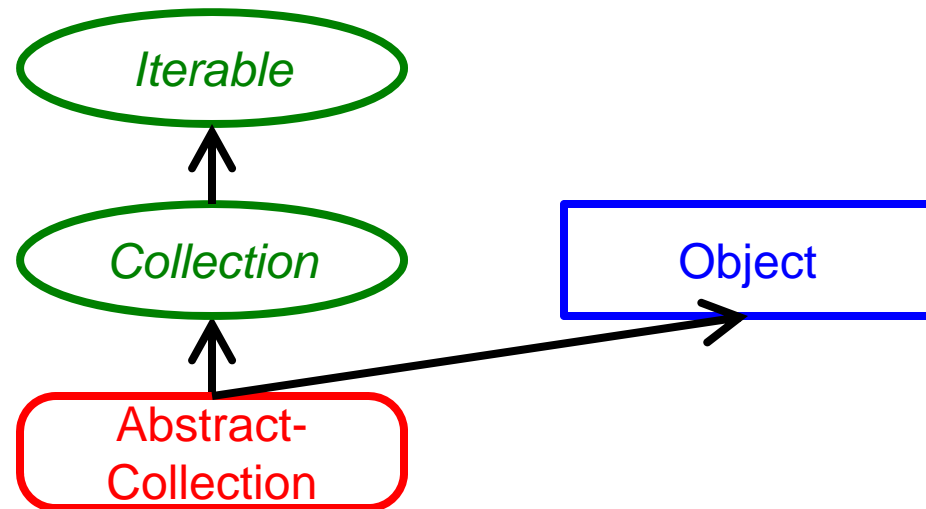
Since `values` returns an object whose dynamic type “supports” `remove` but not `add`, apparently that return type implements a fictitious (phantom?) interface that is stronger than `Collection`, but different than all of `Set`, `List`, and `Queue`.

- The `remove` being called “legal” if the object type of `m.values` is a `List` implementation, but not if it is `Queue`
 - How can the client know what interface it implements?

Iterating Over a `Map`

- Because `Map` does *not* extend `Iterable`, but `Collection` (hence `Set`) does extend `Iterable`, you can (only) iterate over a `Map` using one of its three views:
 - Keys: `Set<K> keySet()`
 - Values: `Collection<V> values()`
 - Pairs: `Set<Map.Entry<K,V>> entrySet()`

Overview of `Collection` Classes



There are no classes that directly and fully implement `Collection`.

AbstractCollection

- Has code for many methods (shared, and possibly overridden, by all later implementations of `Collection`) :
 - `add`
 - `remove`
 - `clear`
 - ...

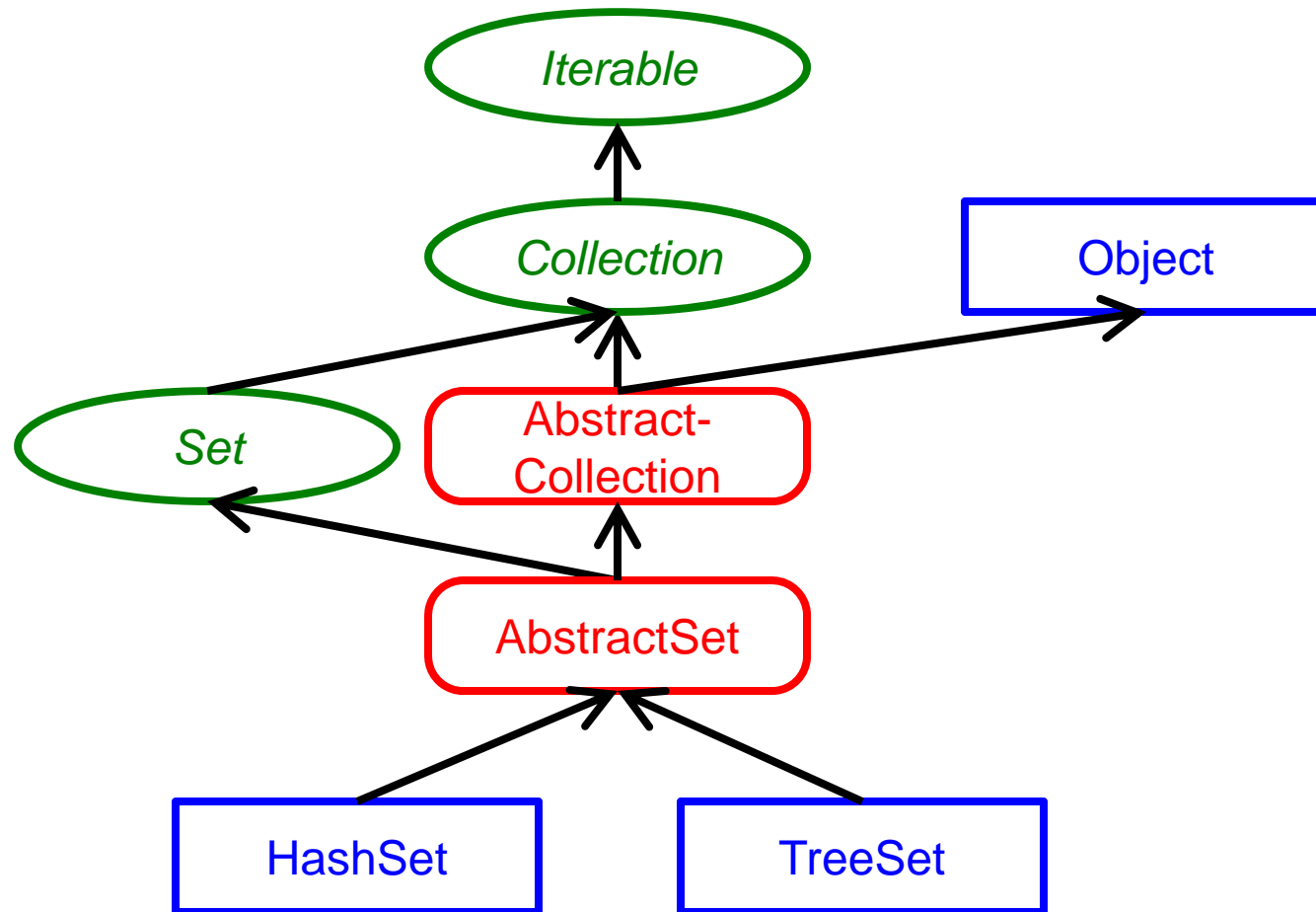
AbstractCollection

- Has code for many methods (shared, and possibly overridden, by all later implementations of `Collection`) :

- `add`
- `remove`
- `clear`
- ...

This method's implementation here, for example, "always throws an `UnsupportedOperationException`".

Overview of Set Classes



AbstractSet

- Has code for these methods (shared, and possibly overridden, by all later implementations of `Set`):
 - `equals`
 - `hashCode`
 - `removeAll`

HashSet

- Uses *hashing* in the `Set` representation
- Has code for these methods (overriding those in `AbstractSet`):
 - `add`
 - `remove`
 - `clear`
 - `clone`

HashSet

- Uses *hashing* in the `Set` representation
- Has code for these methods (overriding those in `AbstractSet`):

- `add`
- `remove`
- `clear`
- `clone`

The first three methods, though “optional”, are implemented here and do what you should expect.

HashSet

- Uses *hashing* in the `Set` representation
- Has code for these methods (overriding those in `AbstractSet`):

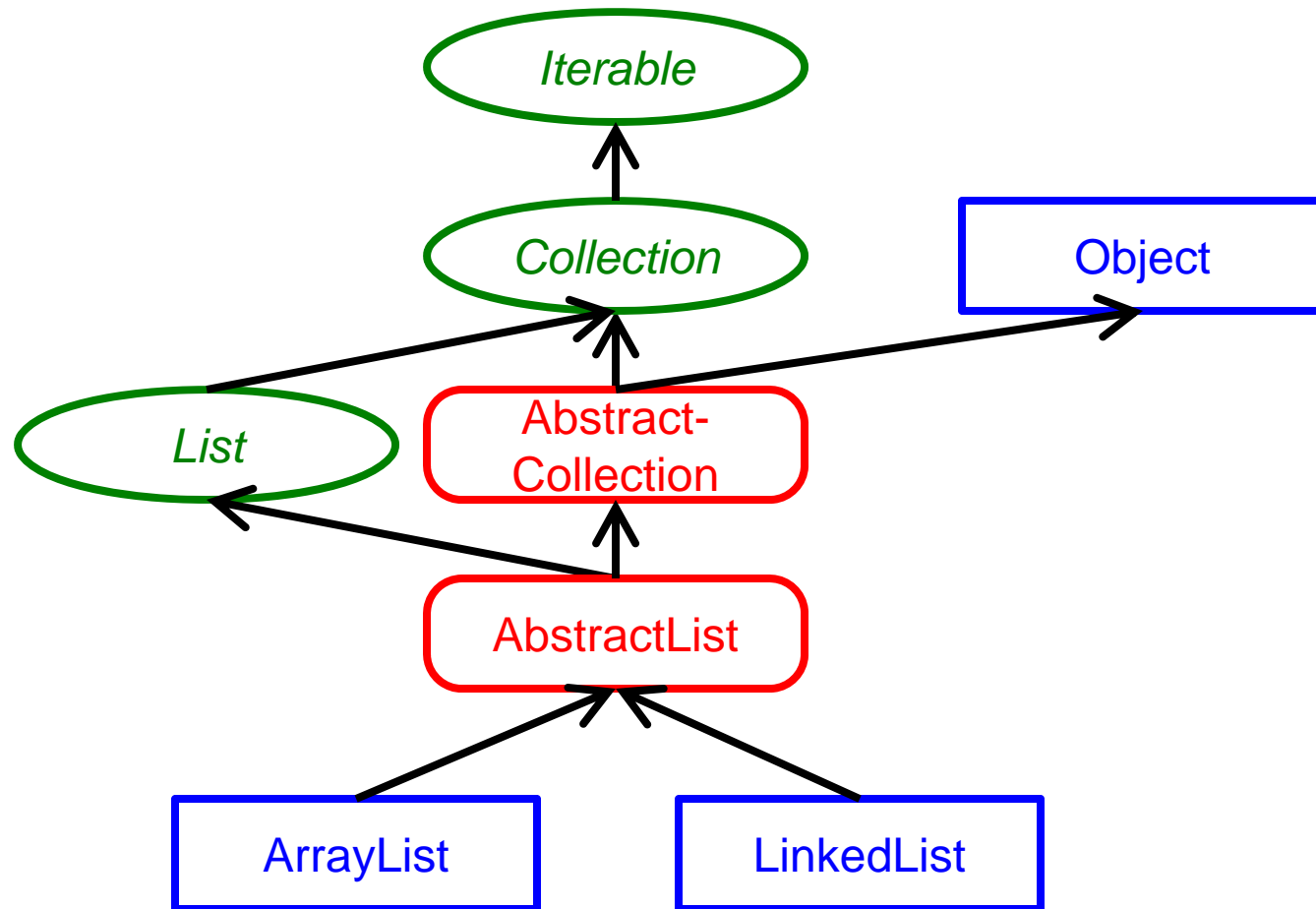
- `add`
- `remove`
- `clear`
- `clone`

The `clone` method “makes a shallow copy”, i.e., the elements are not “cloned”; which raises many questions.
Best practice: do not use it!

TreeSet

- Uses a ***balanced binary search tree*** as the `Set` representation
- Has code for several methods (overriding those in `AbstractSet`)

Overview of `List` Classes



AbstractList

- Has code for many methods (shared, and possibly overridden, by all later implementations of `List`)
- Similar to `AbstractSet` but with code for many more methods (because `List` has many more potentially layered methods than `Set`)

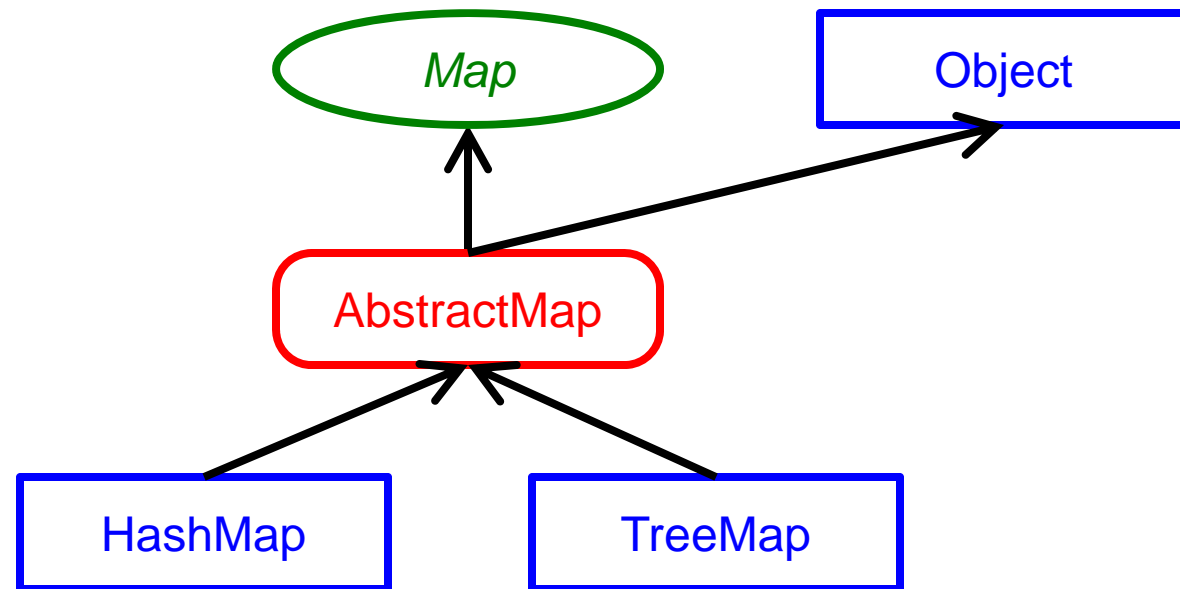
ArrayList

- Uses ***arrays*** in the `List` representation
- Has code for many methods (overriding those in `AbstractList`)

LinkedList

- Uses a ***doubly-linked list*** as the `List` representation
- Has code for many methods (overriding those in `AbstractList`)
- There is even more detail to the interfaces and abstract classes related to `LinkedList`, which you can look up if interested

Overview of `Map` Classes



AbstractMap

- Has code for many methods (shared, and possibly overridden, by all later implementations of `Map`)
- Similar to `AbstractSet` but with code for many more methods (because `Map` has many more potentially layered methods than `Set`)

HashMap

- Uses *hashing* in the `Map` representation
- Has code for many methods (overriding those in `AbstractMap`)

TreeMap

- Uses a ***balanced binary search tree*** as the `Map` representation
- Has code for several methods (overriding those in `AbstractMap`)

JCF Algorithms: Collections

- A number of useful algorithms (and simple but convenient utilities) to process collections are ***static methods*** in the class `Collections`, e.g.:
 - `sort`
 - `reverse`
 - `min, max`
 - `shuffle`
 - `frequency`

JCF Algorithms: `Collections`

- A number of useful algorithms (and simple but convenient utilities) to process collections are ***static methods*** in the class `Collections`, e.g.:

- `sort`
- `reverse`
- `min, max`
- `shuffle`
- `frequency`

Notice that the ***class*** `Collections` is different from the ***interface*** `Collection`, and in particular it does not implement that interface!

JCF Utilities: `Arrays`

- A number of useful algorithms (and simple but convenient utilities) to process built-in arrays are ***static methods*** in the class

`Arrays`, e.g.:

- `sort`
- `fill`
- `deepEquals`
- `deepHashCode`
- `deepToString`

OSU CSE vs. JCF Components

- The OSU CSE components are similar in design to the JCF interfaces and classes
- Though some differences can be attributed to pedagogical concerns, there are other important technical differences, too!

Difference #1: Level of Formalism

- JCF interfaces include only informal Javadoc comments for contracts (rather than using explicit mathematical models and requires/ensures clauses)
 - JCF descriptions and contracts use similar terms, though; e.g., “collections” may:
 - be “ordered” or “unordered”
 - “have duplicates” or “not have duplicates”

Difference #1: Level of Formalism

JCF `java.util.Set<E>`:

boolean `add(E e)`

Adds the specified element to this set if it is not already present (optional operation). More formally, adds the specified element `e` to this set if the set contains no element `e2` such that `(e==null ? e2==null : e.equals(e2))`. If this set already contains the element, the call leaves the set unchanged and returns `false`. In combination with the restriction on constructors, this ensures that sets never contain duplicate elements.

The stipulation above does not imply that sets must accept all elements; sets may refuse to add any particular element, including `null`, and throw an exception, as described in the specification for `Collection.add`. Individual set implementations should clearly document any restrictions on the elements that they may contain.

Throws:

`UnsupportedOperationException` - if the add operation is not supported by this set

`ClassCastException` - if the class of the specified element prevents it from being added to this set

`NullPointerException` - if the specified element is null and this set does not permit null elements

`IllegalArgumentException` - if some property of the specified element prevents it from being added to this set

Difference #1: Level of Formalism

OSU CSE `components.set.Set<T>`:

`void add(T x)`

Adds `x` to `this`.

Aliases:

reference `x`

Updates:

this

Requires:

x is not in this

Ensures:

this = #this union {x}

Difference #1: Level of Formalism

Hypothetical OSU CSE `components.set.Set<T>`:

```
boolean add(T x)
```

Can you write a formal contract for the `add` method *as it is designed in* `java.util.Set`?

Difference #1: Level of Formalism

- JCF interfaces include only informal Javadoc comments for contracts (rather than using explicit mathematical models and requirements clauses)

Warning about the JCF documentation:
The interface/class “summary” at the top of the Javadoc-generated page sometimes contains information that is missing from, or even apparently contradictory to, the method descriptions; e.g.:

- `iterator` for `SortedSet`
- a few methods for `PriorityQueue`

Difference #2: Parameter Modes

- JCF interfaces do not have any notion of parameter modes (rather than using them in contracts to help clarify and simplify behavioral descriptions)
 - If the JCF used parameter modes, though, the default mode also would be “restores”, as with the OSU CSE components

Difference #3: Aliasing

- JCF interfaces almost never explicitly mention aliasing (rather than advertising aliasing when it may arise)
 - JCF components also are *not* designed to try to avoid aliasing whenever possible, as the OSU CSE components are

Difference #4: Null

- JCF interfaces generally permit null references to be stored in collections (rather than having a blanket prohibition against null references)
 - JCF components do, however, sometimes include warnings against null references, which the OSU components always prohibit

Difference #5: Optional Methods

- JCF interfaces generally have “optional” methods (rather than requiring all methods to behave according to their specifications in all implementations)
 - JCF implementations of the same interface are therefore *not **plug-compatible***: “optional” methods have bodies, but calling one might simply throw an exception:
`UnsupportedOperationException`

Difference #6: Copy Constructors

- By convention, every class in the JCF has two “standard” constructors:
 - A ***default constructor***
 - A ***conversion constructor*** that “copies” references to the elements of its argument, which is another JCF collection

Difference #6: Copy Constructors

- By convention, every class in the JCF has two “standard” constructors:
 - A **default constructor**
 - A **conversion constructor** that “copies” references to the elements of its argument, which is another



This no-argument constructor creates an empty collection.

Difference #6: Copy Constructors

- By convention, every class in the JCF has two “standard” constructors:
 - A **default constructor**
 - A **conversion constructor** that “copies” references to the elements of its argument, which is another collection.

Presumably, “copying” from a collection that may have duplicates, to one that may not, simply removes extra copies.

Difference #7: Exceptions

- Violation of what might have been considered a precondition leads to a specific **exception** being thrown (rather than simply a conceptual contract violation, which might or might not be checked using **assert**)
 - Example: an attempt to remove an element from an empty `Queue` is specified to result in a `NoSuchElementException`

Difference #8: Kernel Methods

- A single JCF interface usually contains all methods applicable to a type (rather than “kernel” methods being separated into a separate interface from all other methods)
 - JCF uses abstract classes, however, to provide default implementations of methods that presumably would be implemented in abstract classes in the OSU CSE components
 - Other JCF methods are like “kernel” methods

Resources

- *The Collections Framework (from Oracle)*
 - <http://docs.oracle.com/javase/7/docs/technotes/guides/collections/index.html>
- *Effective Java, Second Edition*
 - <http://proquest.safaribooksonline.com.proxy.lib.ohio-state.edu/book/programming/java/9780137150021>