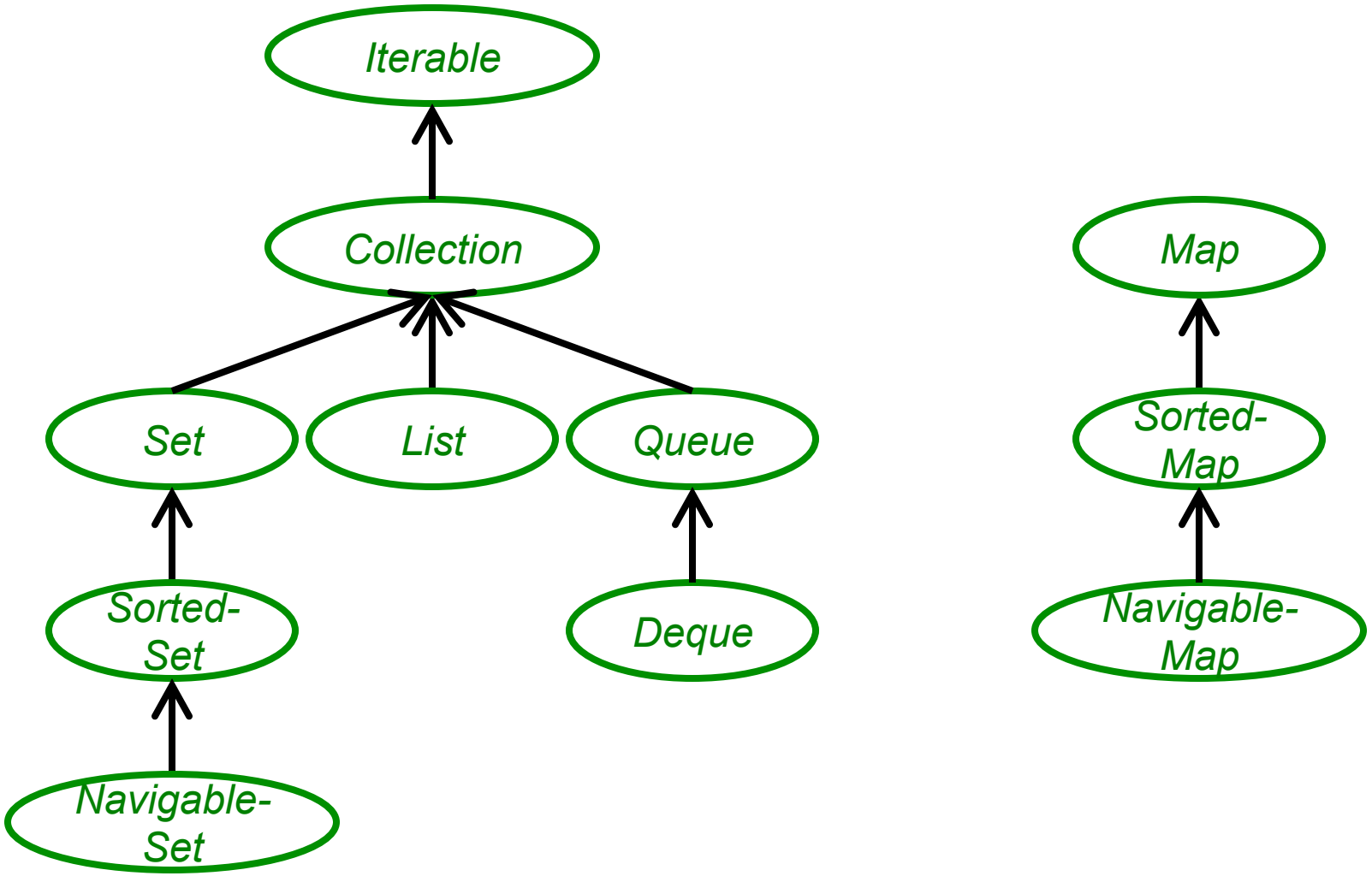
Java Collections Framework

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



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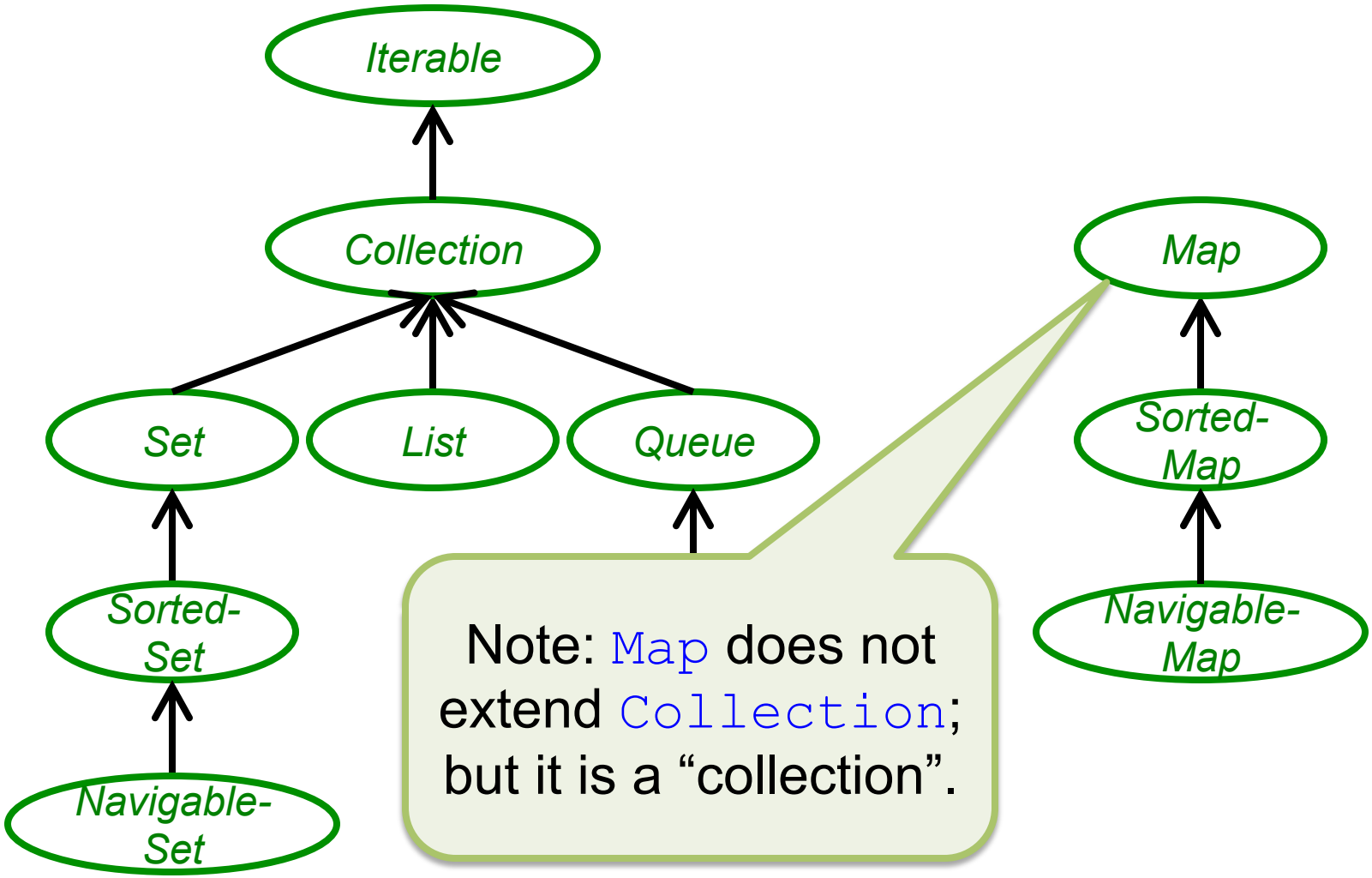
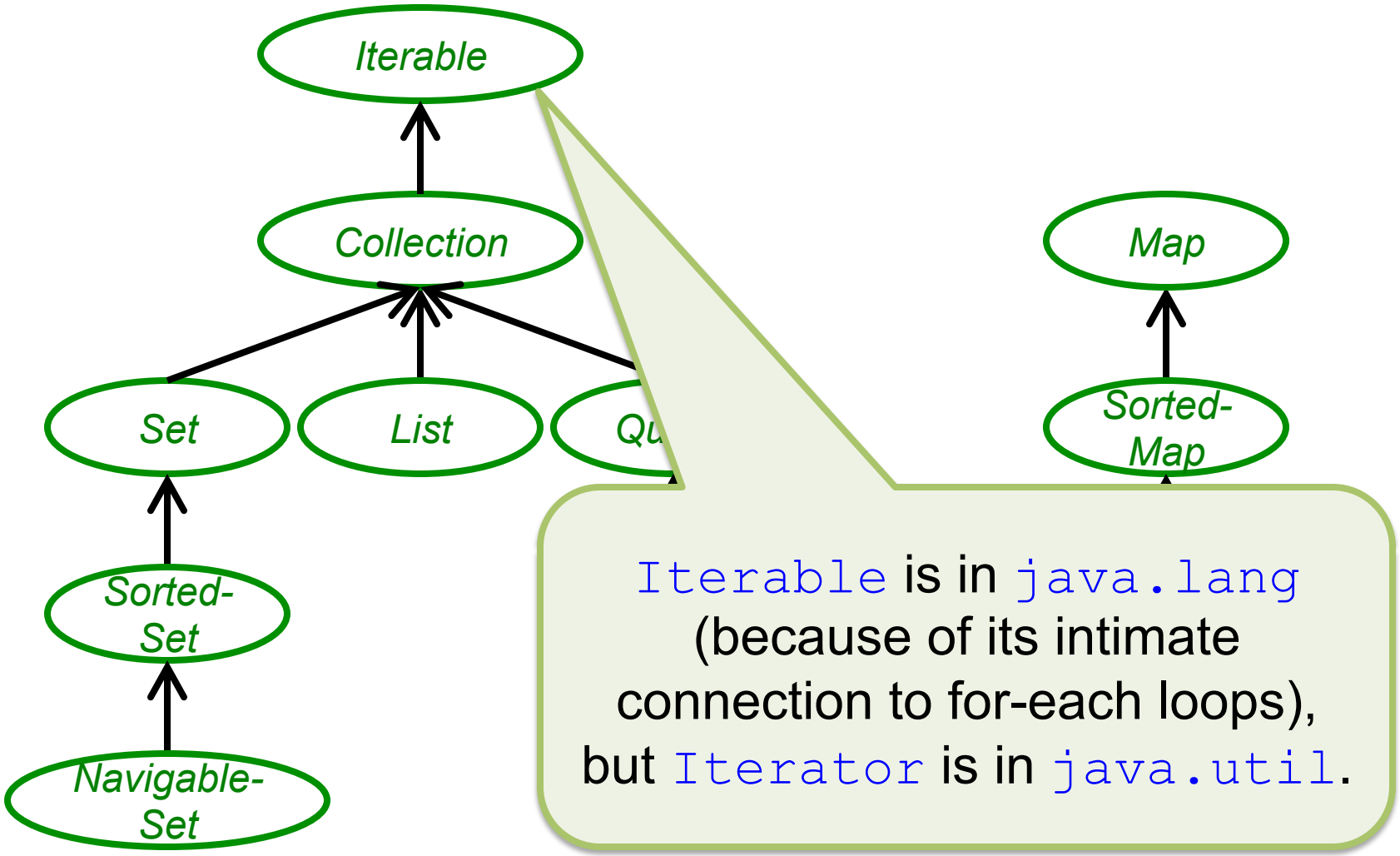
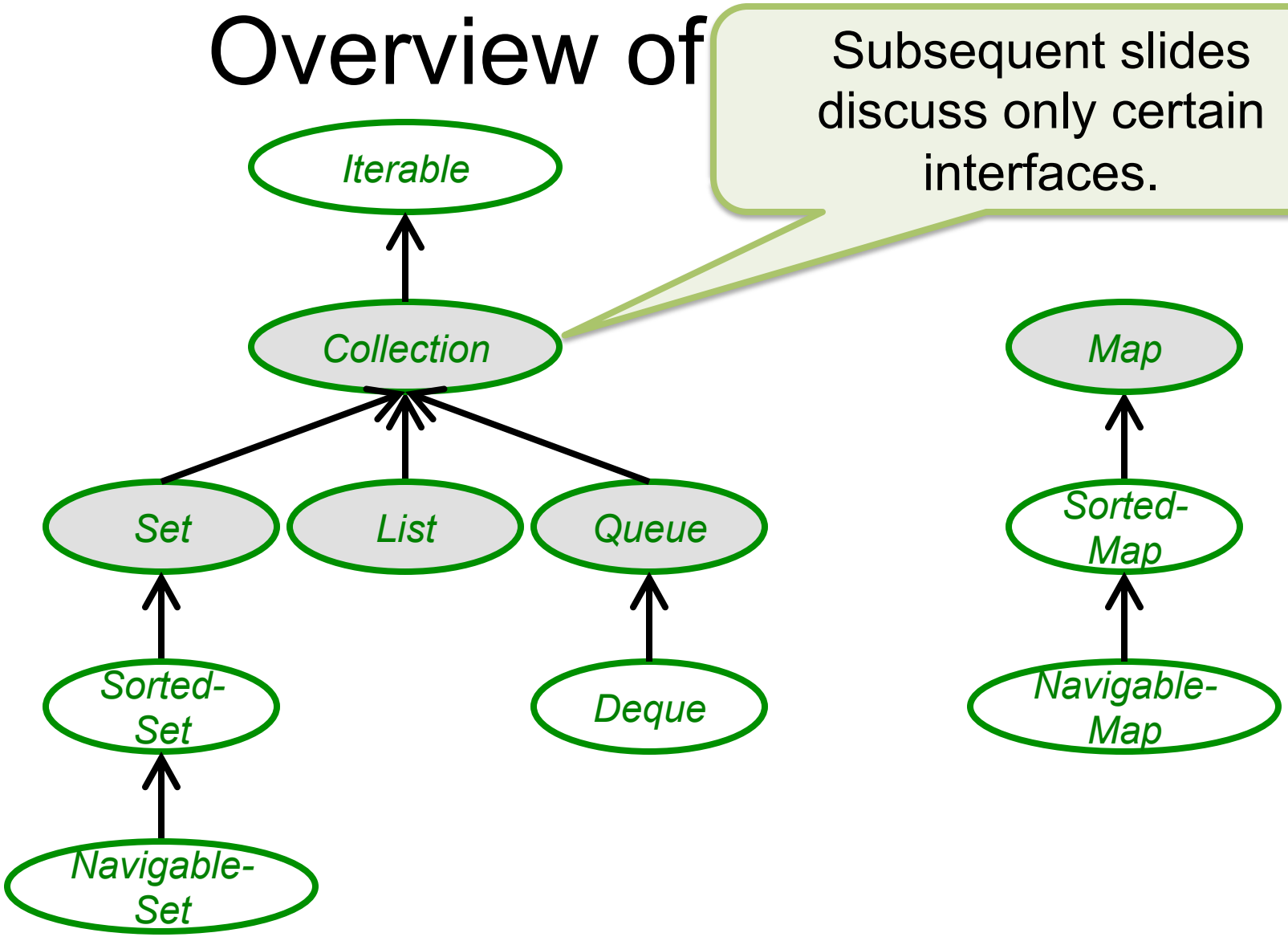


Overview of Interfaces



Overview of


Subsequent slides discuss only certain interfaces.
Iterable
Collection
Map
Set
List
Queue
Sorted-Map
Sorted-Set
Deque
Navigable-Map
Navigable-Set

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

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- Two interesting add al features:
  - Sublist "views" o 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()`

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

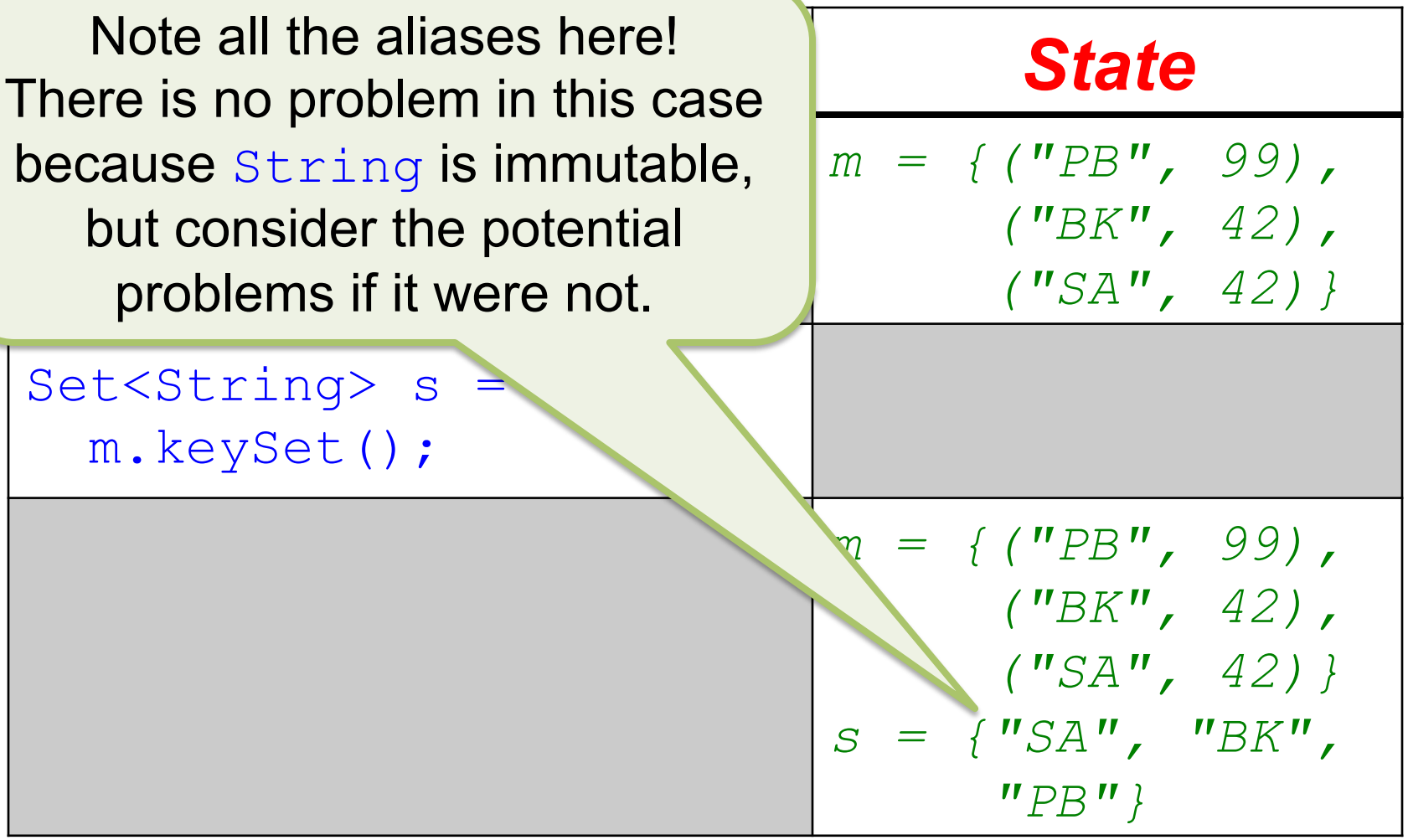
`Map.Entry<K,V>` in the JCF is very similar to `Map.Pair<K,V>` in the OSU CSE components.

Example: `Map<String, Integer> m`

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



Example: `Map<String, Integer> m`

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

Example: `Map<String, Integer> m`

Code	State
	`m = {("PB", 99), ("BK", 42)}`
`Set<Map.Entry<String, Integer>> s = m.entrySet();`	
	`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 or a collection and trying to modify it

Example: `List<Integer> s`

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

Example: `Map<String, Integer> m`

Code	State
	`m = {("PB", 99), ("BK", 42), ("SA", 42)}`
`m.values().remove(42);`	
	`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 "...al" if the object type of `m.values()` is a `List` implementation, but not if it is a `Queue`
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Could `remove` Cause Trouble?

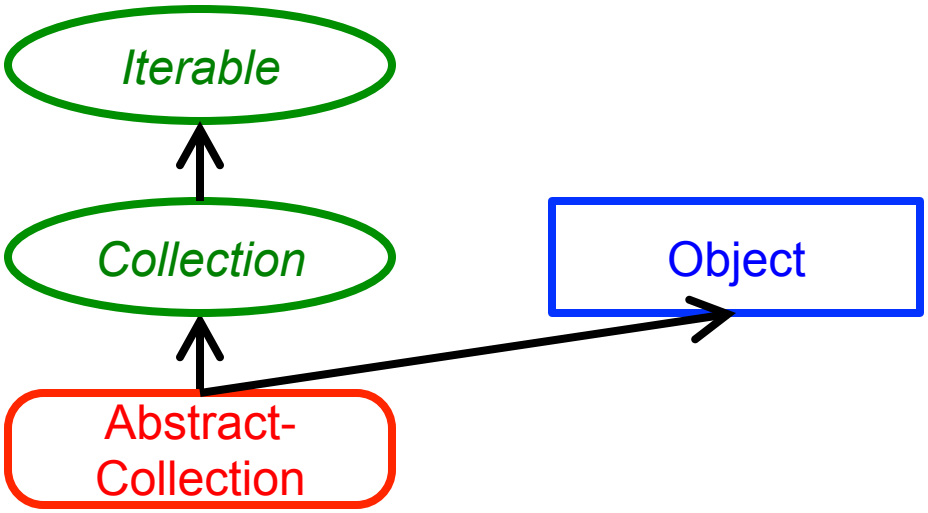
Since `values` returns an object whose dynamic type "supports" `remove` but not `add`, apparently that return type implements a fictitious (phantom?) interface that is stronger than `Collection`, but different than all of `Set`, `List`, and `Queue`.

- The `remove` being called [illegal] 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?

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`
  - `...`

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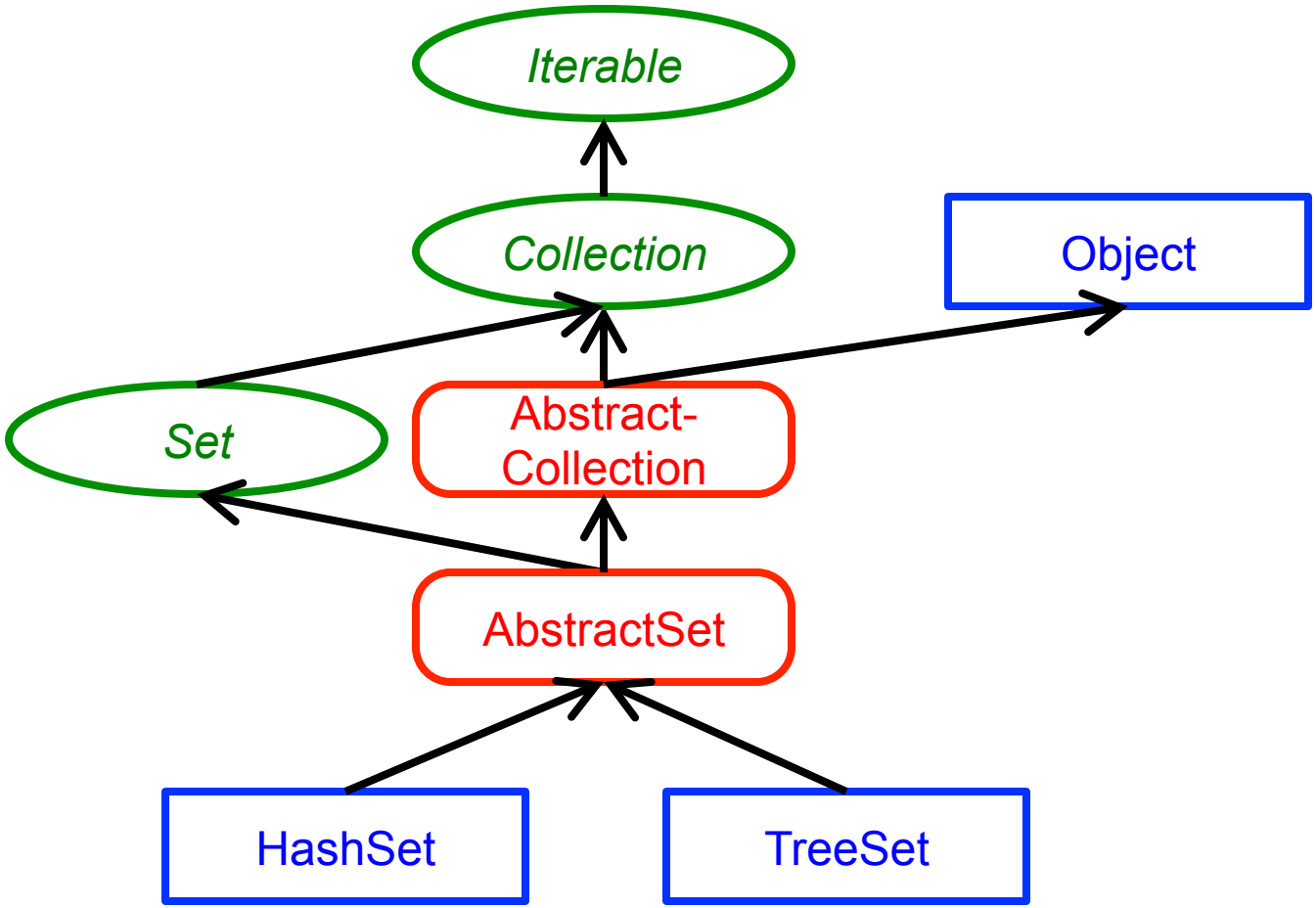
  - `clear`
  - `...`

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`

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

`HashSet`

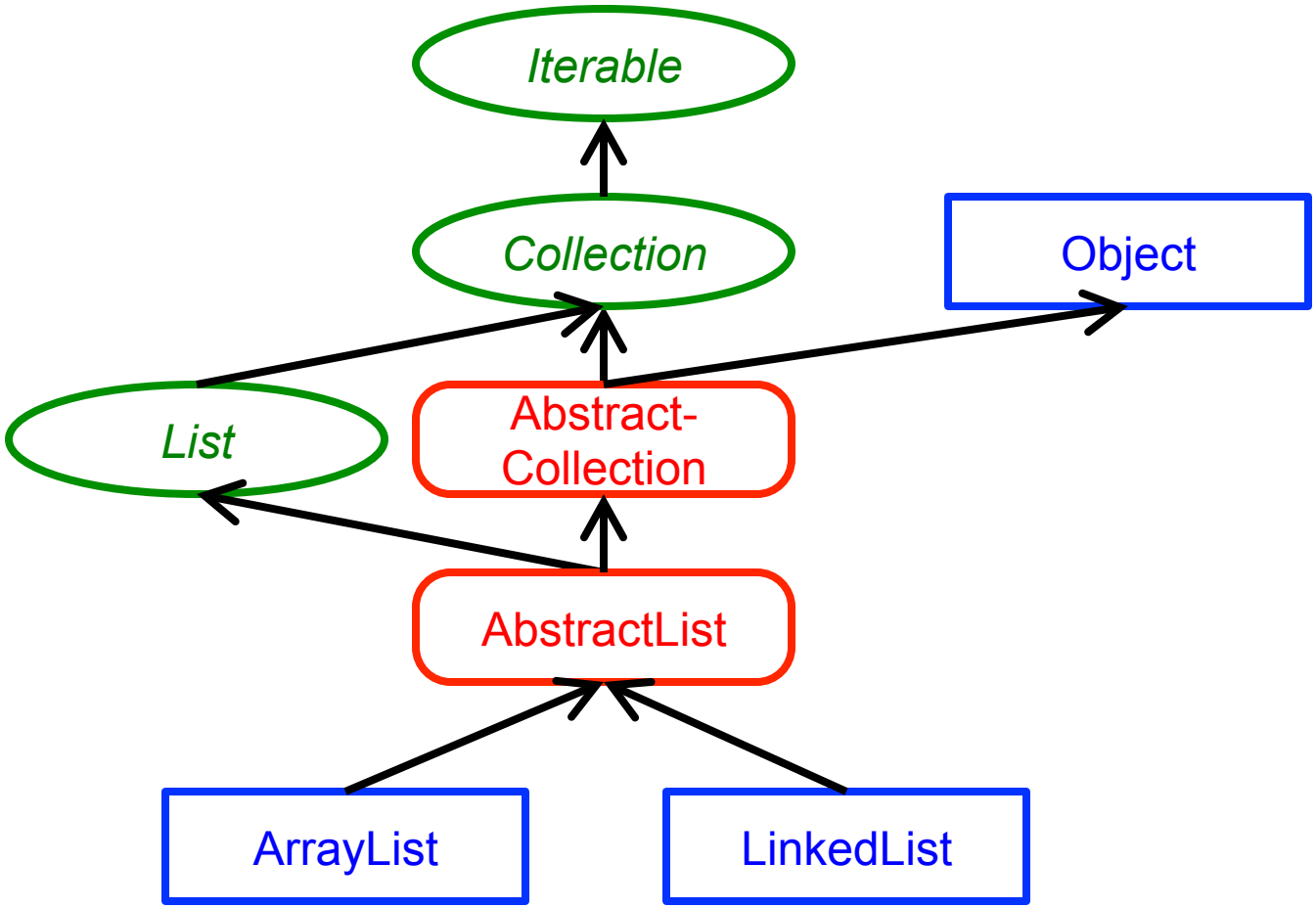
- Uses ***hashing*** in the `Set` representation
- Has code for these methods (overriding those in `AbstractSet`):
  - `add`
  - `remove`
  - `clear`
  - `clone`

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`)

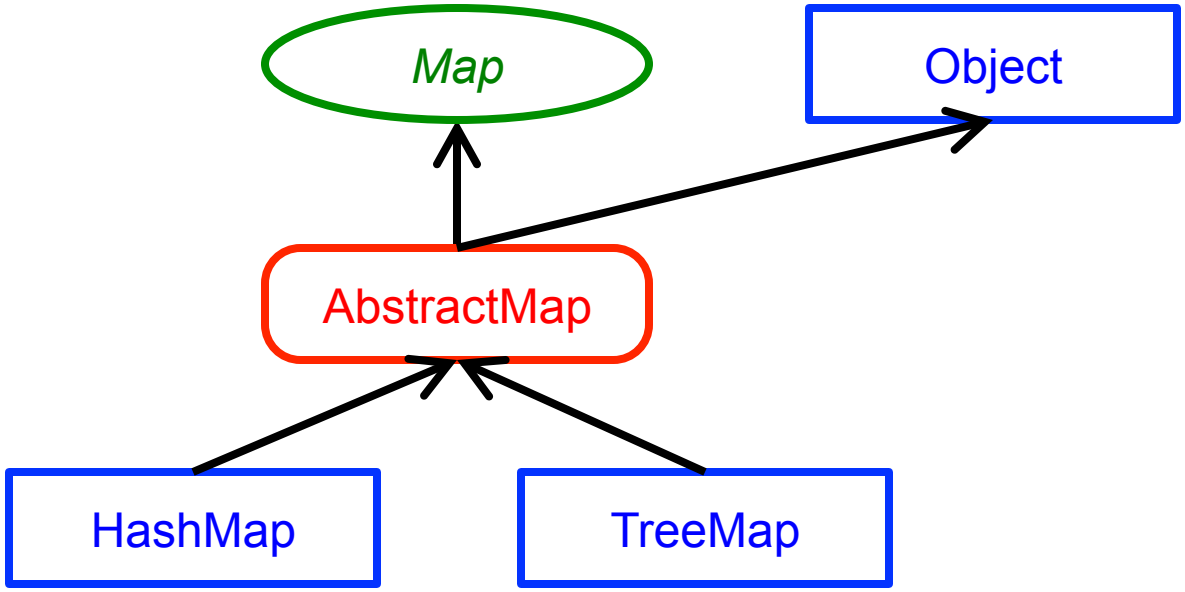
`ArrayList`

- 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`

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- Similar to `AbstractSet` but with code for many more methods (because `Map` has many more potentially layered methods than `Set`)

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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`

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  - `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 requires 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 anoth

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