
Java Collections

CSE 403, Spring 2003
Software Engineering

<http://www.cs.washington.edu/education/courses/403/03sp/>

Readings and References

- "Collections", Java tutorial
- <http://java.sun.com/docs/books/tutorial/collections/index.html>

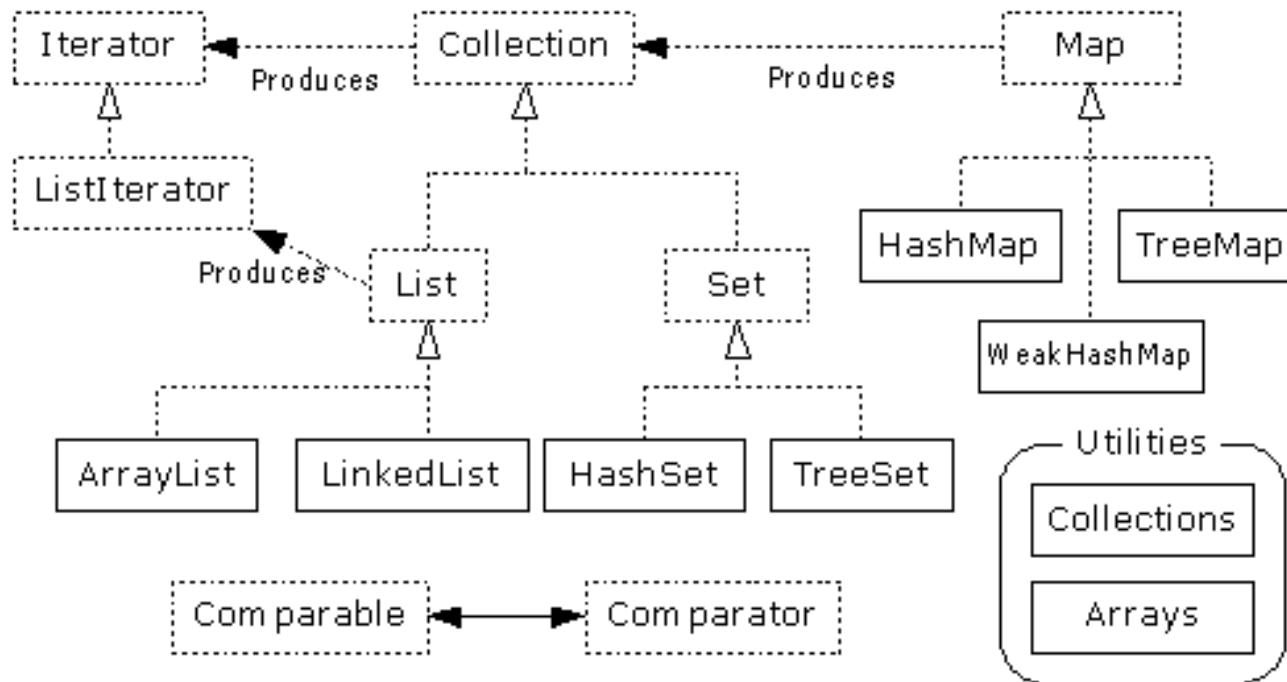
Java 2 Collections

- A collection is an object that groups multiple elements into a single unit
- Very useful
 - » store, retrieve and manipulate data
 - » transmit data from one method to another
 - » data structures and methods written by hotshots in the field
 - Joshua Bloch, who also wrote the Collections tutorial

Collections Framework

- Unified architecture for representing and manipulating collections.
- A collections framework contains three things
 - » Interfaces
 - » Implementations
 - » Algorithms

Collections Framework Diagram



- Interfaces, Implementations, and Algorithms
- From Thinking in Java, page 462

Collection Interface

- Defines fundamental methods
 - » `int size();`
 - » `boolean isEmpty();`
 - » `boolean contains(Object element);`
 - » `boolean add(Object element); // Optional`
 - » `boolean remove(Object element); // Optional`
 - » `Iterator iterator();`
- These methods are enough to define the basic behavior of a collection
- Provides an Iterator to step through the elements in the Collection

Iterator Interface

- Defines three fundamental methods
 - » `Object next()`
 - » `boolean hasNext()`
 - » `void remove()`
- These three methods provide access to the contents of the collection
- An Iterator knows position within collection
- Each call to `next()` “reads” an element from the collection
 - » Then you can use it or remove it

Iterator Position

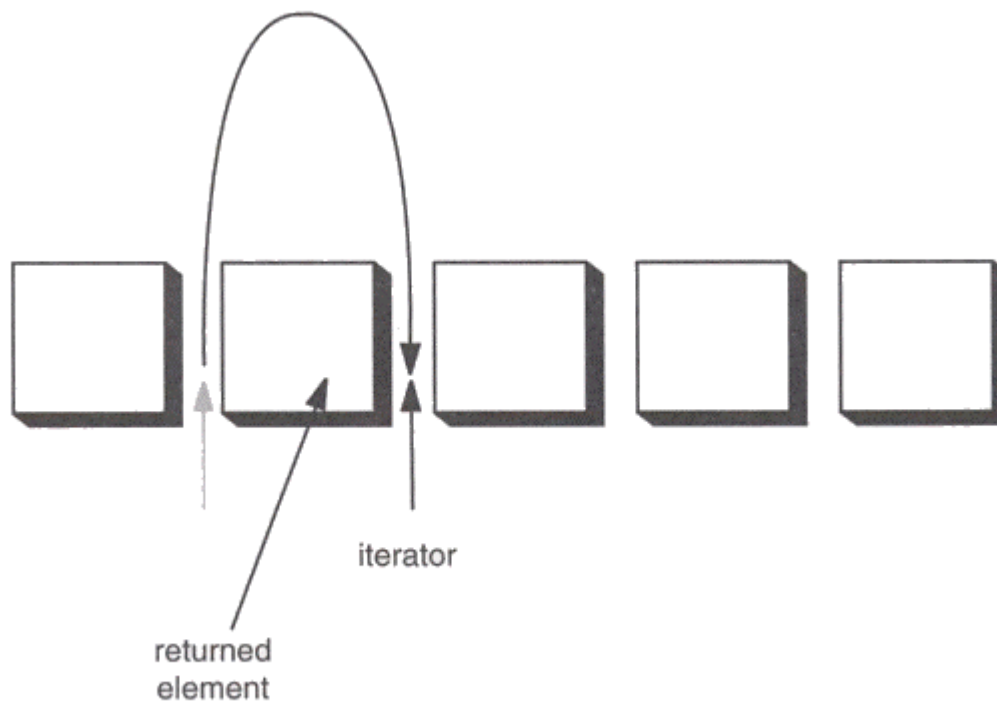
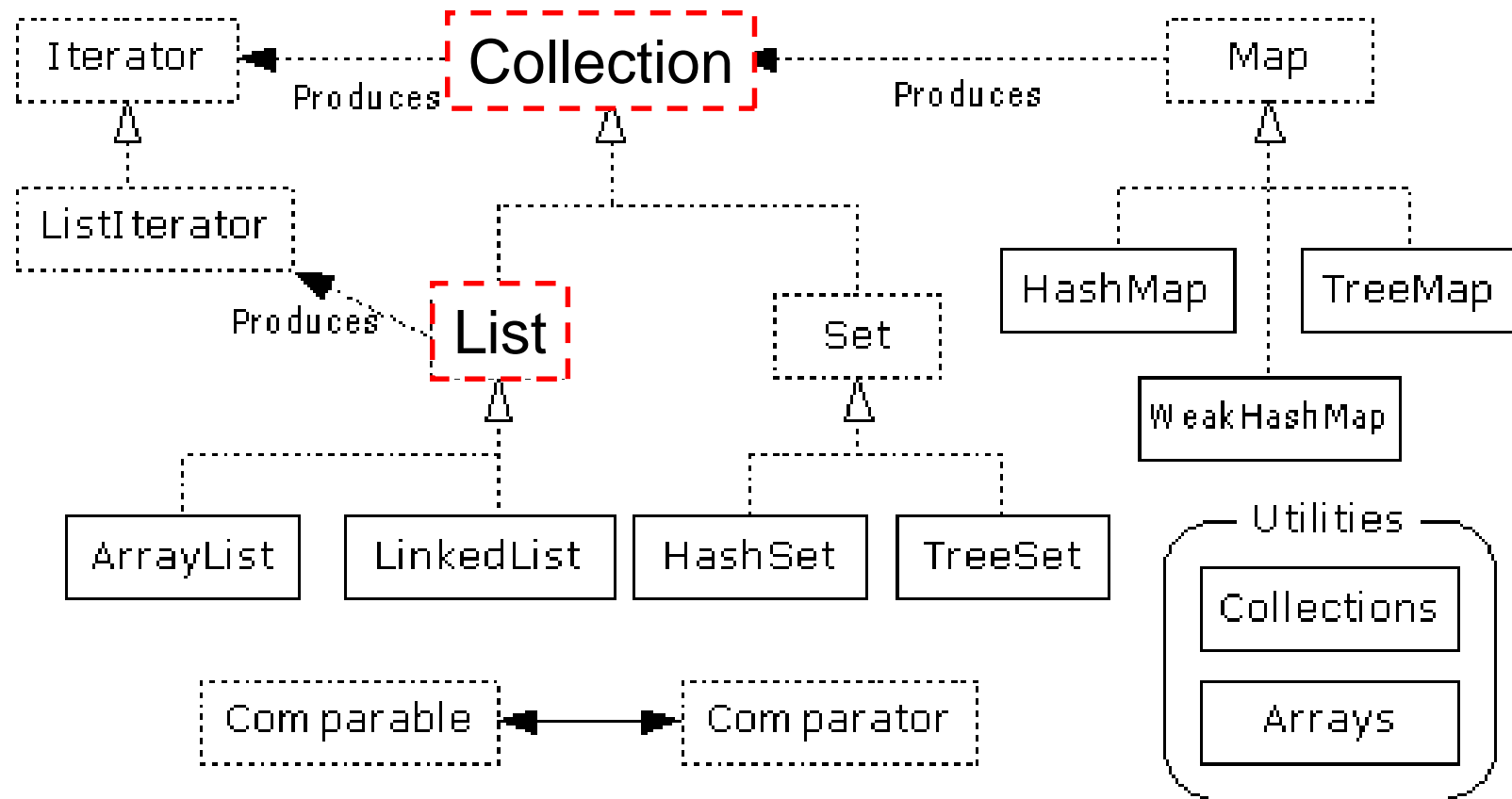


Figure 2-3: Advancing an iterator

Example - SimpleCollection

```
public class SimpleCollection {
    public static void main(String[] args) {
        Collection c;
        c = new ArrayList();
        System.out.println(c.getClass().getName());
        for (int i=1; i <= 10; i++) {
            c.add(i + " * " + i + " = "+i*i);
        }
        Iterator iter = c.iterator();
        while (iter.hasNext())
            System.out.println(iter.next());
    }
}
```

List Interface Context



List Interface

- The List interface adds the notion of *order* to a collection
- The user of a list has control over where an element is added in the collection
- Lists typically allow *duplicate* elements
- Provides a ListIterator to step through the elements in the list.

ListIterator Interface

- Extends the Iterator interface
- Defines three fundamental methods
 - » `void add(Object o)` - before current position
 - » `boolean hasPrevious()`
 - » `Object previous()`
- The addition of these three methods defines the basic behavior of an ordered list
- A ListIterator knows position within list

Iterator Position - `next()`, `previous()`

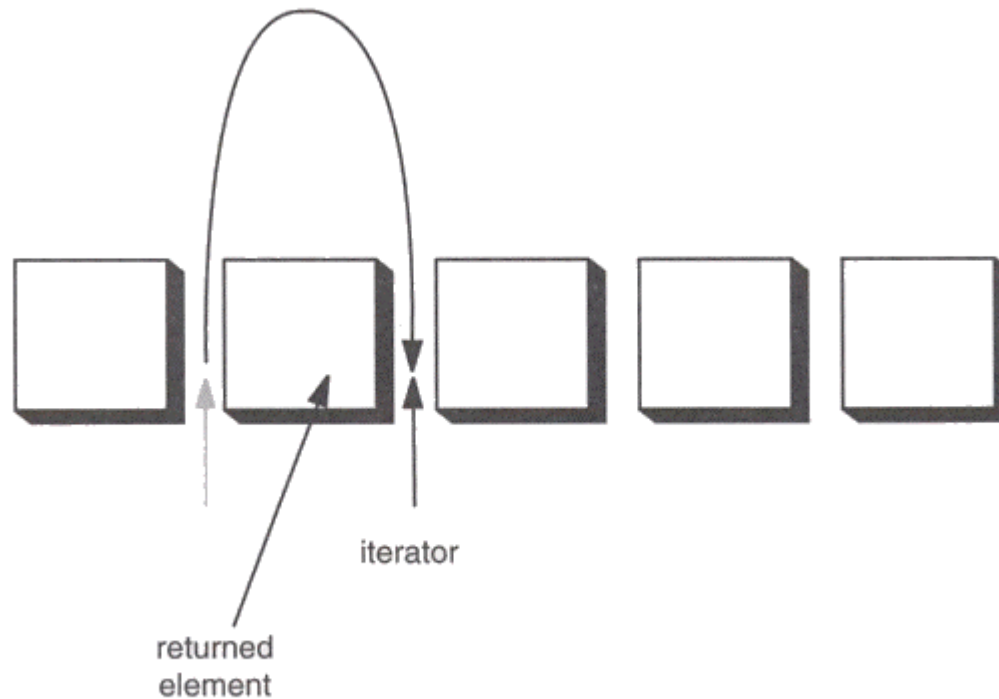
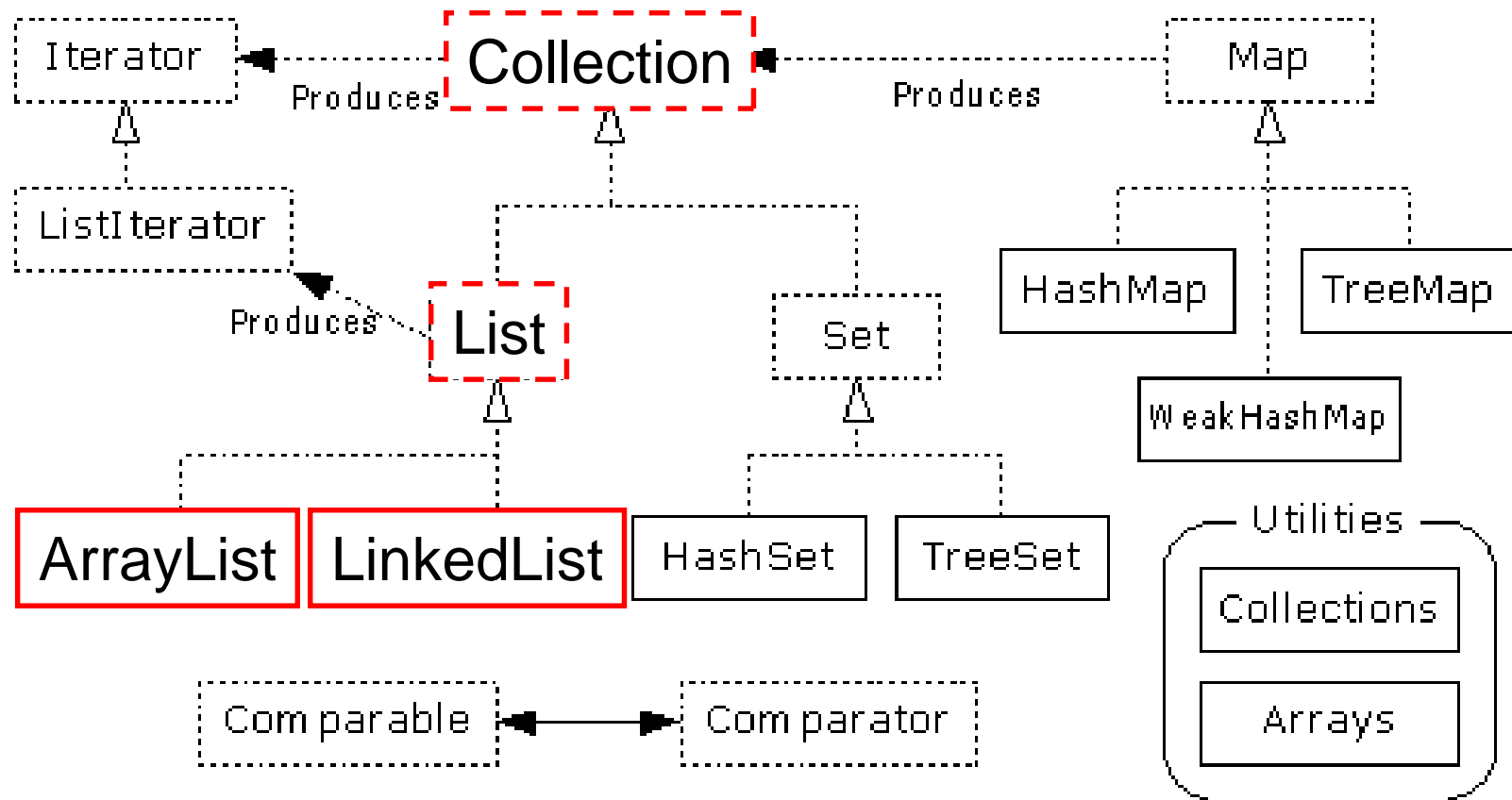


Figure 2-3: Advancing an iterator

ArrayList and LinkedList Context



List Implementations

- ArrayList
 - » low cost random access
 - » high cost insert and delete
 - » array that resizes if need be
- LinkedList
 - » sequential access
 - » low cost insert and delete
 - » high cost random access

ArrayList overview

- Constant time positional access (it's an array)
- One tuning parameter, the initial capacity

```
public ArrayList(int initialCapacity) {  
    super();  
    if (initialCapacity < 0)  
        throw new IllegalArgumentException(  
            "Illegal Capacity: "+initialCapacity);  
    this.elementData = new Object[initialCapacity];  
}
```


ArrayList methods

- The indexed get and set methods of the List interface are appropriate to use since ArrayLists are backed by an array
 - » `Object get(int index)`
 - » `Object set(int index, Object element)`
- Indexed add and remove are provided, but can be costly if used frequently
 - » `void add(int index, Object element)`
 - » `Object remove(int index)`
- May want to resize in one shot if adding many elements
 - » `void ensureCapacity(int minCapacity)`

LinkedList overview

- Stores each element in a node
- Each node stores a link to the next and previous nodes
- Insertion and removal are inexpensive
 - » just update the links in the surrounding nodes
- Linear traversal is inexpensive
- Random access is expensive
 - » Start from beginning or end and traverse each node while counting

LinkedList entries

```
private static class Entry {
    Object element;
    Entry next;
    Entry previous;

    Entry(Object element, Entry next, Entry previous) {
        this.element = element;
        this.next = next;
        this.previous = previous;
    }
}

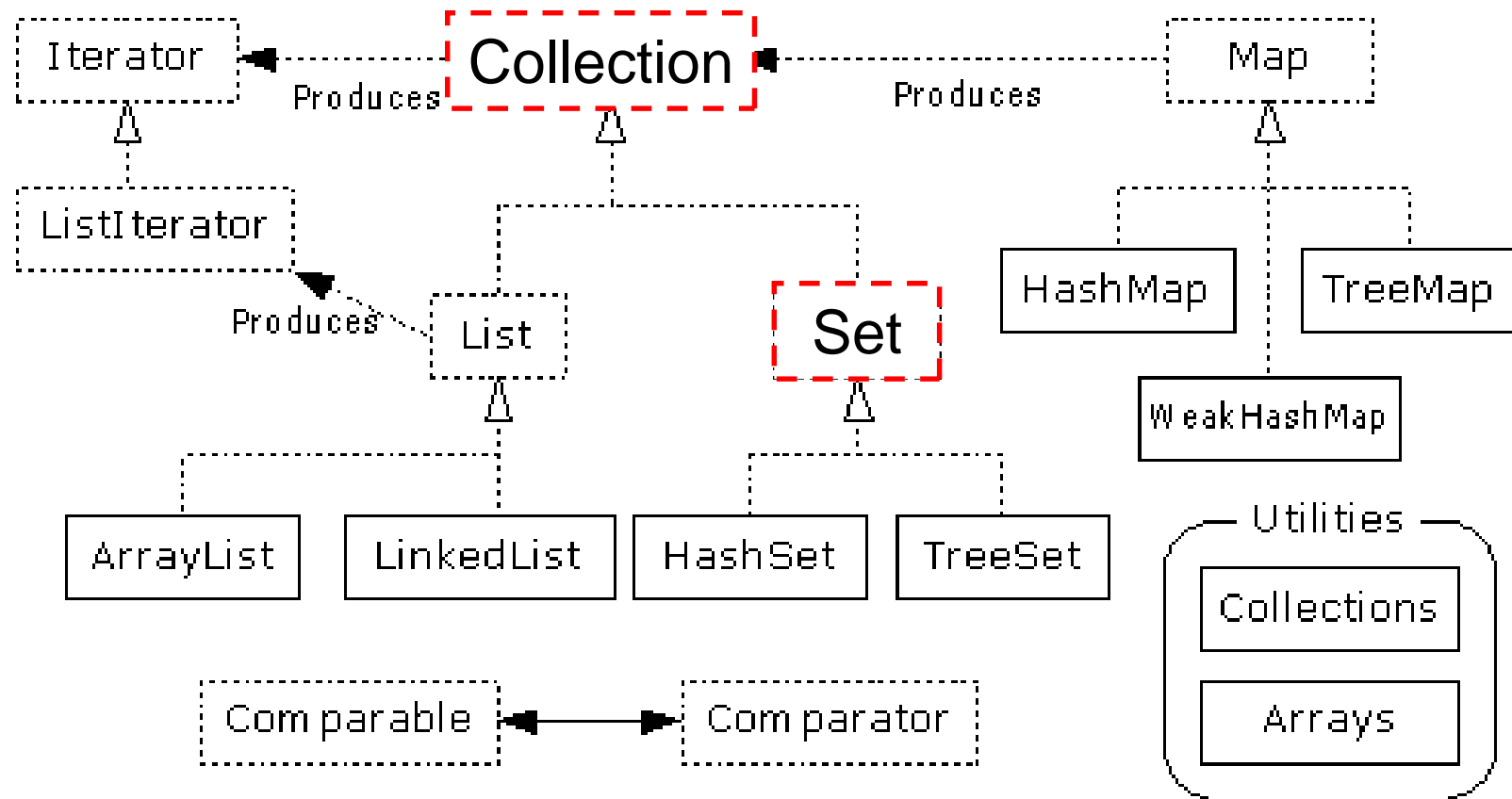
private Entry header = new Entry(null, null, null);

public LinkedList() {
    header.next = header.previous = header;
}
```

LinkedList methods

- The list is sequential, so access it that way
 - » `ListIterator listIterator()`
- ListIterator knows about position
 - » use `add()` from ListIterator to add at a position
 - » use `remove()` from ListIterator to remove at a position
- LinkedList knows a few things too
 - » `void addFirst(Object o), void addLast(Object o)`
 - » `Object getFirst(), Object getLast()`
 - » `Object removeFirst(), Object removeLast()`

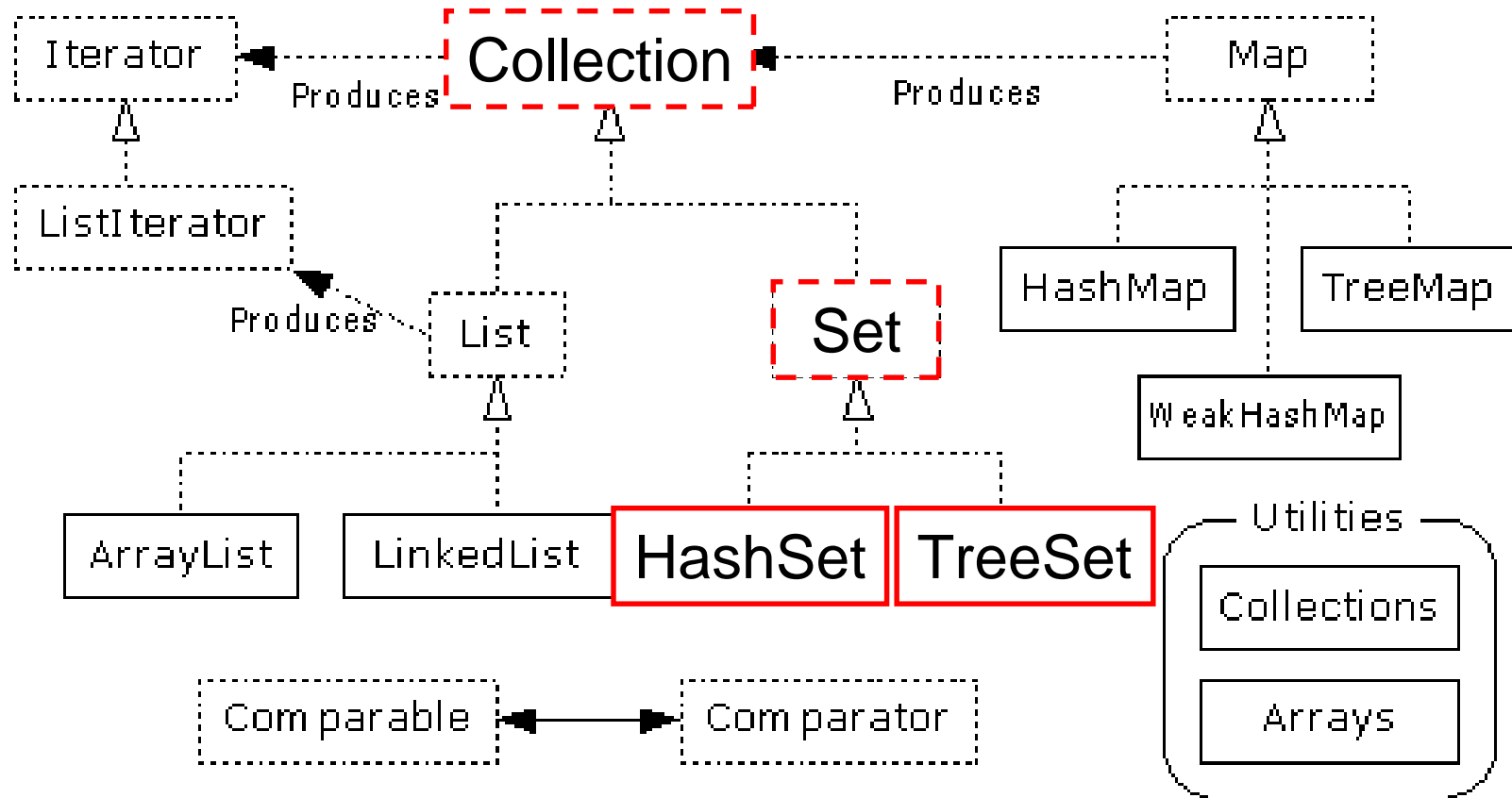
Set Interface Context



Set Interface

- Same methods as Collection
 - » different contract - no duplicate entries
- Defines two fundamental methods
 - » `boolean add(Object o)` - reject duplicates
 - » `Iterator iterator()`
- Provides an Iterator to step through the elements in the Set
 - » No guaranteed order in the basic Set interface
 - » There is a SortedSet interface that extends Set

HashSet and TreeSet Context



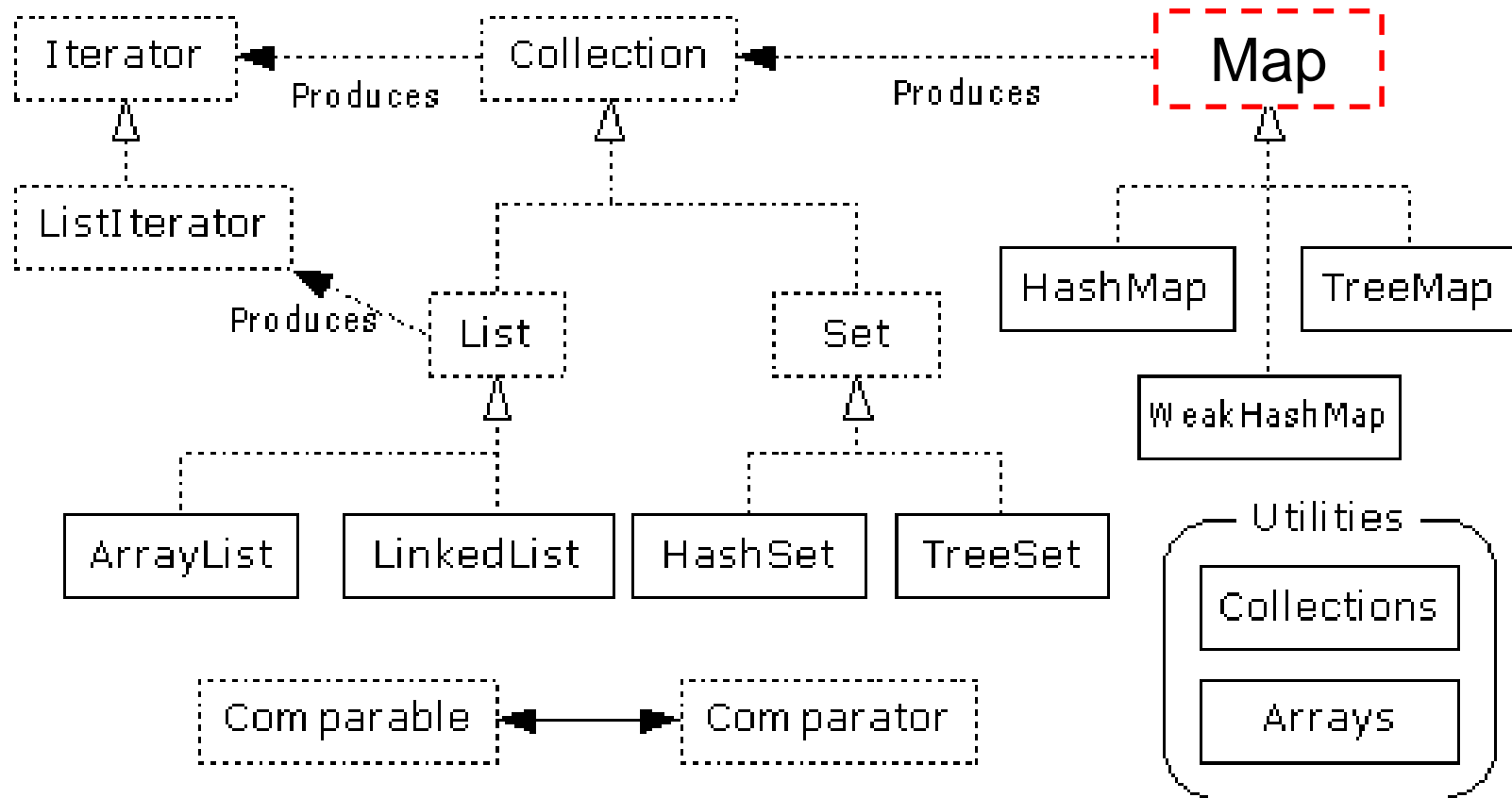
HashSet

- Find and add elements very quickly
 - » uses hashing implementation in HashMap
- Hashing uses an array of linked lists
 - » The **hashCode()** is used to index into the array
 - » Then **equals()** is used to determine if element is in the (short) list of elements at that index
- No order imposed on elements
- The **hashCode()** method and the **equals()** method must be compatible
 - » if two objects are equal, they must have the same **hashCode()** value

TreeSet

- Elements can be inserted in any order
- The TreeSet stores them in order
 - » Red-Black Trees out of Cormen-Leiserson-Rivest
- An iterator always presents them in order
- Default order is defined by natural order
 - » objects implement the Comparable interface
 - » TreeSet uses **compareTo(Object o)** to sort
- Can use a different Comparator
 - » provide Comparator to the TreeSet constructor

Map Interface Context



Map Interface

- Stores key/value pairs
- Maps from the key to the value
- Keys are unique
 - » a single key only appears once in the Map
 - » a key can map to only one value
- Values do not have to be unique

Map methods

`Object put(Object key, Object value)`

`Object get(Object key)`

`Object remove(Object key)`

`boolean containsKey(Object key)`

`boolean containsValue(Object value)`

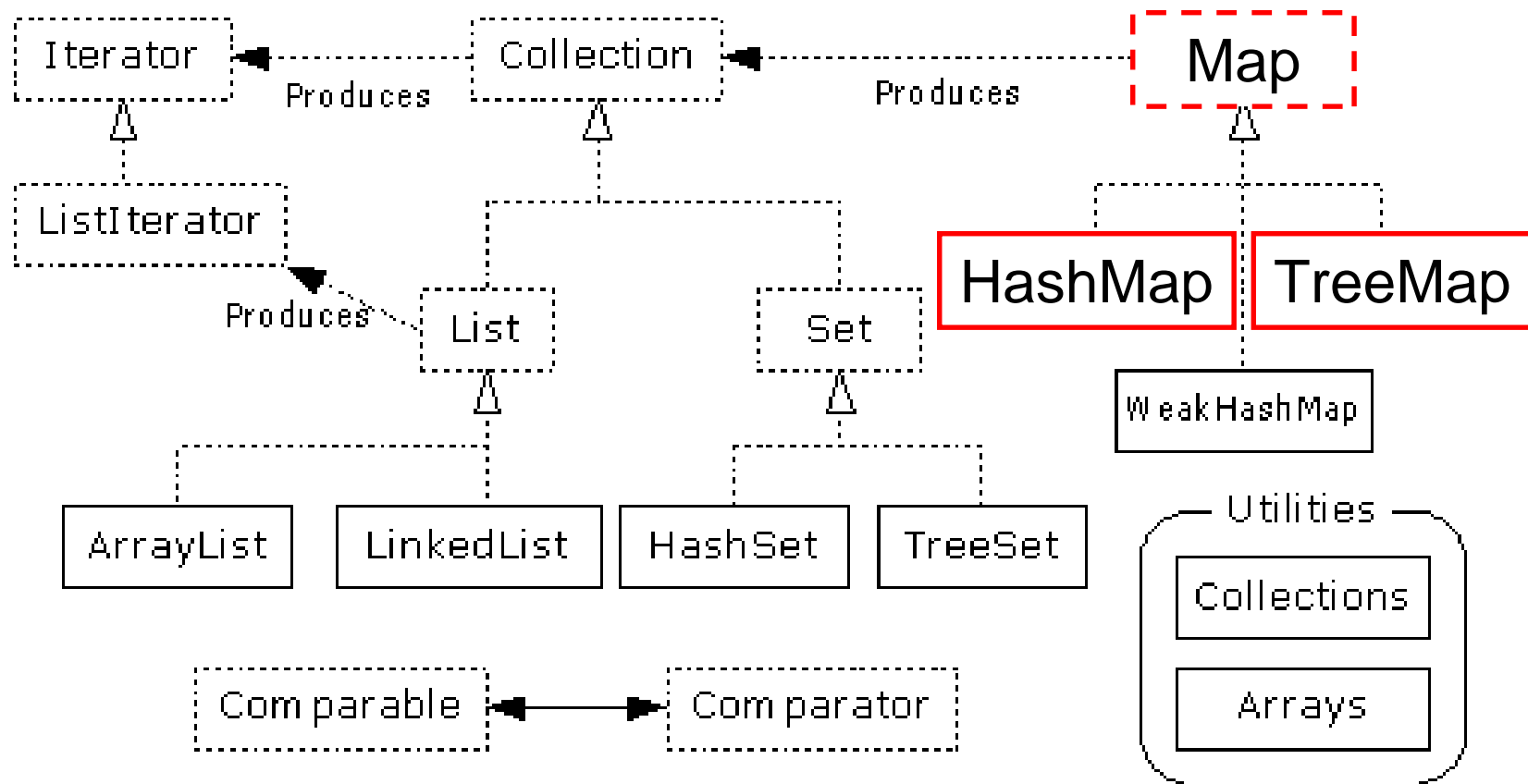
`int size()`

`boolean isEmpty()`

Map views

- A means of iterating over the keys and values in a Map
- **Set keySet()**
 - » returns the Set of keys contained in the Map
- **Collection values()**
 - » returns the Collection of values contained in the Map. This Collection is not a Set, as multiple keys can map to the same value.
- **Set entrySet()**
 - » returns the Set of key-value pairs contained in the Map. The Map interface provides a small nested interface called Map.Entry that is the type of the elements in this Set.

HashMap and TreeMap Context



HashMap and TreeMap

- HashMap
 - » The keys are a set - unique, unordered
 - » Fast

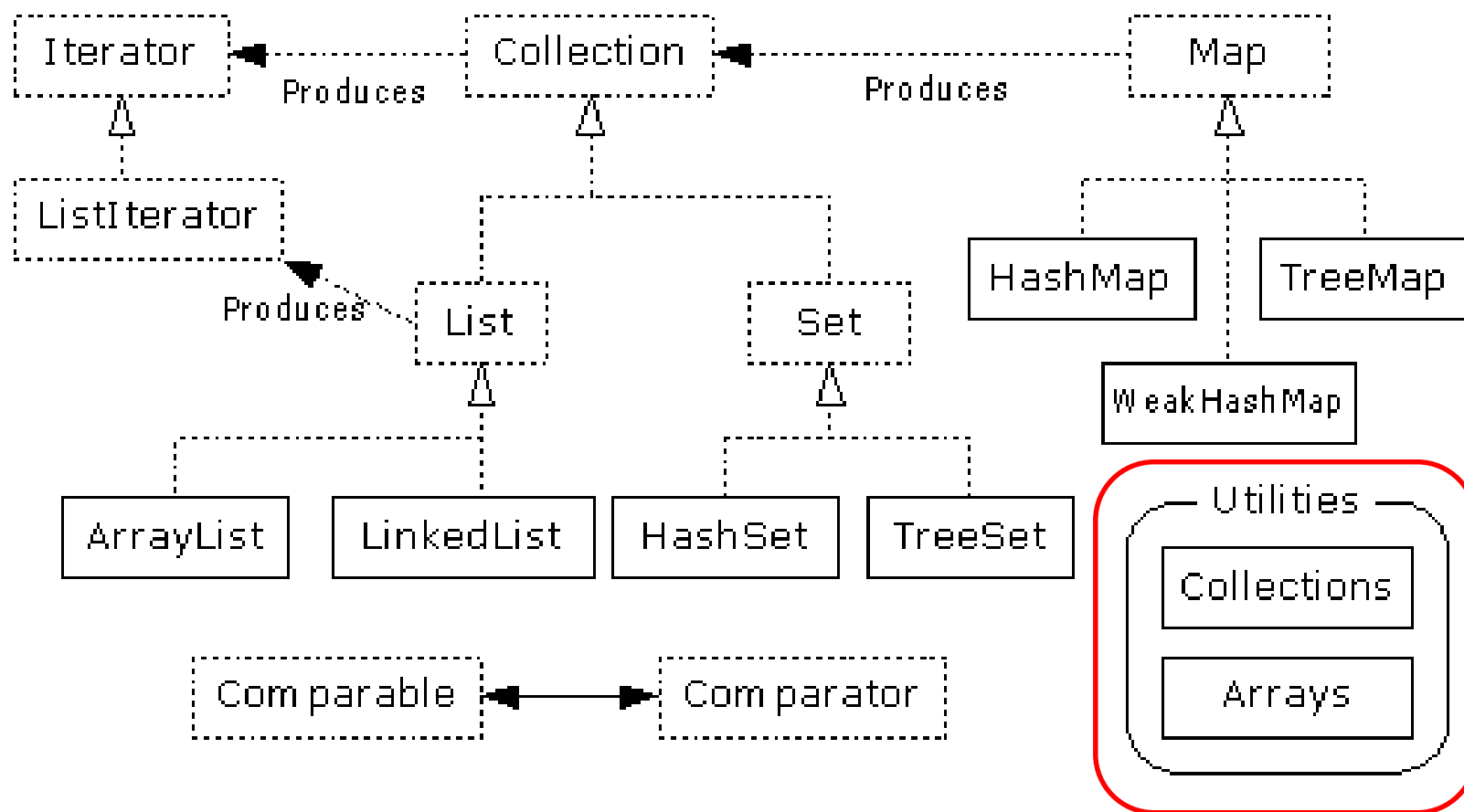
- TreeMap
 - » The keys are a set - unique, ordered
 - » Same options for ordering as a TreeSet
 - *Natural order (Comparable, compareTo(Object))*
 - *Special order (Comparator, compare(Object, Object))*

Bulk Operations

- In addition to the basic operations, a Collection may provide “bulk” operations

```
boolean containsAll(Collection c);  
boolean addAll(Collection c);    // Optional  
boolean removeAll(Collection c); // Optional  
boolean retainAll(Collection c); // Optional  
void clear();                   // Optional  
Object[] toArray();  
Object[] toArray(Object a[]);
```


Utilities Context



Utilities

- The Collections class provides a number of static methods for fundamental algorithms
- Most operate on Lists, some on all Collections
 - » Sort, Search, Shuffle
 - » Reverse, fill, copy
 - » Min, max
- Wrappers
 - » synchronized Collections, Lists, Sets, etc
 - » unmodifiable Collections, Lists, Sets, etc

Appendix

Legacy classes

- Still available
- Don't use for new development
 - » unless you have to, eg, J2ME, J2EE in some cases
- Retrofitted into Collections framework
- Hashtable
 - » use HashMap
- Enumeration
 - » use Collections and Iterators
 - » if needed, can get an Enumeration with `Collections.enumeration(Collection c)`

More Legacy classes

- Vector
 - » use ArrayList
- Stack
 - » use LinkedList
- BitSet
 - » use ArrayList of boolean, unless you can't stand the thought of the wasted space
- Properties
 - » legacies are sometimes hard to walk away from ...
 - » see next few pages

Properties class

- Located in `java.util` package
- Special case of `Hashtable`
 - » Keys and values are `Strings`
 - » Tables can be saved to/loaded from file

System properties

- Java VM maintains set of properties that define system environment
 - » Set when VM is initialized
 - » Includes information about current user, VM version, Java environment, and OS configuration

```
Properties prop = System.getProperties();
Enumeration e = prop.propertyNames();
while (e.hasMoreElements()) {
    String key = (String) e.nextElement();
    System.out.println(key + " value is " +
        prop.getProperty(key));
}
```