Java Collections Framework (JCF)

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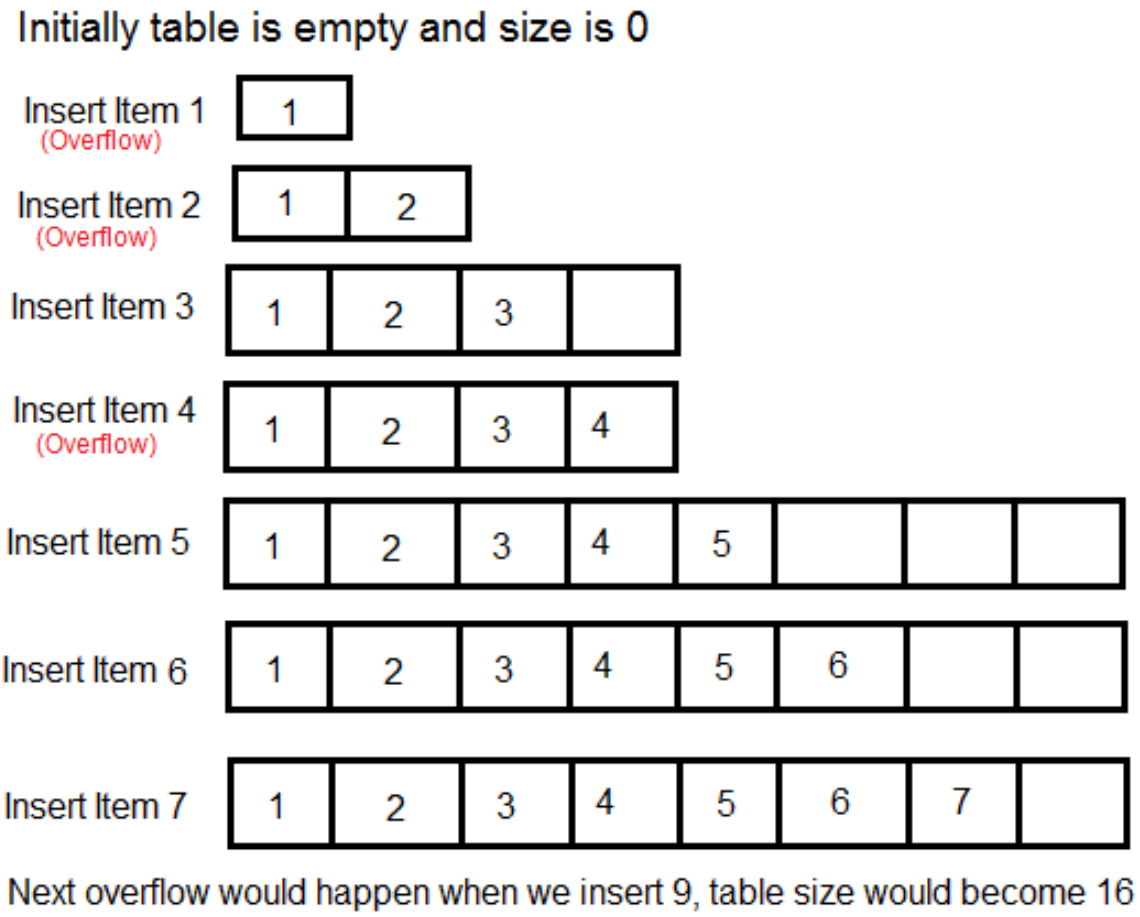
Framework

- The Java collections framework (JCF) is a set of classes and interfaces that implement commonly reusable collection data structures. The JCF provides both interfaces that define various collections and classes that implement them.
  - Interfaces (Abstract Data Types)
  - Implementations (of ADT)
  - Algorithms
  - java.util.*

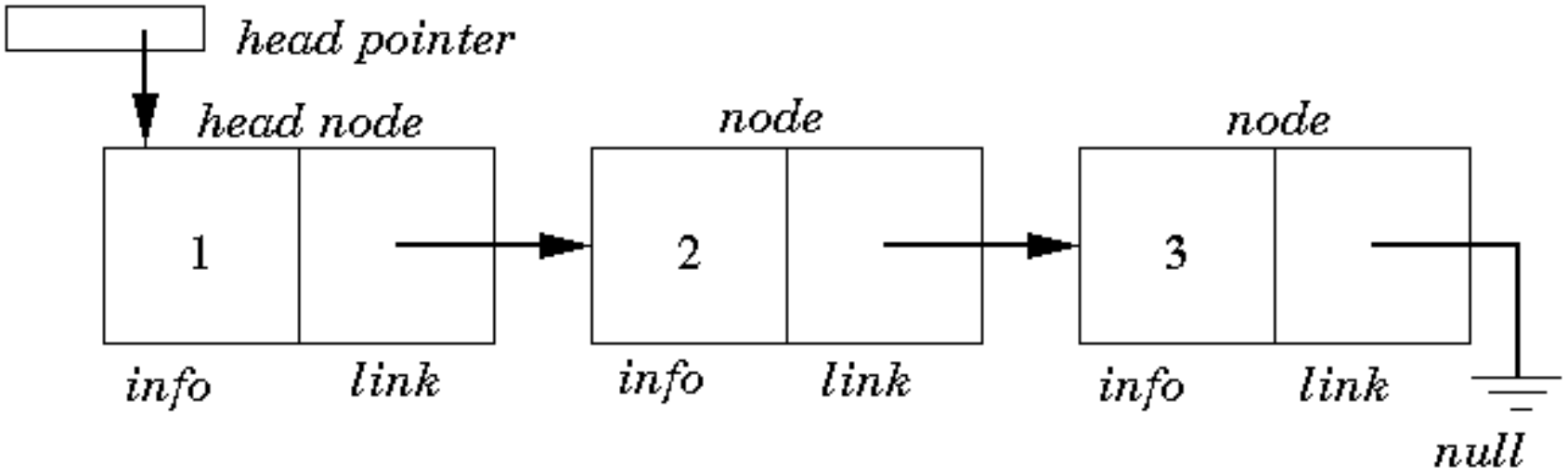
Requisites

- Resizable Array
- Linked List
- Balanced Tree
- Hash Table

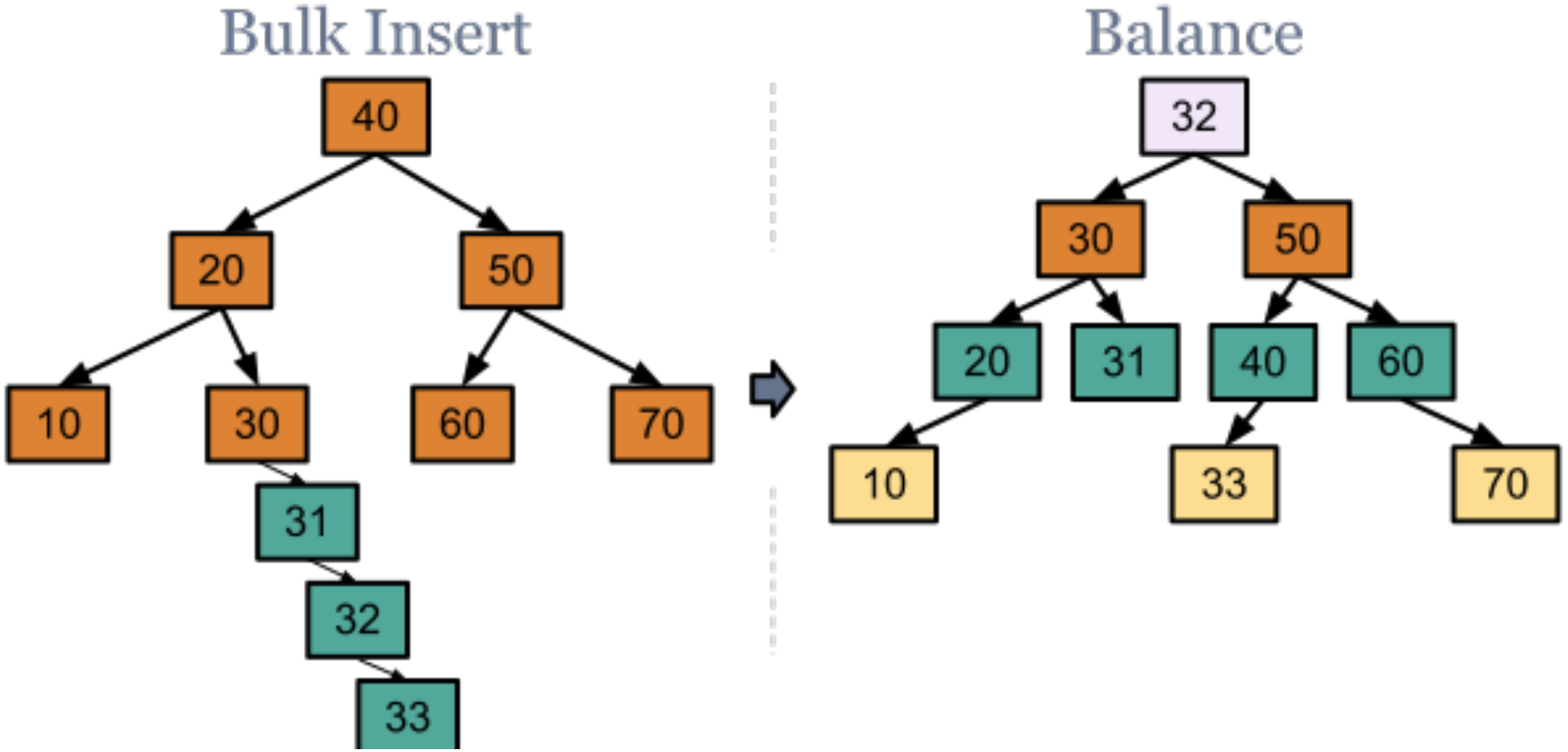
Resizable Array



Linked List


head pointer
head node
node
node
1
2
3
info
link
info
link
info
link
null

Balanced Tree



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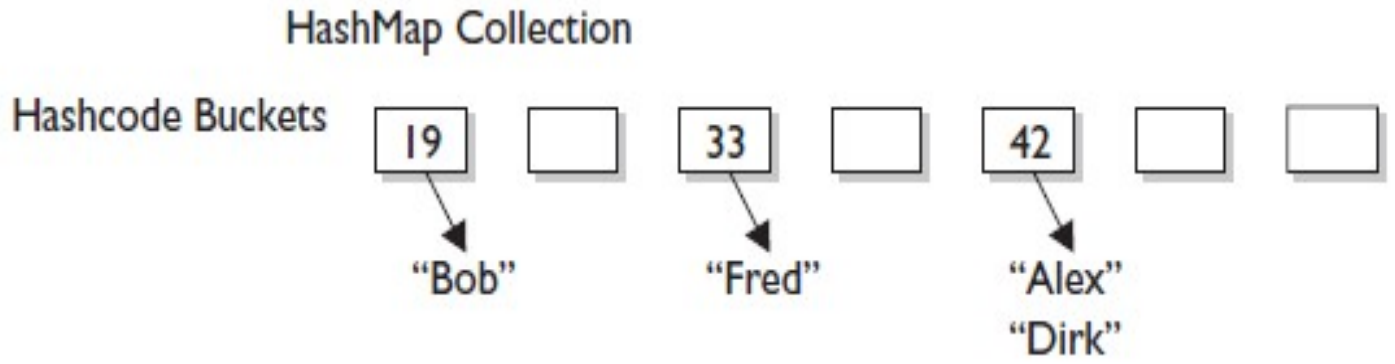
Hash Table

Alex	A(1) + L(12) + E(5) + X(24)	= 42
Bob	B(2) + O(15) + B(2)	= 19
Dirk	D(4) + I(9) + R(18) + K(11)	= 42
Fred	F(6) + R(18) + E(5) + (D)	= 33



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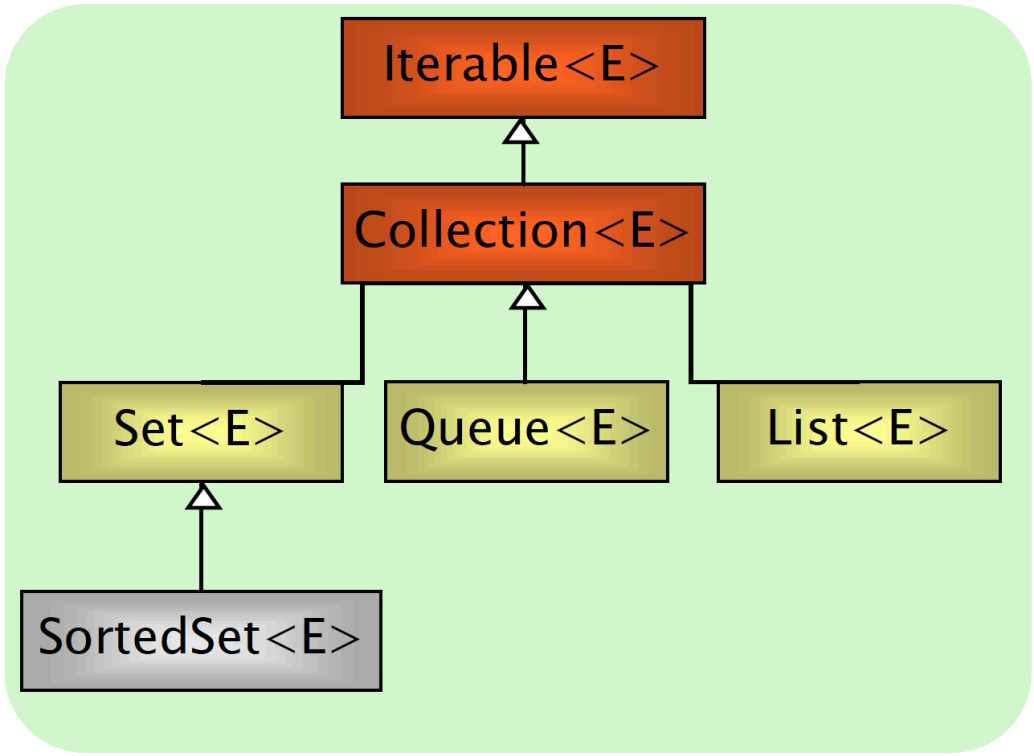
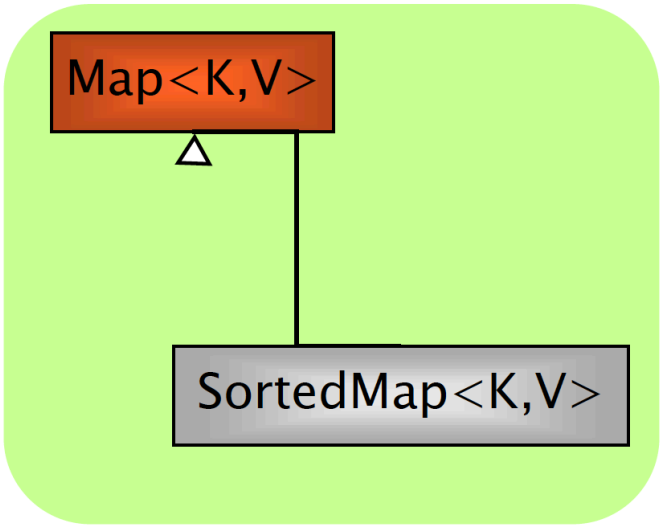
Interfaces



Group containers



Associative containers

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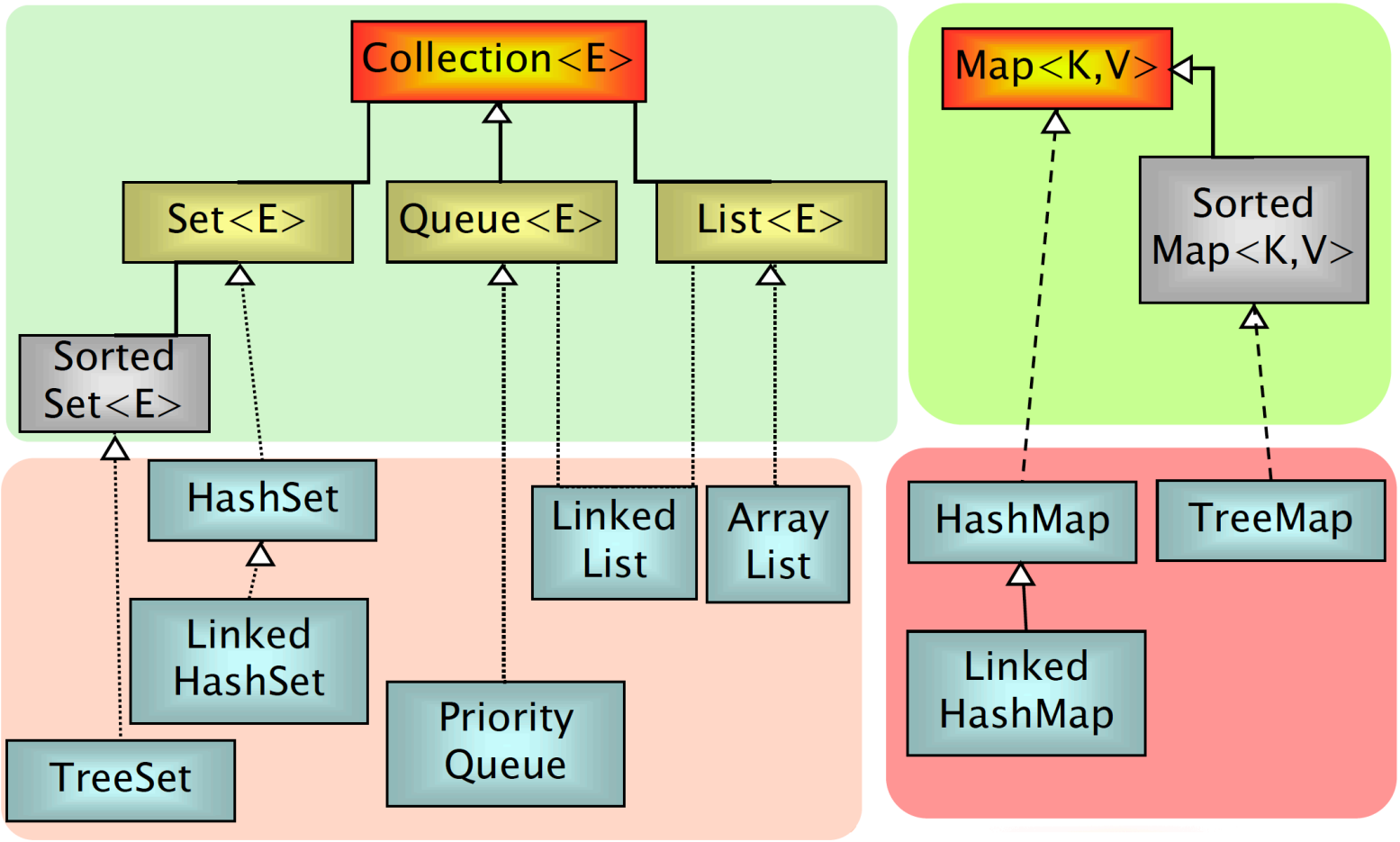
Implementations



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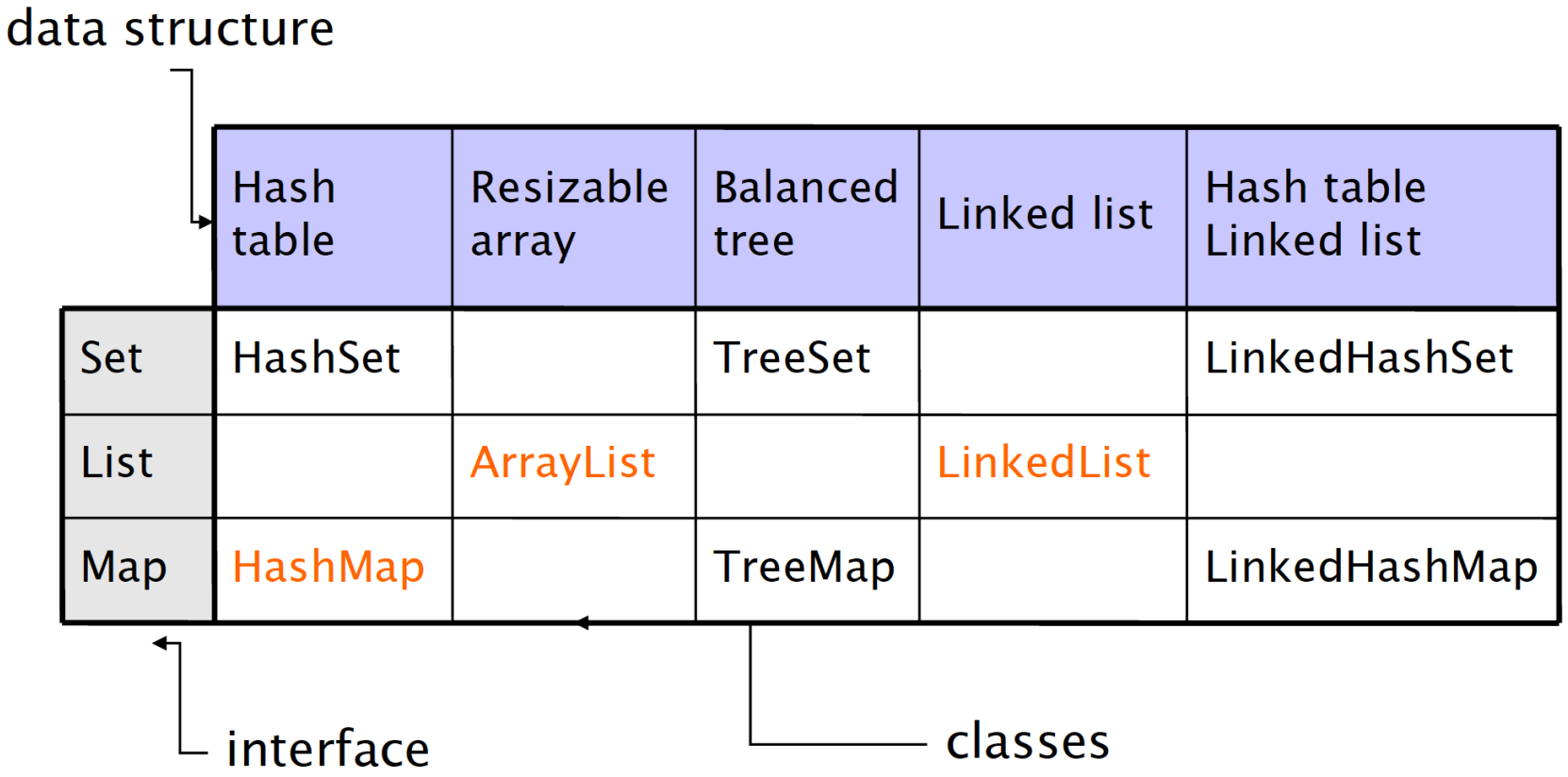
Internals


data structure
Hash table
Resizable array
Balanced tree
Linked list
Hash table Linked list
Set
HashSet
TreeSet
LinkedHashSet
List
ArrayList
LinkedList
Map
HashMap
TreeMap
LinkedHashMap
interface
classes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Iterable Interface

- The Iterable interface (java.lang.Iterable) is the root interface of the Java collection framework. The Collection interface extends Iterable, so all subtypes of Collection also implement the Iterable interface.
- Iterarable, literally, means that “can be iterated”. From a technical perspective, it means that an Iterator can be returned.
- Iterable objects can be used with the new for-loop:

```
List list = new ArrayList();
for(Object o : list){
    //do something;
}
```

- The Iterable interface has only one method:

```
public interface Iterable<T> {
  public Iterator<T> iterator();
}
```

Iterator Interface

- `boolean hasNext()`
- `object next()`
- `void remove()`

Collection Interface

- Group of elements (references to objects)
- It is not specified whether they are
  - Ordered / not ordered
  - Duplicated / not duplicated
- Following constructors are common to all classes implementing Collection
  - T()
  - T(Collection c)

Collection Interface

- `int size()`
- `boolean isEmpty()`
- `boolean contains(Object element)`
- `boolean containsAll(Collection c)`
- `boolean add(Object element)`
- `boolean addAll(Collection c)`
- `boolean remove(Object element)`
- `boolean removeAll(Collection c)`
- `void clear()`
- `Object[] toArray()`
- `Iterator iterator()`

Collection Examples

```
Collection<Person> p = new LinkedList<Person>();
p.add(new Person(“Alice”));
p.add(new Person(“Bob”));
System.out.println(p.size());

Collection<Person> c = new TreeSet<Person>();
c.addAll(p); // new TreeSet(persons)
Person[] array = c.toArray();
```

Map Interface

- An object that associates keys to values (e.g., Person => Phone number)
  - Keys and values must be objects
  - Keys must be unique
- Following constructors are common to all collection implementers
  - T()
  - T(Map m)

Map Interface

- `Object put(Object key, Object value)`
- `Object get(Object key)`
- `Object remove(Object key)`
- `boolean containsKey(Object key)`
- `boolean containsValue(Object value)`
- `public Set keySet()`
- `public Collection values()`
- `int size()`
- `boolean isEmpty()`
- `void clear()`

Map Examples

```
Map<String,Person> people = new HashMap<String,Person>();
people.put(“3474566867”, new Person(“Alice”, “Smith”));
people.put(“3358987278”, new Person(“Bob”, “Green”));

if people.containsKey(“3358987278”) {
    System.out.println(people.get(“3358987278”));
}

System.out.println(people.size());
```

Generic Collections

- From Java 5, all collection interfaces and classes have been redefined as Generics
- Use of generics lead to code that is
  - safer
  - more compact
  - easier to understand
  - equally performing

Generic Collections

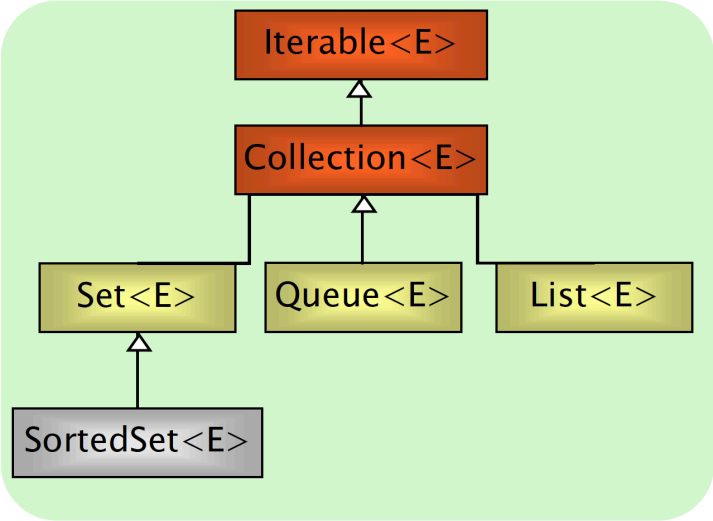
```
List l = new ArrayList<Integer>();

public interface List<E>{
    void add(E x);
    Iterator<E> iterator();
}

public interface Iterator<E>{
    E next();
    booleanhasNext();
}
```

List Interface

- Can contain duplicate elements
- Insertion order is preserved
- User can define insertion point
- Elements can be accessed by position



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List additional methods

- `Object get(int index)`
- `Object set(int index, Object element)`
- `void add(int index, Object element)`
- `Object remove(int index)`

- `boolean addAll(int index, Collection c)`
- `int indexOf(Object o)`
- `int lastIndexOf(Object o)`
- `List subList(int fromIndex, int toIndex)`

List Implementations

- ArrayList
  - Get(n) -> Constant time
  - Insert (beginning) -> Linear time
- LinkedList
  - Get(n) -> Linear time
  - Insert (beginning) -> Constant time

ArrayList Example

```
List<Car> garage = new ArrayList<Car>(20);
garage.add(new Car());
garage.add(new ElectricCar());
garage.add(new ElectricCar());
garage.add(new Car());
for(int i; i < garage.size(); i++){
   Car c = garage.get(i);
   c.turnOn();
}
```

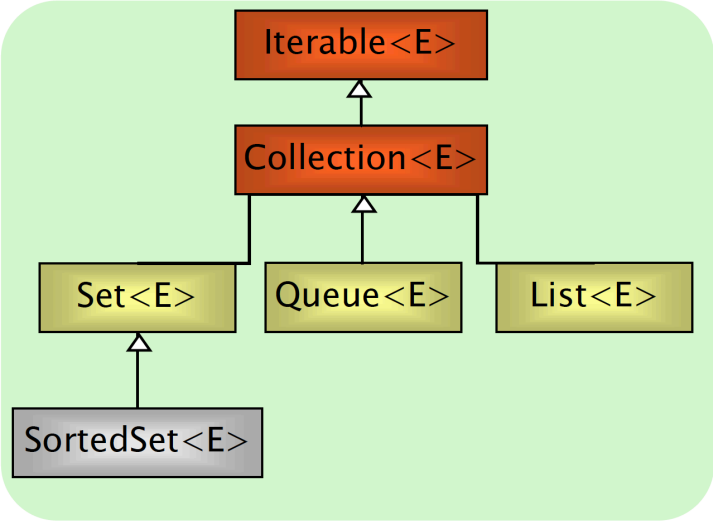
LinkedList Example

```
List<Car> garage = new LinkedList<Car>();
garage.add(new Car());
garage.add(new ElectricCar());

garage.addFirst(new ElectricCar());
garage.addLast(new ElectricCar());
garage.getfirst();
garage.getLast();
garage.removeFirst();
garage.removeLast();
```

Queue Interface

- Collection whose elements have an order (not and ordered collection though)
- Defines a head (first element) and a tail (last element)
  - **peek()**
  - **poll()**



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Queue Implementations

- LinkedList
  - head is the first element of the list
  - FIFO internal policy: Fist-In-First-Out
- PriorityQueue
  - head is the smallest element

Queue Example

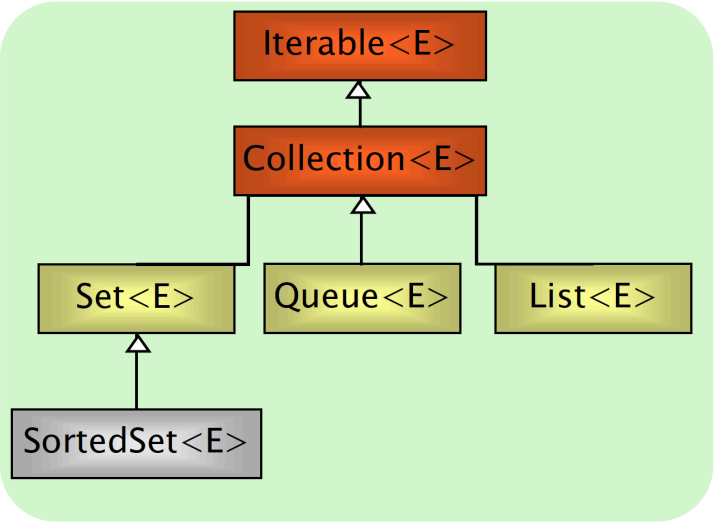
```
Queue<Integer> fifo = new LinkedList<Integer>();
Queue<Integer> pq = new PriorityQueue<Integer>();

fifo.add(3); pq.add(3);
fifo.add(1); pq.add(1);
fifo.add(2); pq.add(2);

System.out.println(fifo.peek()); // 3
System.out.println(pq.peek());   // 1
```

Set Interface

- Contains no methods other than those inherited from Collection
- **add()** has restriction that no duplicate elements are allowed
- **Iterator**: the elements are traversed in no particular order



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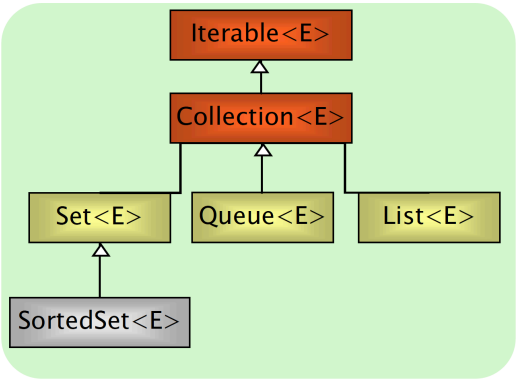
SortedSet Interface

- No duplicate elements
- Iterator
  - The elements are traversed according to the natural ordering(ascending)
- Augments Set interface
  - `Object first()`
  - `Object last()`
  - `SortedSet headSet(Object toElement)`
  - `SortedSet tailSet(Object fromElement)`
  - `SortedSet subSet(Object from, Object to)`



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Set Implementations

- HashSet implements Set
  - Hash tables as internal data structure (fast!)
  - No order
- LinkedHashSet extends HashSet
  - Insertion order
- TreeSet implements SortedSet
  - R-B trees as internal data structure (slow!)
  - Natural (ascending) order

Set Implementations

- Depending on the constructor used, SortedSet implementations can use different orderings
- TreeSet()
  - Natural ordering (elements must implement the Comparable Interface)
- TreeSet(Comparator c)
  - Ordering is according to the comparator rules, instead of natural ordering

Set Example I

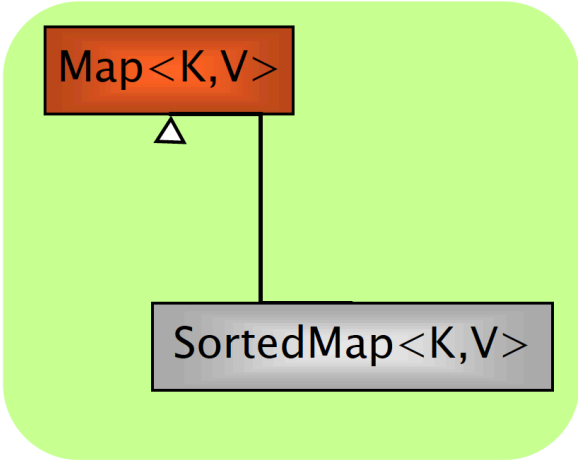
```
Set setA = new HashSet();

setA.add("element 0");
setA.add("element 1");
setA.add("element 2");

// access via Iterator
Iterator iterator = setA.iterator();
while(iterator.hasNext(){
  String element = (String) iterator.next();
}

// access via new for-loop
for(Object object : setA) {
    String element = (String) object;
}
```

Set Example II

```
ArrayList<String> l = new ArrayList<String>();
ArrayList<String> lHashSet = new ArrayList<String>();
ArrayList<String> lLinkedHashSet = new ArrayList<String>();
ArrayList<String> lTreeSet = new ArrayList<String>();

l.add("Nicola"); l.add("Silvia");
l.add("Marzia"); l.add("Silvia");

lHashSet.addAll(new HashSet<String>(l));
lLinkedHashSet.addAll(new LinkedHashSet<String>(l));
lTreeSet.addAll(new TreeSet<String>(l));

System.out.println(l);
System.out.println(lLinkedHashSet);// [Nicola, Silvia, Marzia]
System.out.println(lHashSet);      // [Silvia, Marzia, Nicola]
System.out.println(lTreeSet);      // [Marzia, Nicola, Silvia]
```

Map Interface

- An object that associates keys to values (e.g., Person => Phone number)
  - Keys and values must be objects
  - Keys must be unique



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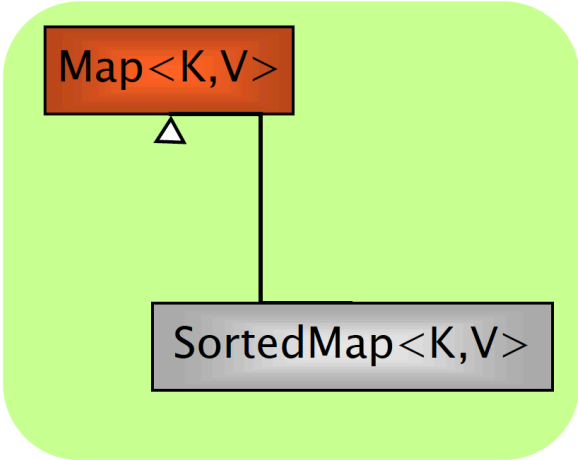
SortedMap Interface

- …



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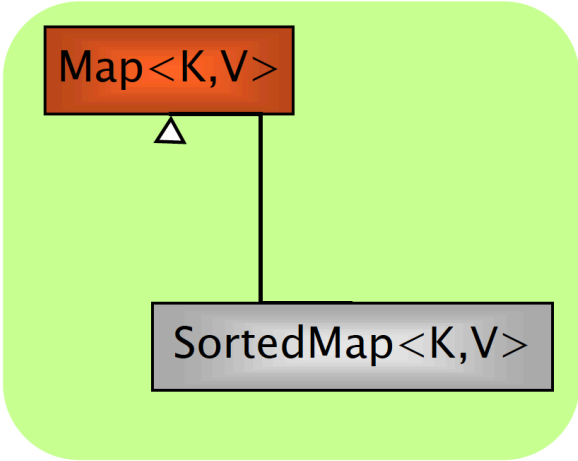
Map Implementations

- Similar to Set



- HashMap implements Map
  - No order
- LinkedHashMap extends HashMap
  - Insertion order
- TreeMap implements SortedMap
  - Natural (ascending) key order

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HashMap

- Get/set takes constant time(in case of no collisions)
- Automatic re-allocation when load factor reached
- Constructor optional arguments
  - load factor(default = .75)
  - initial capacity(default = 16)

Map Example I

```
Map<String, Integer> lhm = new LinkedHashMap<String, Integer>();

lhm.put("Silvia", 2);
lhm.put("Marzia", 3);
lhm.put("Silvia", 4);
lhm.put("Nicola", 1);

Map<String, Integer> hm = new HashMap<String, Integer>(lhm);
Map<String, Integer> tm = new TreeMap<String, Integer>(lhm);

System.out.println(lhm);   // {Silvia=4, Marzia=3, Nicola=1}
System.out.println(hm);    // {Silvia=4, Nicola=1, Marzia=3}
System.out.println(tm);    // {Marzia=3, Nicola=1, Silvia=4}
```

Map Example II

```
Map<String, Integer> hm = new HashMap<String, Integer>();
…
List<String> keys = hm.keySet();
for(String s : keys) {
    System.out.println(s + " -> " + hm.get(s));
}
```

Iterator

- A common operation with collections is to iterate over their elements
- Interface Iterator provides a transparent means to cycle through all elements of a Collection
- Keeps track of last visited element of the related collection
- Each time the current element is queried, it moves on automatically

Iterator Interface

- `boolean hasNext()`
- `Object next()`
- `void remove()`

ListIterator

- An iterator for lists that allows the programmer to traverse the list in either direction, modify the list during iteration, and obtain the iterator's current position in the list.
- A ListIterator has no current element; its cursor position always lies between the element that would be returned by a call to previous() and the element that would be returned by a call to next().

ListIterator Interface

- boolean hasNext()
- boolean hasPrevious()
- object next()
- object previous()
- void add()
- void set()
- void remove()
- int nextIndex()
- int previousIndex()

Iterator Example

```
List<Person> pl = new ArrayList<Person>();

/* C style */
for (int i = 0; i < pl.size; i++)
     System.out.println(pl.get(i))

/* Java style */
for (Person p : pl)
     System.out.println(p);

/* Iterator style */
for(Iterator<Person> i = pl.iterator(); i.hasNext();) {
     Person p = i.next();
     System.out.println(p);
}

/* While style */
Iterator i = pl.iterator();
while (i.hasNext())
     System.out.println((Person)i.next());
```

Caveat

- It is unsafe to iterate over a collection you are modifying (add/del) at the same time!

- Unless you are using the iterator methods
  - **Iterator.remove()**
  - **ListIterator.add()**

Caveat

```
List<Integer> l = new LinkedList<Integer>();
l.add(new Integer(10));
l.add(new Integer(11));
l.add(new Integer(13));
l.add(new Integer(20));

count = 0
for (Iterator<Integer> i = l.iterator(); itr.hasNext();){
    i.next();
    if (count++ == 1) l.remove(count);
    if (count++ == 2) l.add(new Integer(22));
    // Wrong! We modify the list while iterating
}
```

Caveat

```
List<Integer> l = new LinkedList<Integer>();
l.add(new Integer(10));
l.add(new Integer(11));
l.add(new Integer(13));
l.add(new Integer(20));

count = 0
for (Iterator<Integer> i = l.iterator(); itr.hasNext();){
    i.next();
    if (count++ == 1) i.remove();
}
```

Caveat

```
List<Integer> l = new LinkedList<Integer>();
l.add(new Integer(10));
l.add(new Integer(11));
l.add(new Integer(13));
l.add(new Integer(20));

count = 0
for (ListIterator<Integer> i = l.listIterator();
itr.hasNext();){
    i.next();
    if (count++ == 2) i.add(new Integer(22));
}
```

The Comparable Interface

```
public interface Comparable<T> {
   public int compareTo(T obj);
}
```

- Compares the receiving object with the specified object
- Return value must be:
  - < 0 if ***this*** precedes ***obj***
  - == 0 if ***this*** has the same order as ***obj***
  - > 0 if ***this*** follows ***obj***

The Comparable Interface

- The interface is implemented by language common types in packages java.lang and java.util
  - String objects are lexicographically ordered
  - Date objects are chronologically ordered
  - Number and sub-classes are ordered numerically

The Comparable Interface

Given the following class:

```
class Person {
   protected String name;
   protected String surname;
   protected Integer name;
   …
}
```

The Comparable Interface

- How to define an ordering upon Person objects according to the “natural alphabetic order”

```
class Person implements Comparable<Person> {
    protected String name;
    protected String surname;
    protected Integer name;
    …
    public int compareTo(Student s) {…}
}
```

The Comparable Interface

```
public int compareTo(Student s) {
   // order by surname
   cmp = lastName.compareTo(s.lastName);
   if(cmp == 0)
      // if equal surnames, order by name
      cmp = firstName.compareTo(s.firstName);
   return cmp;
}
```

The Comparator Interface

```
public interface Comparator<T> {
    public int compare(T o1, T o2);
}
```

- java.util
- Compares its two arguments
- Return value must be
  - < 0 if **o1** precedes **o2**
  - == 0 if **o1** has the same ordering as **o2**
  - > 0 if **o1** follows **o2**

The Comparator Interface

```
public class StudentComparator implements
Comparator<Student> {
    public int compare(Student s1, Student s2) {
        cmp = s1.lastName.compareTo(s2.lastName);
        if(cmp == 0)
            cmp = s1.firstName.compareTo(s2.firstName);
        return cmp;
    }
}
```

Algorithms

- Static methods of java.util.Collections class
  - Work on lists

- `sort()` - merge sort implementation, n log(n)
- `binarySearch()` - requires ordered sequence
- `shuffle()` - unsort
- `reverse()` - requires ordered sequence
- `rotate()` - of a given distance
- `min()`, `max()` - in a Collection