Session 08
Collections

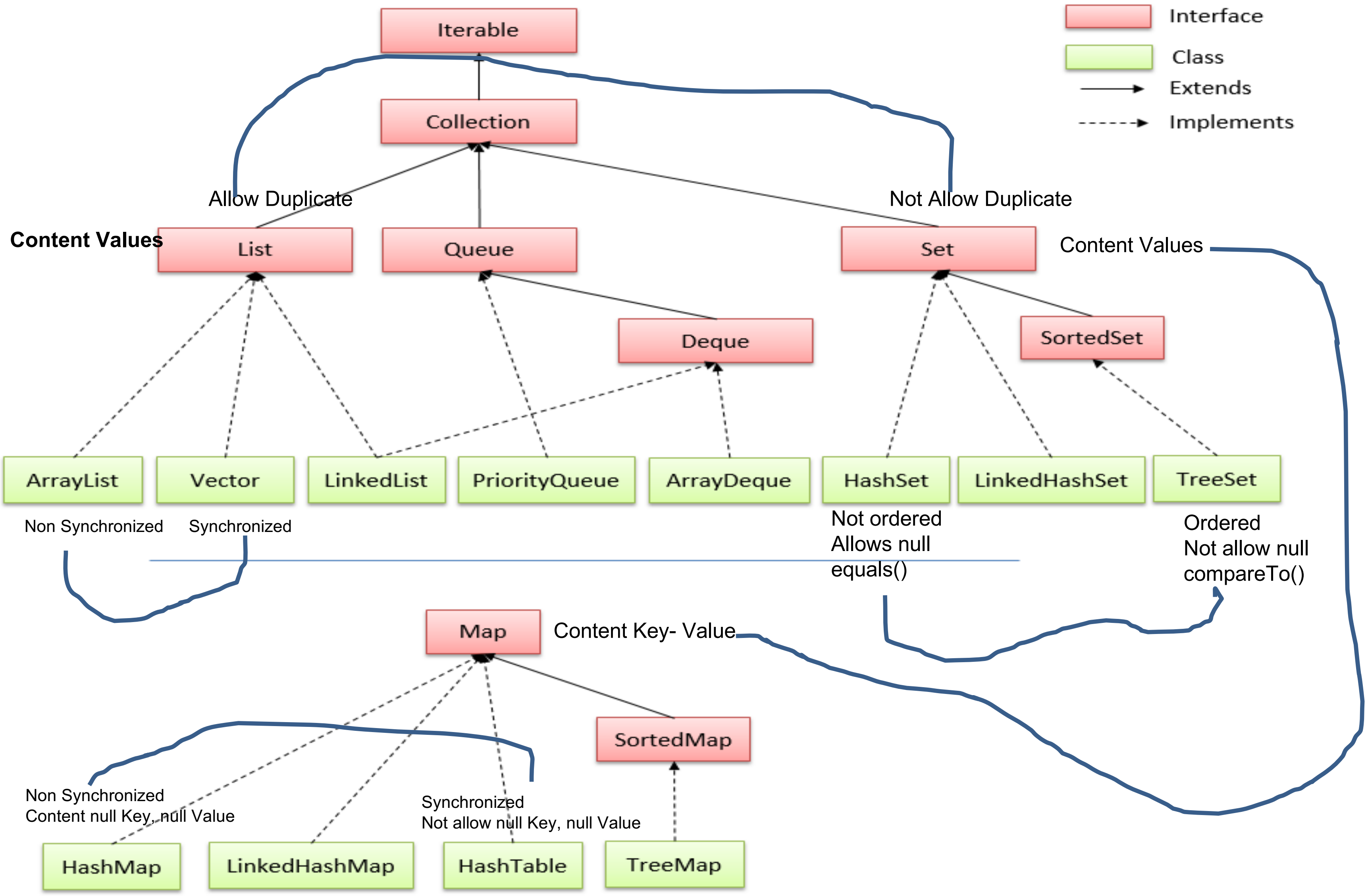
(http://docs.oracle.com/javase/tutorial/collections/
index.html)

Objectives

- Collections Framework (package java.util):
  - List: ArrayList, Vector → Duplicates are agreed
  - Set: HashSet, TreeSet → Duplicates are not agreed
  - Map: HashMap, TreeMap
  - Queue: LinkedList, PriorityQueue
  - Deque: LinkedList, ArrayDeque

Add, Search, Remove, Replace: quickly

Objectives



🟥 Interface

🟩 Class

→ Extends

⇢ Implements

Iterable

Collection

Allow Duplicate

Not Allow Duplicate

Content Values

List

Queue

Set

Content Values

Deque

SortedSet

ArrayList

Vector

LinkedList

PriorityQueue

ArrayDeque

HashSet

LinkedHashSet

TreeSet

Non Synchronized

Synchronized

Not ordered
Allows null
equals()

Ordered
Not allow null
compareTo()

Map

Content Key- Value

SortedMap

Non Synchronized
Content null Key, null Value

Synchronized
Not allow null Key, null Value

HashMap

LinkedHashMap

HashTable

TreeMap

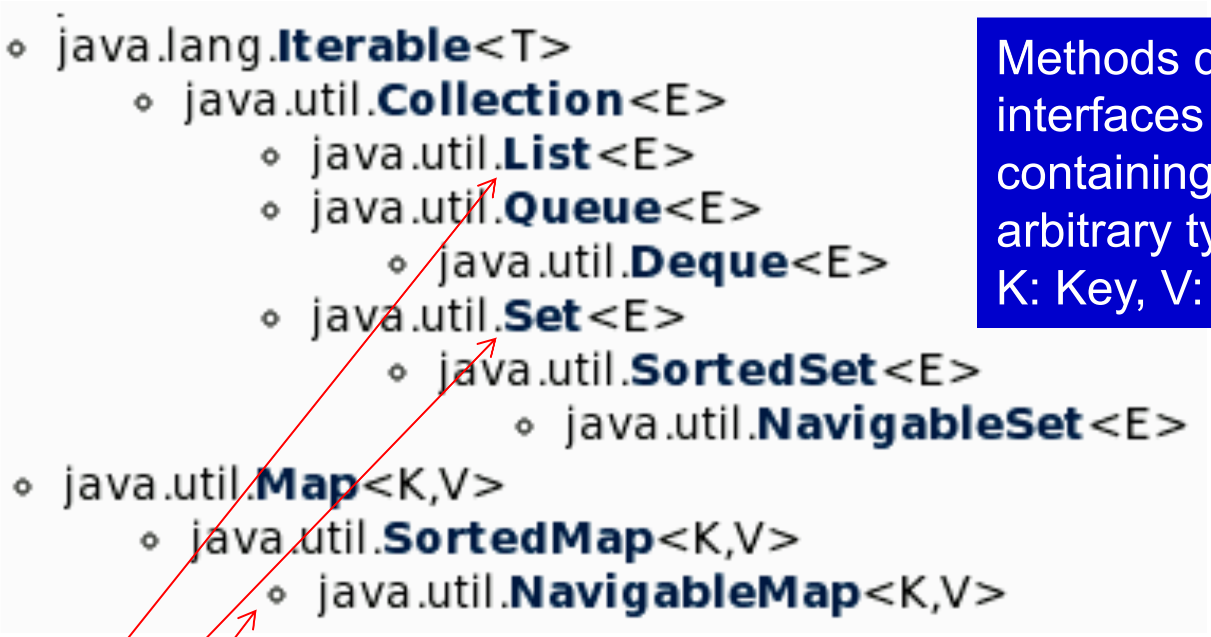
The Collections Framework

- The Java 2 platform includes a new *collections framework*.
- A *collection* is an object that represents a group of objects.
- The Collections Framework is a unified architecture for representing and manipulating collections.
- The collections framework as a whole is not threadsafe.

The Collections Framework…

- **Reduces programming effort** by providing useful data structures and algorithms so you don't have to write them yourself.
- **Increases performance** by providing high-performance implementations of useful data structures and algorithms.
- **Provides interoperability between unrelated APIs** by establishing a common language to pass collections back and forth.
- **Reduces the effort required to learn APIs** by eliminating the need to learn multiple ad hoc collection APIs.
- **Reduces the effort required to design and implement APIs** by eliminating the need to produce ad hoc collections APIs.
- **Fosters software reuse** by providing a standard interface for collections and algorithms to manipulate them.

Collection Interfaces



- java.lang.**Iterable**<T>
    - java.util.**Collection**<E>
        - java.util.**List**<E>
        - java.util.**Queue**<E>
            - java.util.**Deque**<E>
        - java.util.**Set**<E>
            - java.util.**SortedSet**<E>
                - java.util.**NavigableSet**<E>
- java.util.**Map**<K,V>
    - java.util.**SortedMap**<K,V>
        - java.util.**NavigableMap**<K,V>

Methods declared in these interfaces can work on a list containing elements which belong to arbitrary type. T: type, E: Element, K: Key, V: Value

Details of this will be introduced in the topic Generic

3 types of group:

List can contain duplicate elements

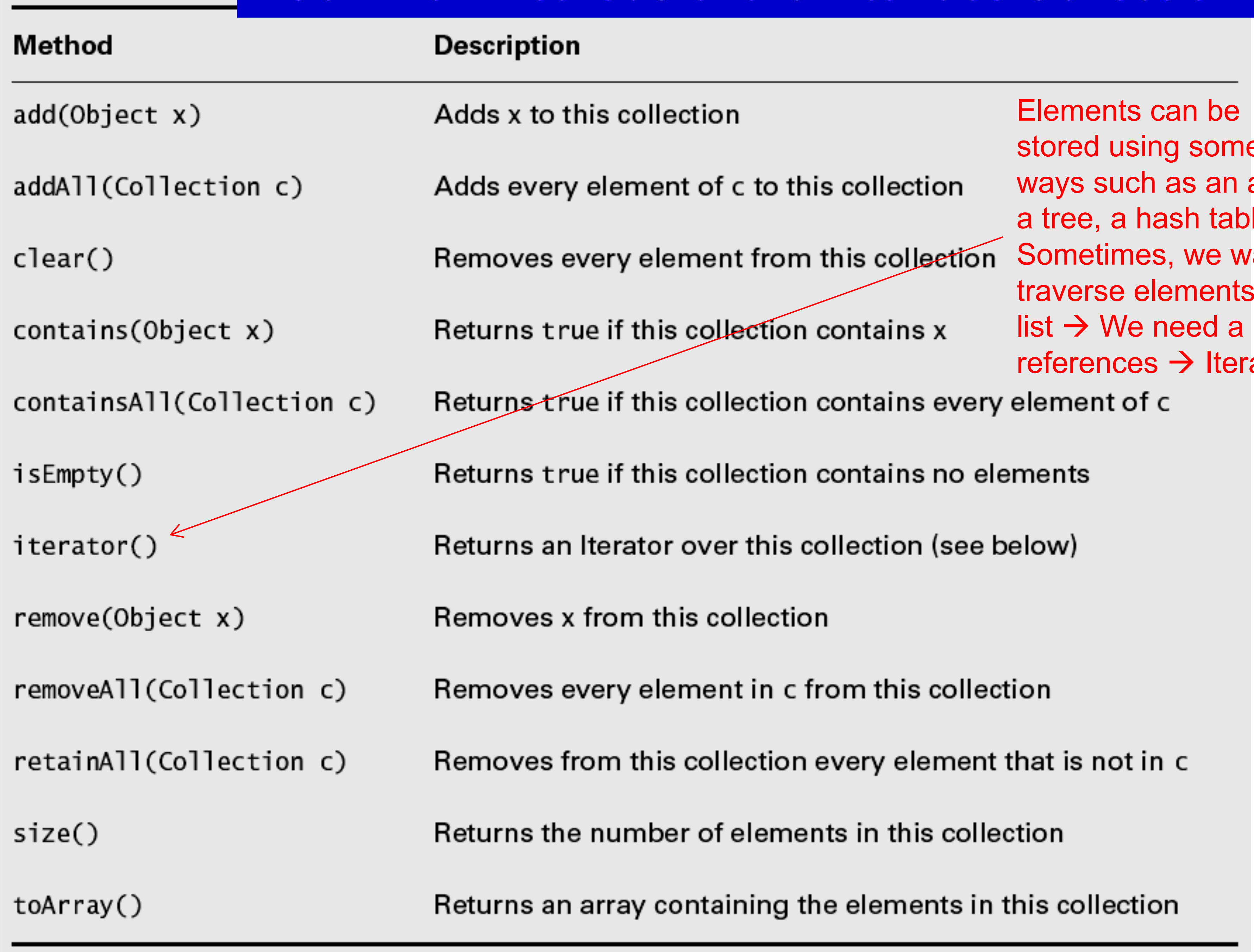
Set can contain distinct elements only

Map can contain pairs <key, value>. Key of element is data for fast searching

Queue, Deque contains methods of restricted list.

Common methods on group are: Add, Remove, Search, Clear,…

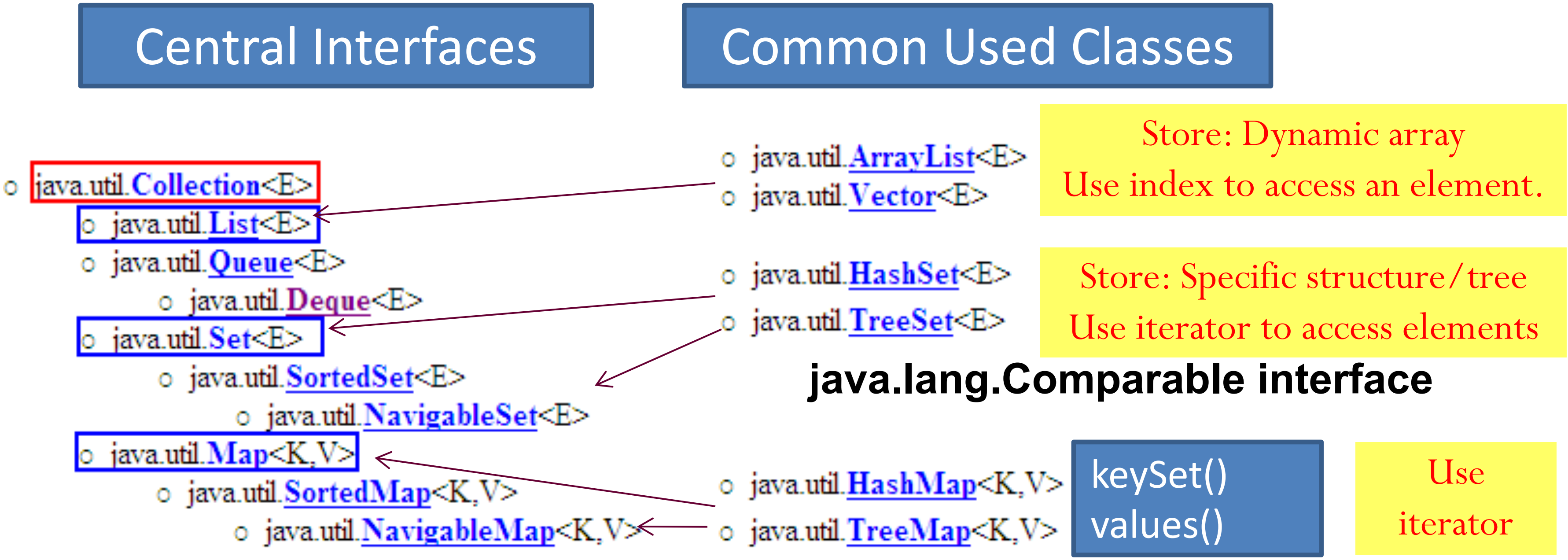
Common Methods of the interface Collection



Method	Description
`add(Object x)`	Adds x to this collection
`addAll(Collection c)`	Adds every element of c to this collection
`clear()`	Removes every element from this collection
`contains(Object x)`	Returns true if this collection contains x
`containsAll(Collection c)`	Returns true if this collection contains every element of c
`isEmpty()`	Returns true if this collection contains no elements
`iterator()`	Returns an Iterator over this collection (see below)
`remove(Object x)`	Removes x from this collection
`removeAll(Collection c)`	Removes every element in c from this collection
`retainAll(Collection c)`	Removes from this collection every element that is not in c
`size()`	Returns the number of elements in this collection
`toArray()`	Returns an array containing the elements in this collection

Elements can be stored using some ways such as an array, a tree, a hash table. Sometimes, we want to traverse elements as a list → We need a list of references → Iterator

The Collection Framework…



Central Interfaces

Common Used Classes

- java.util.Collection<E>
  - java.util.List<E>
  - java.util.Queue<E>
    - java.util.Deque<E>
  - java.util.Set<E>
    - java.util.SortedSet<E>
      - java.util.NavigableSet<E>
  - java.util.Map<K,V>
    - java.util.SortedMap<K,V>
      - java.util.NavigableMap<K,V>

- java.util.ArrayList<E>
- java.util.Vector<E>

Store: Dynamic array
Use index to access an element.

- java.util.HashSet<E>
- java.util.TreeSet<E>

Store: Specific structure/tree
Use iterator to access elements

java.lang.Comparable interface

- java.util.HashMap<K,V>
- java.util.TreeMap<K,V>

keySet()
values()

Use
iterator

A TreeSet will stored elements using ascending order. Natural ordering is applied to numbers and lexicographic (dictionary) ordering is applied to strings.
If you want a TreeSet containing your own objects, you must implement the method compareTo(Object), declared in the Comparable interface.

Lists

- A List keeps it elements in the order in which they were added.
- Each element of a List has an index, starting from 0.
- Common methods:
  - **void add(int index, Object x)**
  - **Object get(int index)**
  - **int indexOf(Object x)**
  - **Object remove(int index)**

Classes Implementing the interface List

- AbstractList
- ArrayList
- Vector (like ArrayList but it is synchronized)
- LinkedList: *linked lists can be used as a stack, queue, or double-ended queue (deque)*

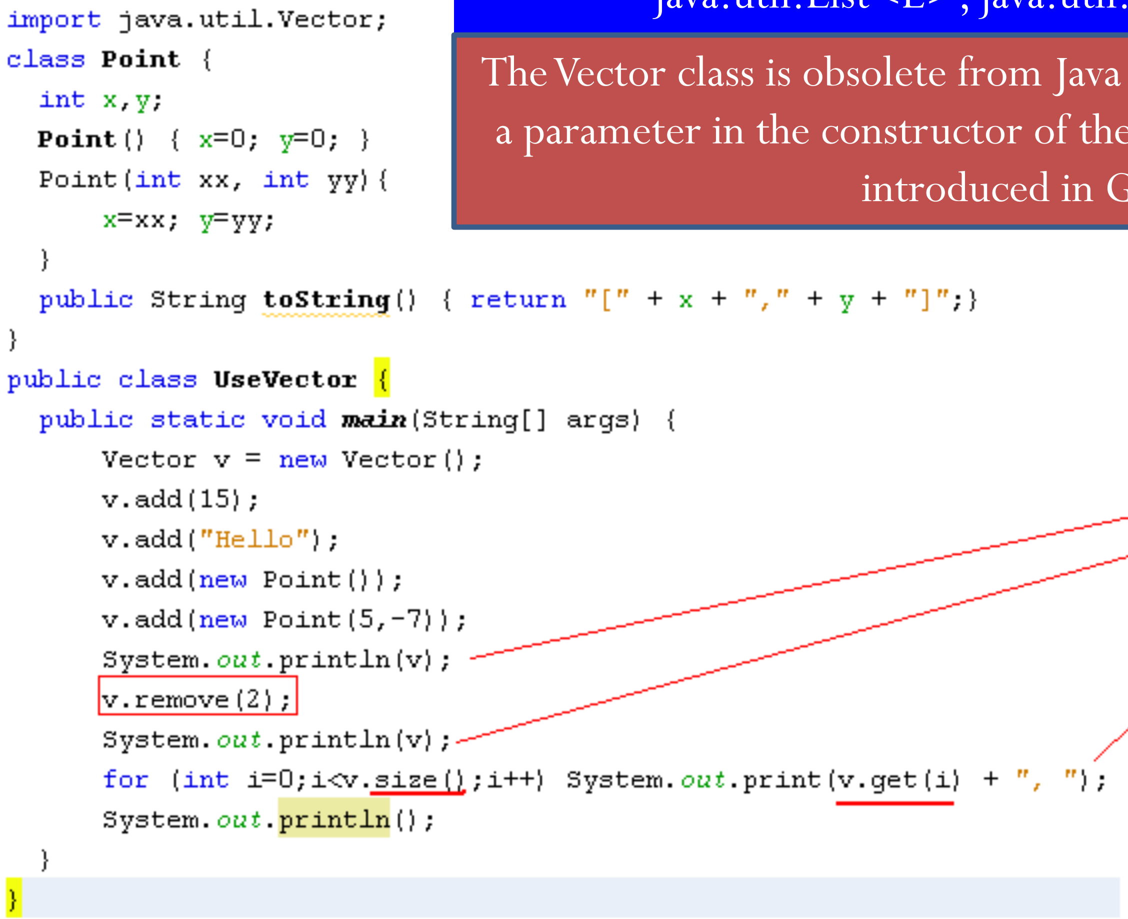
List Implementing Classes

```
Vector vec = new Vector();
for (int i = 101; i <= 110; i++) {
        vec.add(i);
}
for (int i = 0; i < vec.size(); i++) {
        System.out.println(vec.get(i));
}
//or using Iterator
/*
    Iterator iter = vec.iterator();
    while (iter.hasNext()) {
        System.out.println(iter.next());
    }
*/
```

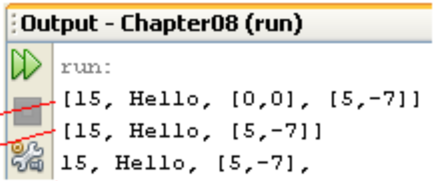
Using the Vector class

java.util.**Vector**<E> (implements java.lang.Cloneable, java.util.List<E>, java.util.RandomAccess, java.io.Serializable)

The Vector class is obsolete from Java 1.6 but it is still introduced because it is a parameter in the constructor of the javax.swing.JTable class, a class will be introduced in GUI programming.



```
import java.util.Vector;
class Point {
   int x,y;
   Point() { x=0; y=0; }
   Point(int xx, int yy){
        x=xx; y=yy;
   }
   public String toString() { return "[" + x + "," + y + "]";}
}
public class UseVector {
   public static void main(String[] args) {
        Vector v = new Vector();
        v.add(15);
        v.add("Hello");
        v.add(new Point());
        v.add(new Point(5,-7));
        System.out.println(v);
        v.remove(2);
        System.out.println(v);
        for (int i=0;i<v.size();i++) System.out.print(v.get(i) + ", ");
        System.out.println();
   }
}
```



Output - Chapter08 (run)

```
run:
[15, Hello, [0,0], [5,-7]]
[15, Hello, [5,-7]]
15, Hello, [5,-7],
```

Sets

- Lists are based on an ordering of their members. Sets have no concept of order.
- A Set is just a cluster of references to objects.
- Sets may not contain duplicate elements.
- Sets use the equals() method, not the == operator, to check for duplication of elements.

```
void addTwice(Set set) {
      set.clear();
      Point p1 = new Point(10, 20);
      Point p2 = new Point(10, 20);
      set.add(p1);
      set.add(p2);
      System.out.println(set.size());
}
```

will print out 1, not 2.

Sets…

- Set extends Collection but does not add any additional methods.
- The two most commonly used implementing classes are:
  - TreeSet
    - Guarantees that the sorted set will be in ascending element order.
    - log(n) time cost for the basic operations (add, remove and contains).
  - HashSet
    - Constant time performance for the basic operations (add, remove, contains and size).

TreeSet and Iterator

- Ordered Tree – Introduced in the subject Discrete Mathematics
- Set: Group of different elements
- TreeSet: Set + ordered tree, each element is called as node
- Iterator: An operation in which references of all node are grouped to make a linked list. Iterator is a way to access every node of a tree.
- Linked list: a group of elements, each element contains a reference to the next

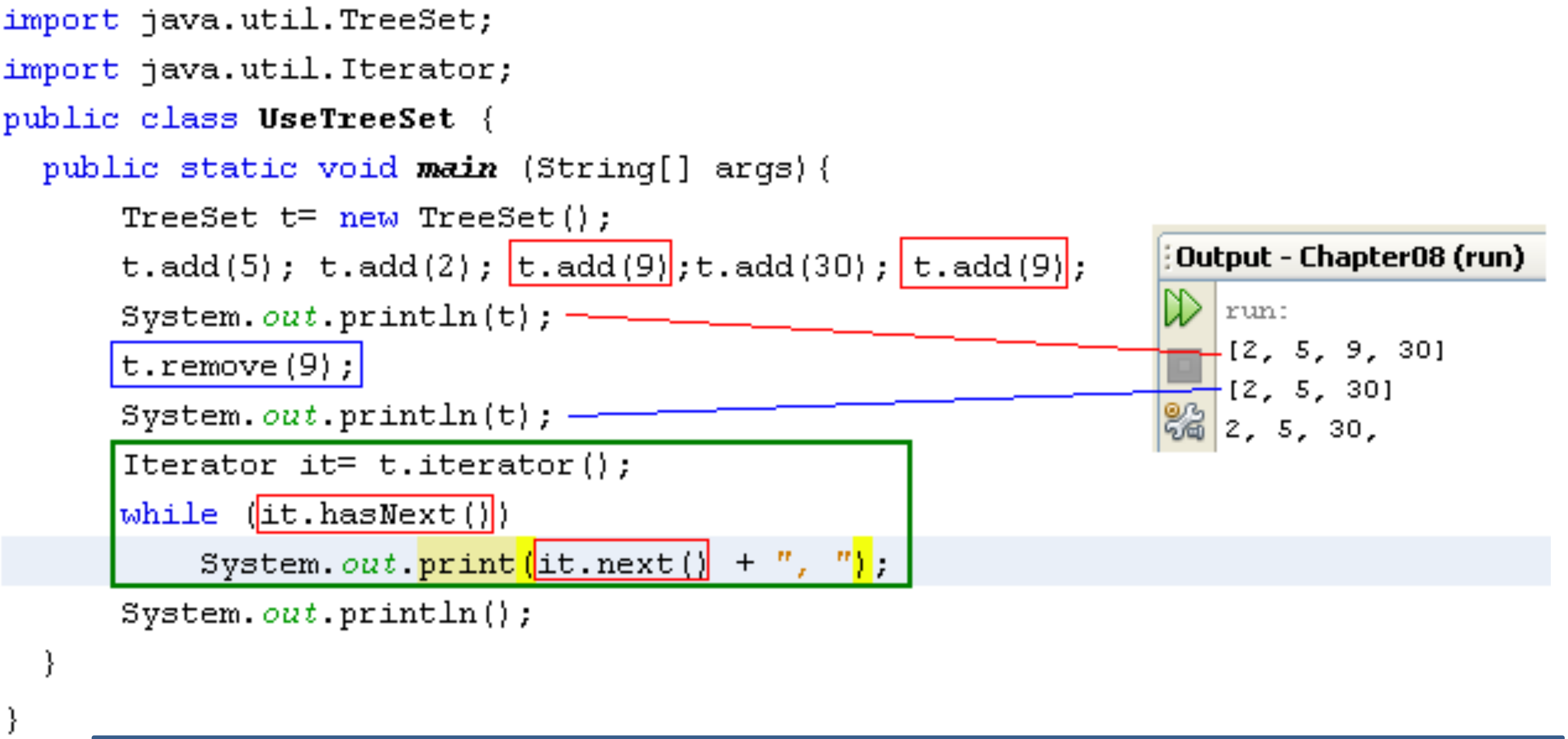
TreeSet = Set + Tree

```
Random r = new Random();
TreeSet myset = new TreeSet();
for (int i = 0; i < 10; i++) {
    int number = r.nextInt(100);
    myset.add(number);
}
//using Iterator
Iterator iter = myset.iterator();
while (iter.hasNext()) {
    System.out.println(iter.next());
}
```

The result may be:

```
7
27
36
41
43
46
49
57
75
83
```

Using the TreeSet class & Iterator



```
import java.util.TreeSet;
import java.util.Iterator;
public class UseTreeSet {
  public static void main (String[] args){
      TreeSet t= new TreeSet();
      t.add(5); t.add(2); t.add(9);t.add(30); t.add(9);
      System.out.println(t);
      t.remove(9);
      System.out.println(t);
      Iterator it= t.iterator();
      while (it.hasNext())
          System.out.print(it.next() + ", ");
      System.out.println();
  }
}
```

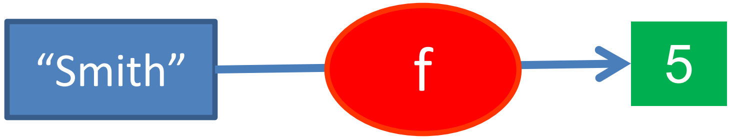
Output - Chapter08 (run)

```
run:
[2, 5, 9, 30]
[2, 5, 30]
2, 5, 30,
```

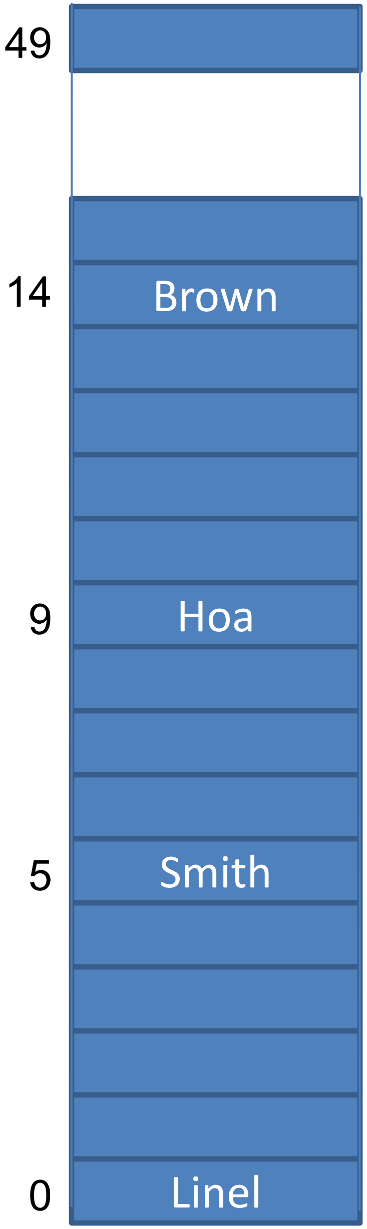
A TreeSet will stored elements using ascending order. Natural ordering is applied to numbers and lexicographic (dictionary) ordering is applied to strings.
If you want a TreeSet containing your own objects, you must implement the method compareTo(Object), declared in the Comparable interface.

Hash Table

- In array, elements are stored in a contiguous memory blocks → Linear search is applied → slow, binary search is an improvement.
- Hash table: elements can be stored in a different memory blocks. The index of an element is determined by a function (hash function) → Add/Search operation is very fast (O(1)).



The hash function f may be:
'S'*10000+'m'*1000+'i'*100+'t'*10+'h' % 50



HashSet = Set + Hash Table

```
Random r = new Random();
HashSet myset = new HashSet();
for (int i = 0; i < 10; i++) {
    int number = r.nextInt(100);
    myset.add(number);
}
//using Iterator
Iterator iter = myset.iterator();
while (iter.hasNext()) {
    System.out.println(iter.next());
}
```

The result may be:

```
84
55
7
76
77
95
94
12
91
44
```

HashSet or TreeSet?

- If you care about iteration order, use a Tree Set and pay the time penalty.
- If iteration order doesn’t matter, use the higher-performance Hash Set.

How to TreeSet ordering elements?

- Tree Sets rely on all their elements implementing the interface java.lang.Comparable.

  public int compareTo(Object x)

  - Returns a positive number if the current object is “greater than” x, by whatever definition of “greater than” the class itself wants to use.

How to TreeSet ordering elements?

```
class Student implements Comparable{
   int no;
   ...
  public int compareTo(Object o) {
        Student st = (Student) o;
        if(no > st.getNo())
            return 1;
        else if(no == st.getNo())
            return 0;
        else
            return -1;
    }
   . . .
}
```

Comparing 2 students based on their IDs (field ***no***)

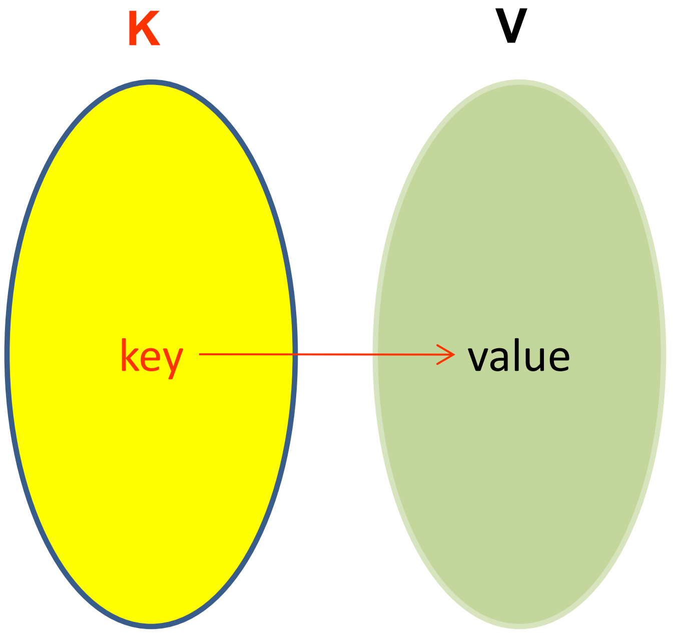
How to TreeSet ordering elements?

```
public static void main(String[] args) {
   Random r =  new Random();
   TreeSet myset = new TreeSet();
   for (int i = 0; i < 10; i++) {
         int no = r.nextInt(100);
         Student st = new Student(no, "abc");
         myset.add(st);
   }
   //using Iterator
   Iterator iter = myset.iterator();
   while (iter.hasNext()) {
         Student st = (Student)iter.next();
         System.out.println("No: " + st.getNo());
   }
}
```

```
No: 2
No: 8
No: 11
No: 19
No: 33
No: 52
No: 78
No: 83
No: 92
No: 96
```

Maps

- Map doesn’t implement the java.util.Collection interface.
- A Map combines *two* collections, called keys and values.
- The Map’s job is to associate exactly one value with each key.
- A Map like a dictionary.
- Maps check for key uniqueness based on the equals() method, not the == operator.
- IDs, Item code, roll numbers are keys.
- The normal data type for keys is String.



Each element: <key,value>

Maps..

- Java’s two most important Map classes:
  - HashMap (mapping keys are unpredictable order – hash table is used, hash function is pre-defined in the Java Library).
  - TreeMap (mapping keys are natural order)-> all keys must implement Comparable (a tree is used to store elements).

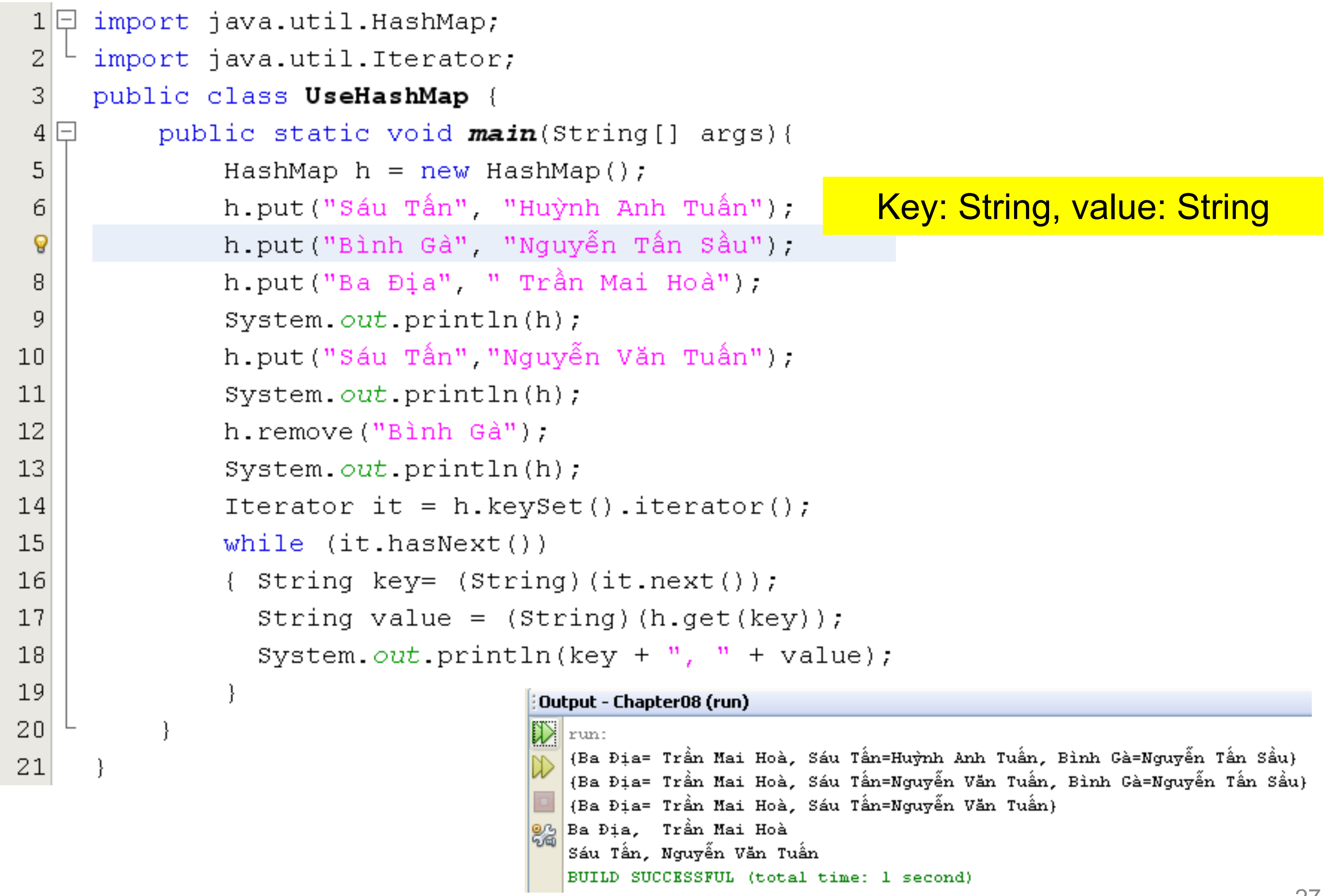
HashMap

```
public static void main(String[] args) {
        HashMap mymap = new HashMap();
        mymap.put(1, “One");
        mymap.put(2, “Two");
        mymap.put(3, “Three");
        mymap.put(4, “Four");
        //using Iterator
        Iterator iter = mymap.keySet().iterator();
        while (iter.hasNext()) {
            Object key = iter.next();
            System.out.println(key + ": " + mymap.get(key));
        }
    }
```

```
//output
1: One
2: Two
3: Three
4: Four
```

Key: integer, value: String

Using HashMap class & Iterator



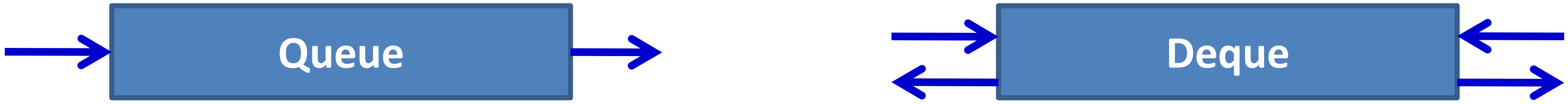
```java
import java.util.HashMap;
import java.util.Iterator;
public class UseHashMap {
    public static void main(String[] args){
        HashMap h = new HashMap();
        h.put("Sáu Tấn", "Huỳnh Anh Tuấn");
        h.put("Bình Gà", "Nguyễn Tấn Sầu");
        h.put("Ba Địa", " Trần Mai Hoà");
        System.out.println(h);
        h.put("Sáu Tấn","Nguyễn Văn Tuấn");
        System.out.println(h);
        h.remove("Bình Gà");
        System.out.println(h);
        Iterator it = h.keySet().iterator();
        while (it.hasNext())
        { String key= (String)(it.next());
          String value = (String)(h.get(key));
          System.out.println(key + ", " + value);
        }
    }
}
```

Key: String, value: String

Output - Chapter08 (run)

```
run:
{Ba Địa= Trần Mai Hoà, Sáu Tấn=Huỳnh Anh Tuấn, Bình Gà=Nguyễn Tấn Sầu}
{Ba Địa= Trần Mai Hoà, Sáu Tấn=Nguyễn Văn Tuấn, Bình Gà=Nguyễn Tấn Sầu}
{Ba Địa= Trần Mai Hoà, Sáu Tấn=Nguyễn Văn Tuấn}
Ba Địa,  Trần Mai Hoà
Sáu Tấn, Nguyễn Văn Tuấn
BUILD SUCCESSFUL (total time: 1 second)
```

Interface Queue and Deque



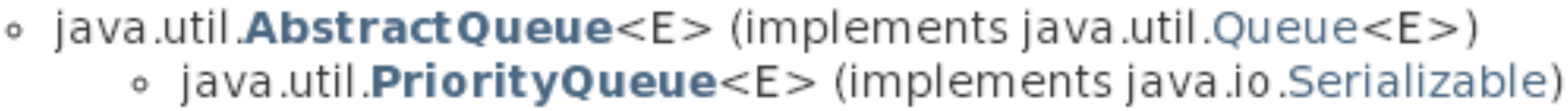
- Interfaces for restricted list (limited manipulation), programmers can not access an arbitrary element but elements at the beginning or the end of the list only.
- Deque: A linear collection that supports element insertion and removal at both ends. The name *deque* is short for "double ended queue" and is usually pronounced "deck". Most Deque implementations place no fixed limits on the number of elements they may contain, but this interface supports capacity-restricted deques as well as those with no fixed size limit.

Interface Queue

public interface **Queue<E>** extends Collection<E>

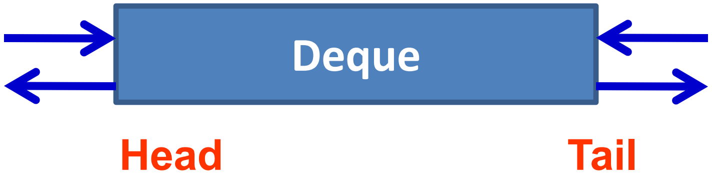
boolean	add(E e) Inserts the specified element into this queue if it is possible to do so immediately without violating capacity restrictions, returning true upon success and throwing an IllegalStateException if no space is currently available.
E	element() Retrieves, but does not remove, the head of this queue.
boolean	offer(E e) Inserts the specified element into this queue if it is possible to do so immediately without violating capacity restrictions.
E	peek() Retrieves, but does not remove, the head of this queue, or returns null if this queue is empty.
E	poll() Retrieves and removes the head of this queue, or returns null if this queue is empty.
E	remove() Retrieves and removes the head of this queue.

Classes:



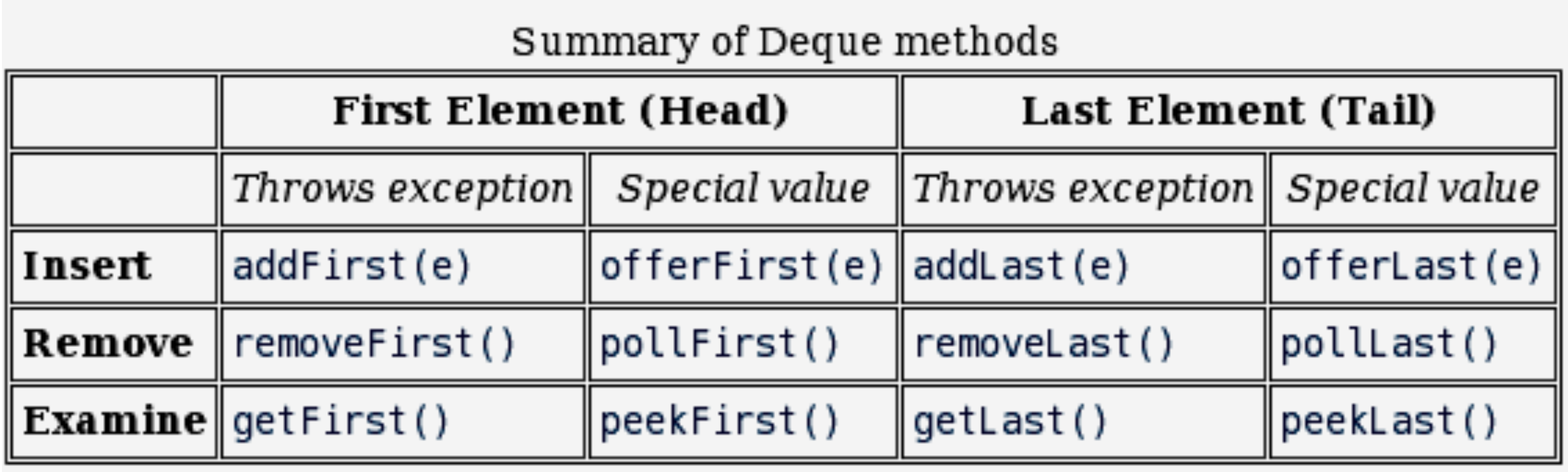
- java.util.**AbstractQueue**<E> (implements java.util.Queue<E>)
  - java.util.**PriorityQueue**<E> (implements java.io.Serializable)

Interface Deque…



public interface **Deque<E>** extends Queue<E>

IN addition to methods inherited from the interface Queue, some methods are declared:



Summary of Deque methods

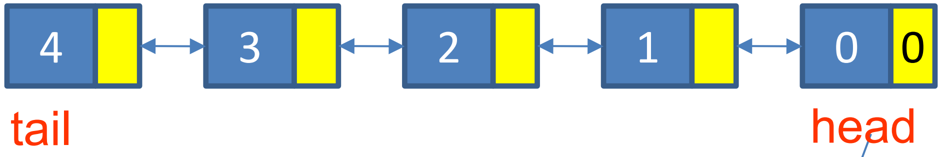
	First Element (Head)		Last Element (Tail)	
	Throws exception	*Special value*	*Throws exception*	*Special value*
Insert	`addFirst(e)`	`offerFirst(e)`	`addLast(e)`	`offerLast(e)`
Remove	`removeFirst()`	`pollFirst()`	`removeLast()`	`pollLast()`
Examine	`getFirst()`	`peekFirst()`	`getLast()`	`peekLast()`

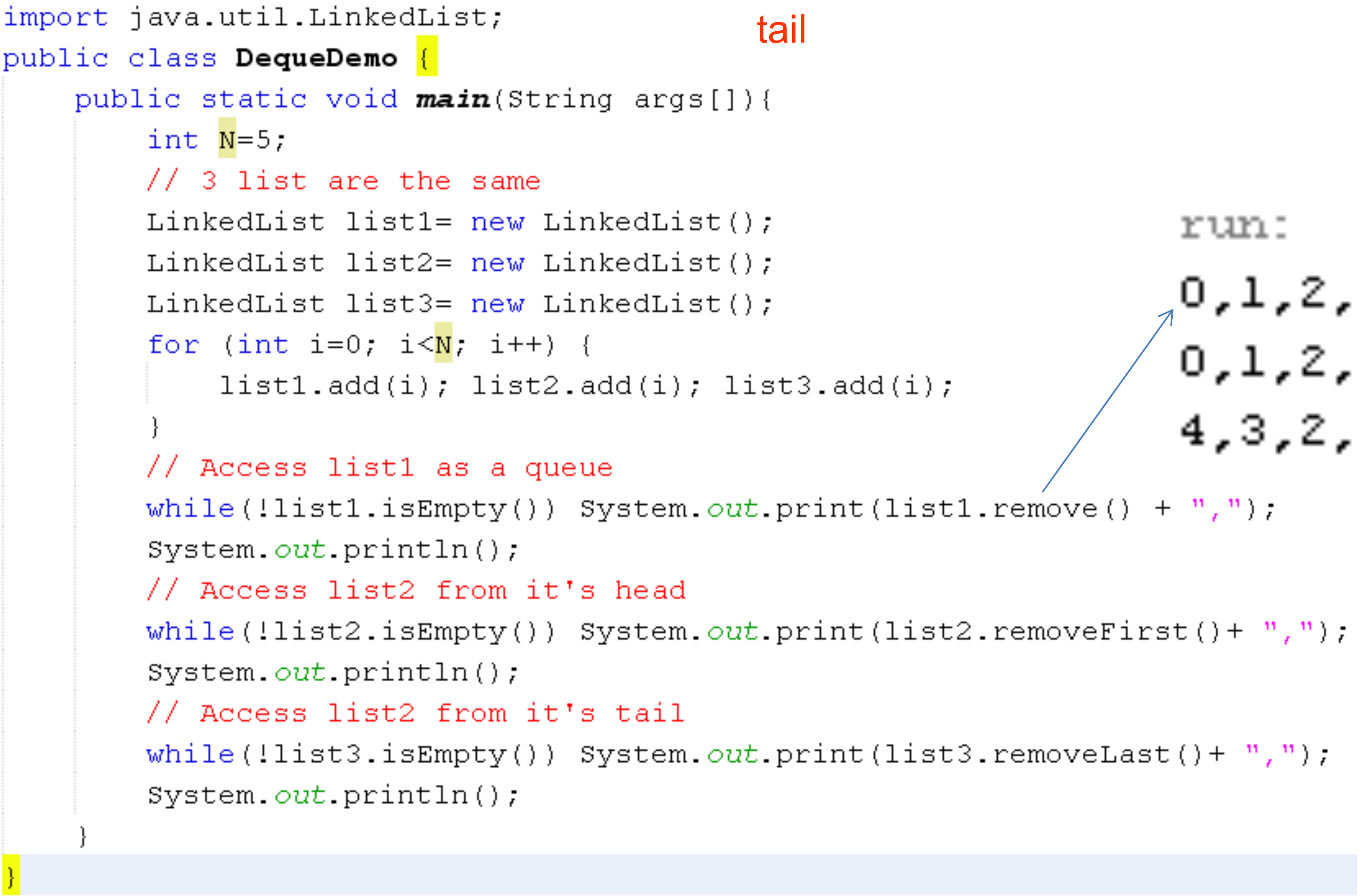
Classes

java.util.**LinkedList**<E> (implements java.lang.Cloneable, java.util.Deque<E>, java.util.List<E>, java.io.Serializable)

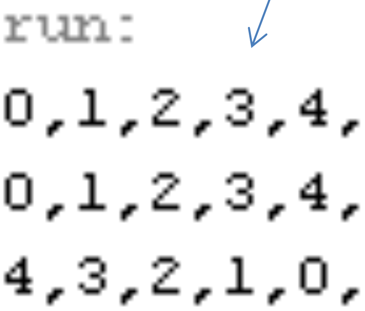
java.util.**ArrayDeque**<E> (implements java.lang.Cloneable, java.util.Deque<E>, java.io.Serializable)

Queue/Deque Demo.





```
import java.util.LinkedList;
public class DequeDemo {
    public static void main(String args[]){
        int N=5;
        // 3 list are the same
        LinkedList list1= new LinkedList();
        LinkedList list2= new LinkedList();
        LinkedList list3= new LinkedList();
        for (int i=0; i<N; i++) {
            list1.add(i); list2.add(i); list3.add(i);
        }
        // Access list1 as a queue
        while(!list1.isEmpty()) System.out.print(list1.remove() + ",");
        System.out.println();
        // Access list2 from it's head
        while(!list2.isEmpty()) System.out.print(list2.removeFirst()+ ",");
        System.out.println();
        // Access list2 from it's tail
        while(!list3.isEmpty()) System.out.print(list3.removeLast()+ ",");
        System.out.println();
    }
}
```

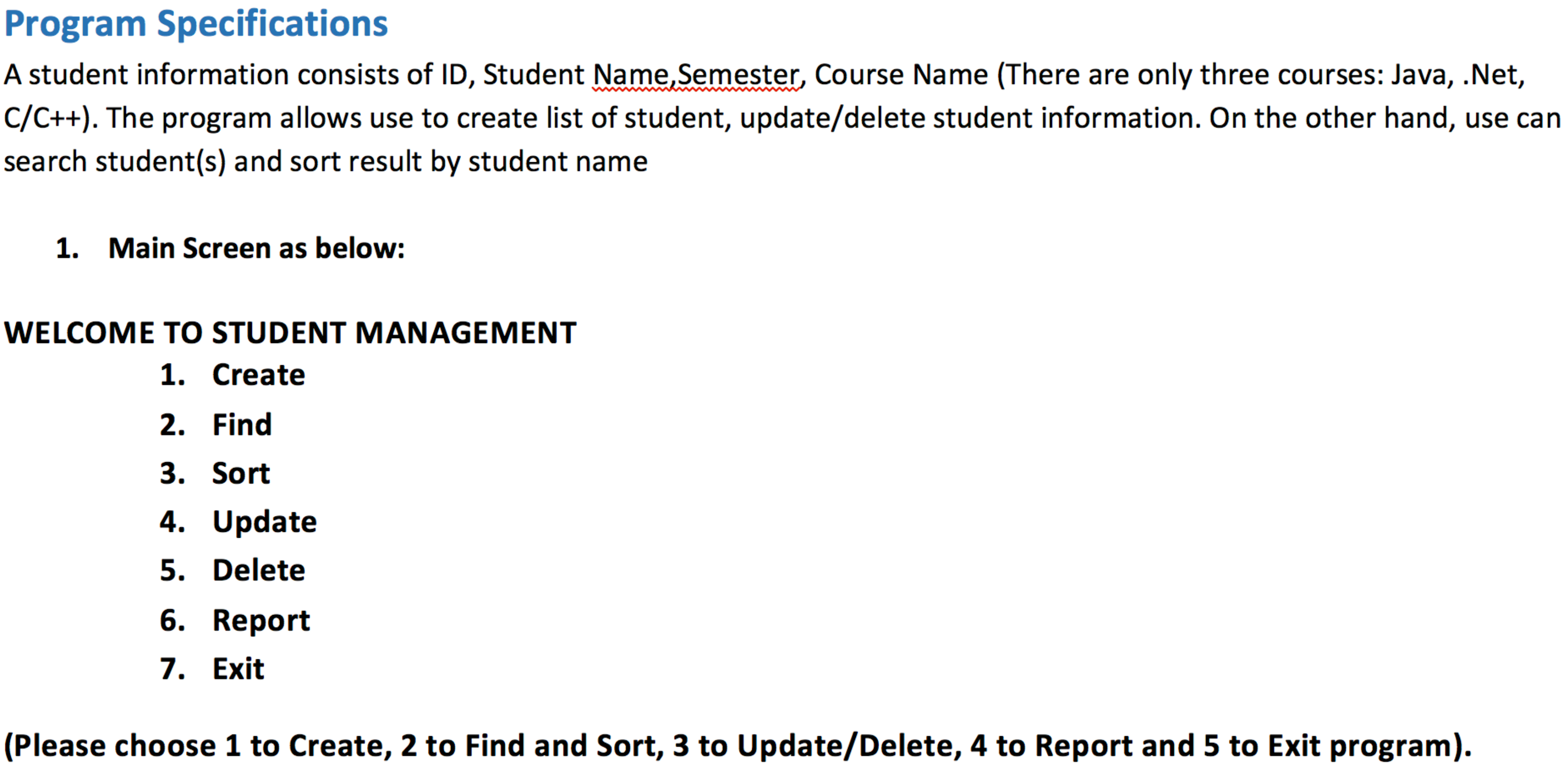


```
run:
0,1,2,3,4,
0,1,2,3,4,
4,3,2,1,0,
```

Summary

- The Collections Framework
  - **The *Collection* Super interface and Iteration**
  - **Lists**
  - **Sets**
  - **Maps**
  - **Support Classes**
  - **Collections and Code Maintenance**

Assignment



Program Specifications

A student information consists of ID, Student Name,Semester, Course Name (There are only three courses: Java, .Net, C/C++). The program allows use to create list of student, update/delete student information. On the other hand, use can search student(s) and sort result by student name

1. **Main Screen as below:**

WELCOME TO STUDENT MANAGEMENT

1. **Create**
2. **Find**
3. **Sort**
4. **Update**
5. **Delete**
6. **Report**
7. **Exit**

(Please choose 1 to Create, 2 to Find and Sort, 3 to Update/Delete, 4 to Report and 5 to Exit program).