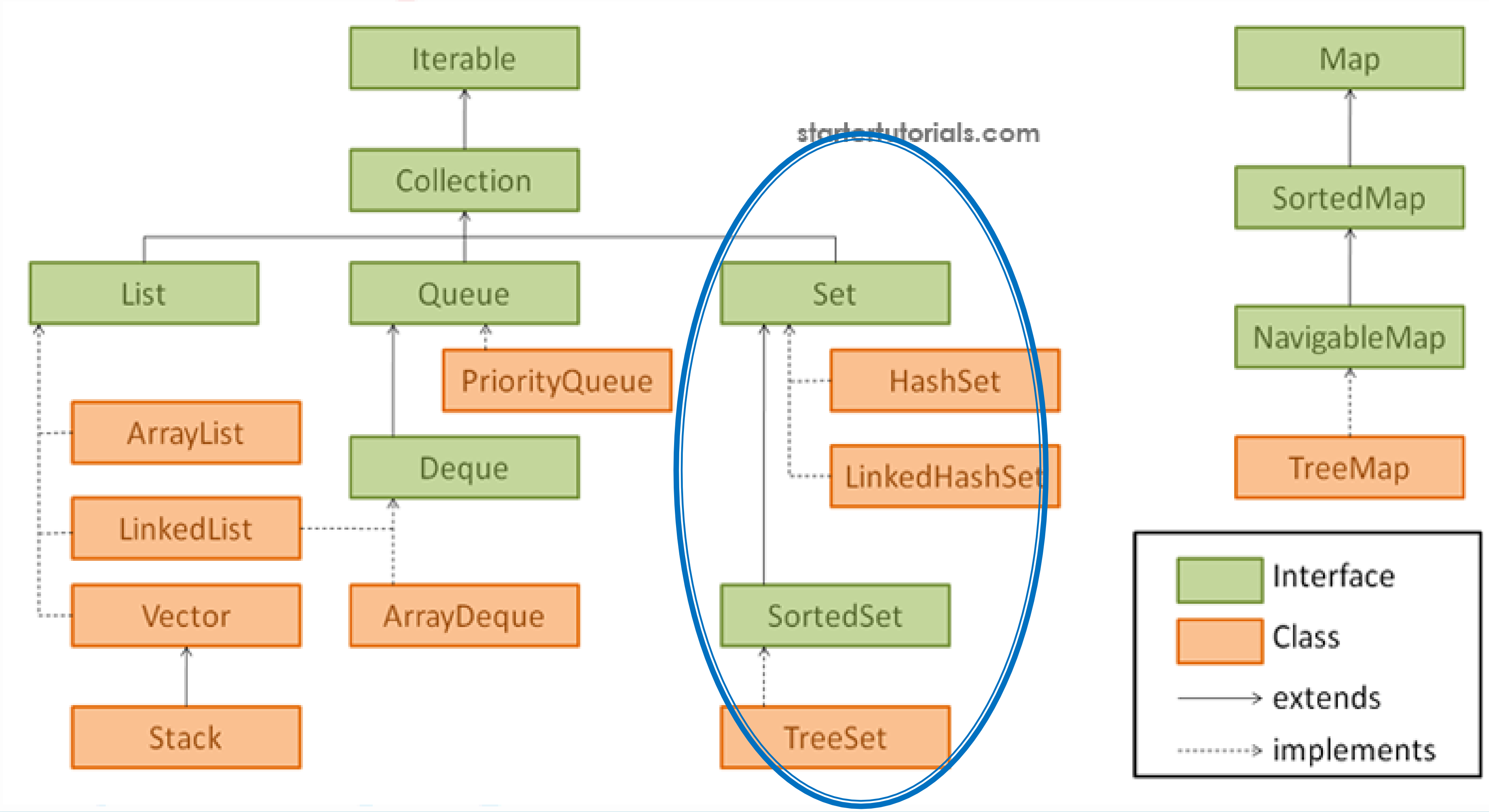
FACULTY OF INFORMATION TECHNOLOGY

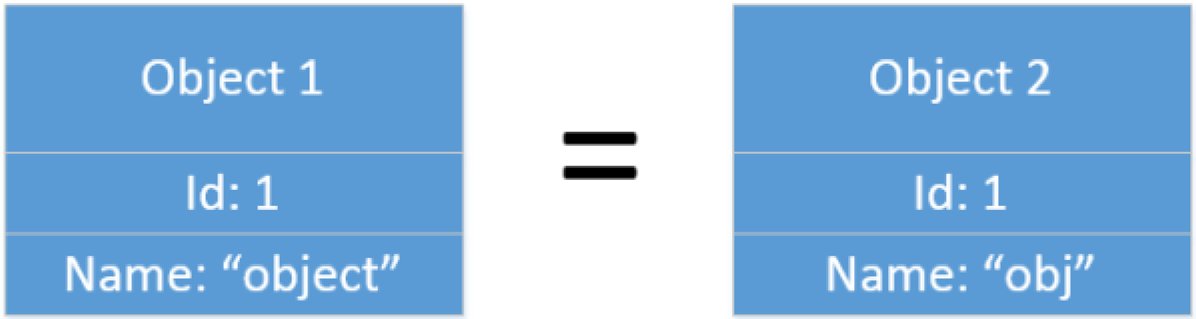
DATA STRUCTURES (CTDL)

Semester 1, 2021/2022

Java Collection framework



Objects Equality



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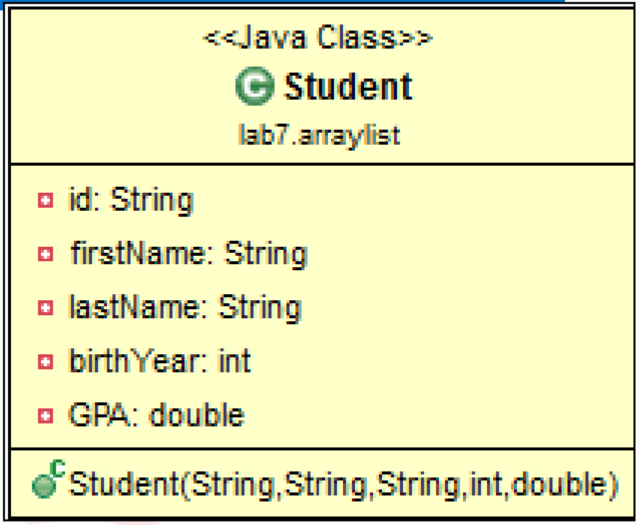
Example

- For a given Student class as follows:



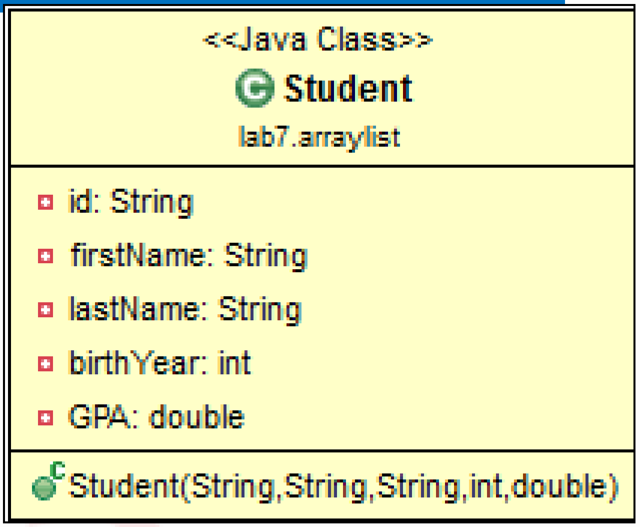
- What is the result of the following code fragment.

```
public static void main(String[] args) {
    Student st1 = new Student("18130006", "Binh", "Nguyen", 1996, 8.5);
    Student st2 = st1;
    Student st3 = new Student("18130006", "Binh", "Nguyen", 1996, 8.5);

    System.out.println(st1 == st2);// ???
    System.out.println(st1 == st3);// ???
    System.out.println(st1.equals(st2));// ???
    System.out.println(st1.equals(st3));// ???
}
```

Example

- For a given Student class as follows:



- What is the result of the following code fragment.

```
public static void main(String[] args) {
    Student st1 = new Student("18130006", "Binh", "Nguyen", 1996, 8.5);
    Student st2 = st1;
    Student st3 = new Student("18130006", "Binh", "Nguyen", 1996, 8.5);

    System.out.println(st1 == st2);// ???
    System.out.println(st1 == st3);// ???
    System.out.println(st1.equals(st2));// ???
    System.out.println(st1.equals(st3));// ???
}
```

true
false
true
false

Approaches to comparing 2 Objects

- Two ways to compare equality of two Objects:
  - **Shallow comparison**:
    - The default implementation of equals method in Java.lang.Object class
    - Simply, it checks if x == y, meaning two Object references (say x and y) refer to the same Object
  - **Deep Comparison**:
    - A class provides its own implementation of equals() method in order to compare the Objects of that class w.r.t state of the Objects.
    - Data members (i.e. fields) of Objects are to be compared with one another.

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Equality comparison for primitives

- Comparison a == b, a != b:
  - Primitives:
    - Equal values
  - Objects: Compares references, not values. The use of == with object references is generally limited to the following:
    - Comparing to see if a reference is null.
    - Comparing two enum values. This works because there is only one object for each enum constant.
    - Comparing to see if two references are to the *same object*

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Principles of equals

- If some other object is equal to a given object, then it follows these rules:
  - Reflexive: for any reference value a, a.equals(a) should return true.
  - Symmetric: for any reference values a and b, if a.equals(b) should return true then b.equals(a) must return true.
  - Transitive: for any reference values a, b, and c, if a.equals(b) returns true and b.equals(c) returns true, then a.equals(c) should return true.
  - Consistent: for any reference values a and b, multiple invocations of a.equals(b) consistently return true or consistently return false, provided no information used in equals comparisons on the object is modified.

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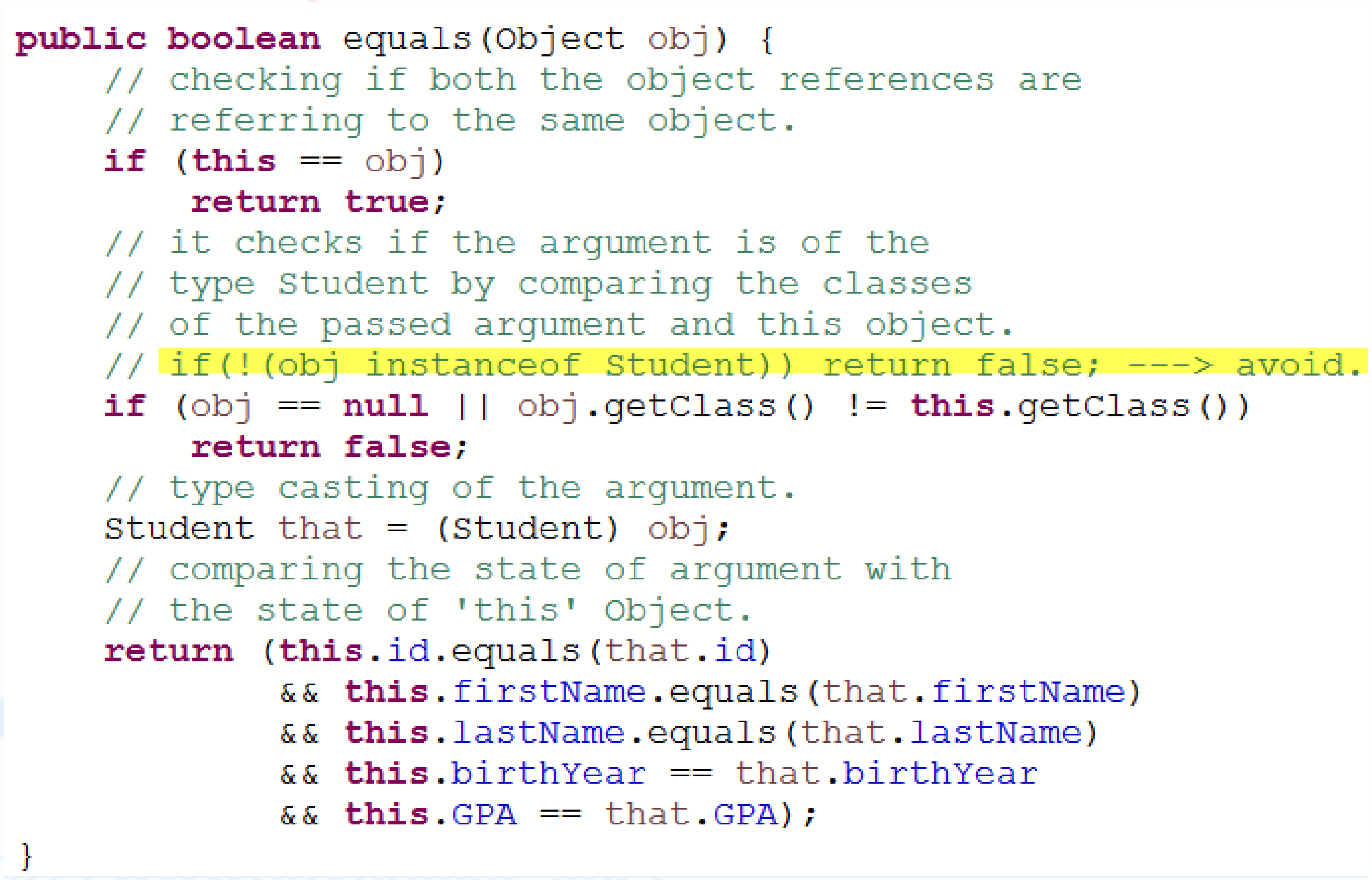
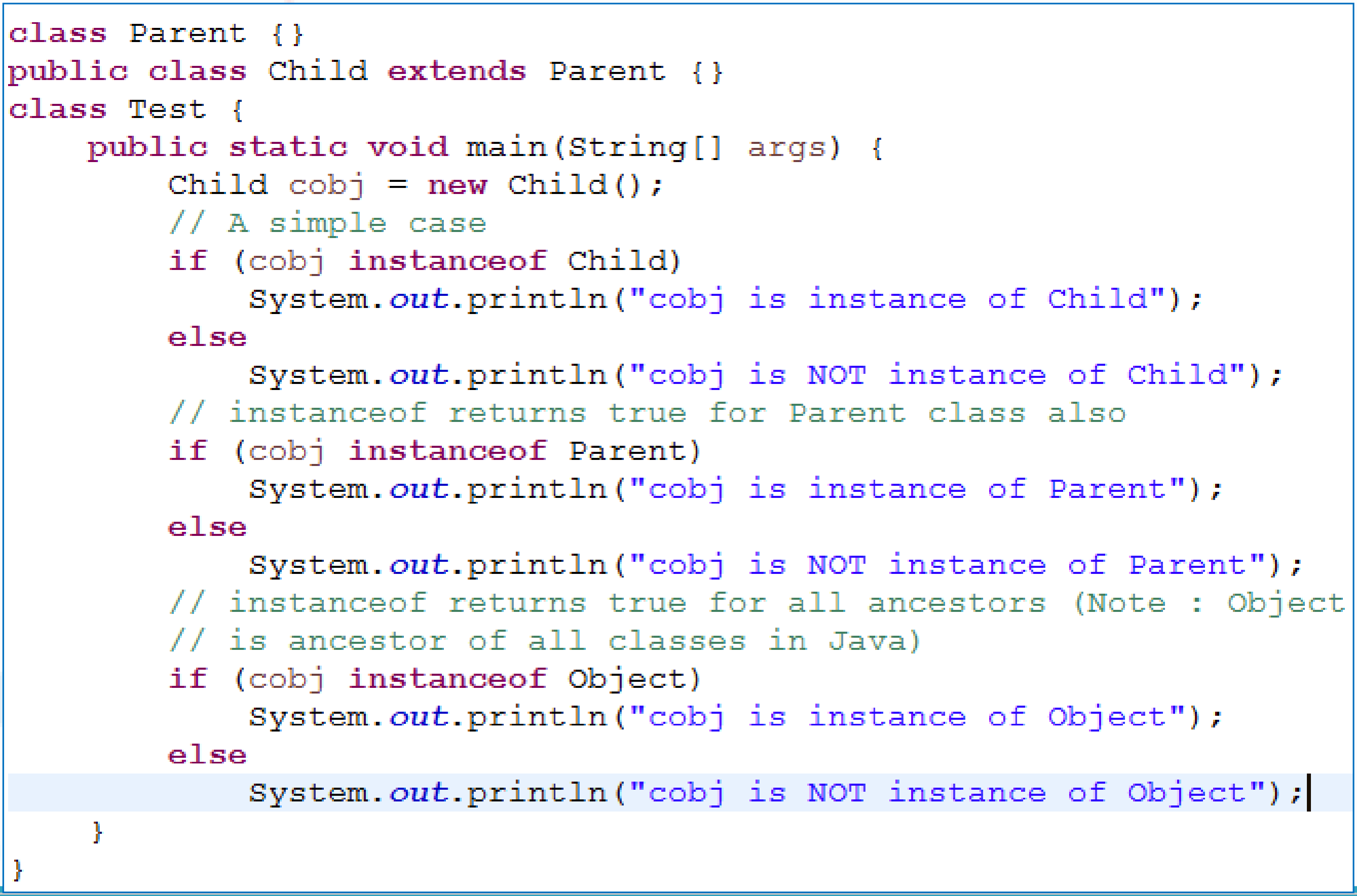
Equals method implementation



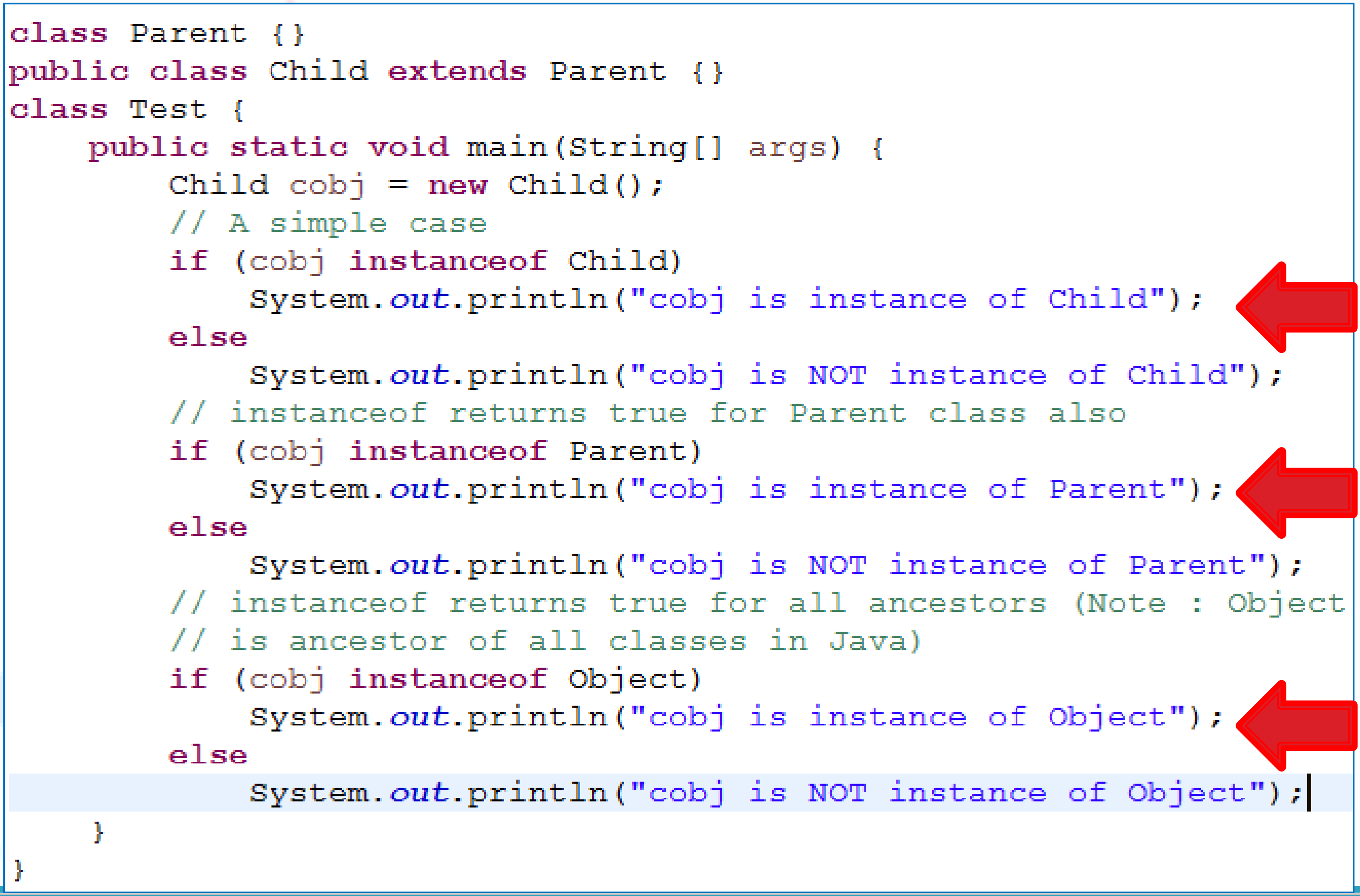
```
public boolean equals(Object obj) {
    // checking if both the object references are
    // referring to the same object.
    if (this == obj)
        return true;
    // it checks if the argument is of the
    // type Student by comparing the classes
    // of the passed argument and this object.
    // if(!(obj instanceof Student)) return false; ---> avoid.
    if (obj == null || obj.getClass() != this.getClass())
        return false;
    // type casting of the argument.
    Student that = (Student) obj;
    // comparing the state of argument with
    // the state of 'this' Object.
    return (this.id.equals(that.id)
            && this.firstName.equals(that.firstName)
            && this.lastName.equals(that.lastName)
            && this.birthYear == that.birthYear
            && this.GPA == that.GPA);
}
```

Why avoiding instanceof?



```
class Parent {}
public class Child extends Parent {}
class Test {
    public static void main(String[] args) {
        Child cobj = new Child();
        // A simple case
        if (cobj instanceof Child)
            System.out.println("cobj is instance of Child");
        else
            System.out.println("cobj is NOT instance of Child");
        // instanceof returns true for Parent class also
        if (cobj instanceof Parent)
            System.out.println("cobj is instance of Parent");
        else
            System.out.println("cobj is NOT instance of Parent");
        // instanceof returns true for all ancestors (Note : Object
        // is ancestor of all classes in Java)
        if (cobj instanceof Object)
            System.out.println("cobj is instance of Object");
        else
            System.out.println("cobj is NOT instance of Object");
    }
}
```

Why avoiding instanceof?



```java
class Parent {}
public class Child extends Parent {}
class Test {
    public static void main(String[] args) {
        Child cobj = new Child();
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        if (cobj instanceof Object)
            System.out.println("cobj is instance of Object");
        else
            System.out.println("cobj is NOT instance of Object");
    }
}
```

Notes on instanceof

- A parent object is not an instance of Child

```
Parent pobj = new Parent();
if (pobj instanceof Child)
   System.out.println("pobj is instance of Child");
else
   System.out.println("pobj is NOT instance of Child");
```

- A parent reference referring to a Child is an instance of Child

```
// Reference is Parent type but object is
// of child type.
Parent cobj = new Child();
if (cobj instanceof Child)
   System.out.println("cobj is instance of Child");
else
   System.out.println("cobj is NOT instance of Child");
```

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Notes on instanceof

- A parent object is not an instance of Child

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Parent pobj = new Parent();
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// Reference is Parent type but object is
// of child type.
Parent cobj = new Child();
if (cobj instanceof Child)
    System.out.println("cobj is instance of Child");
else
    System.out.println("cobj is NOT instance of Child");
```

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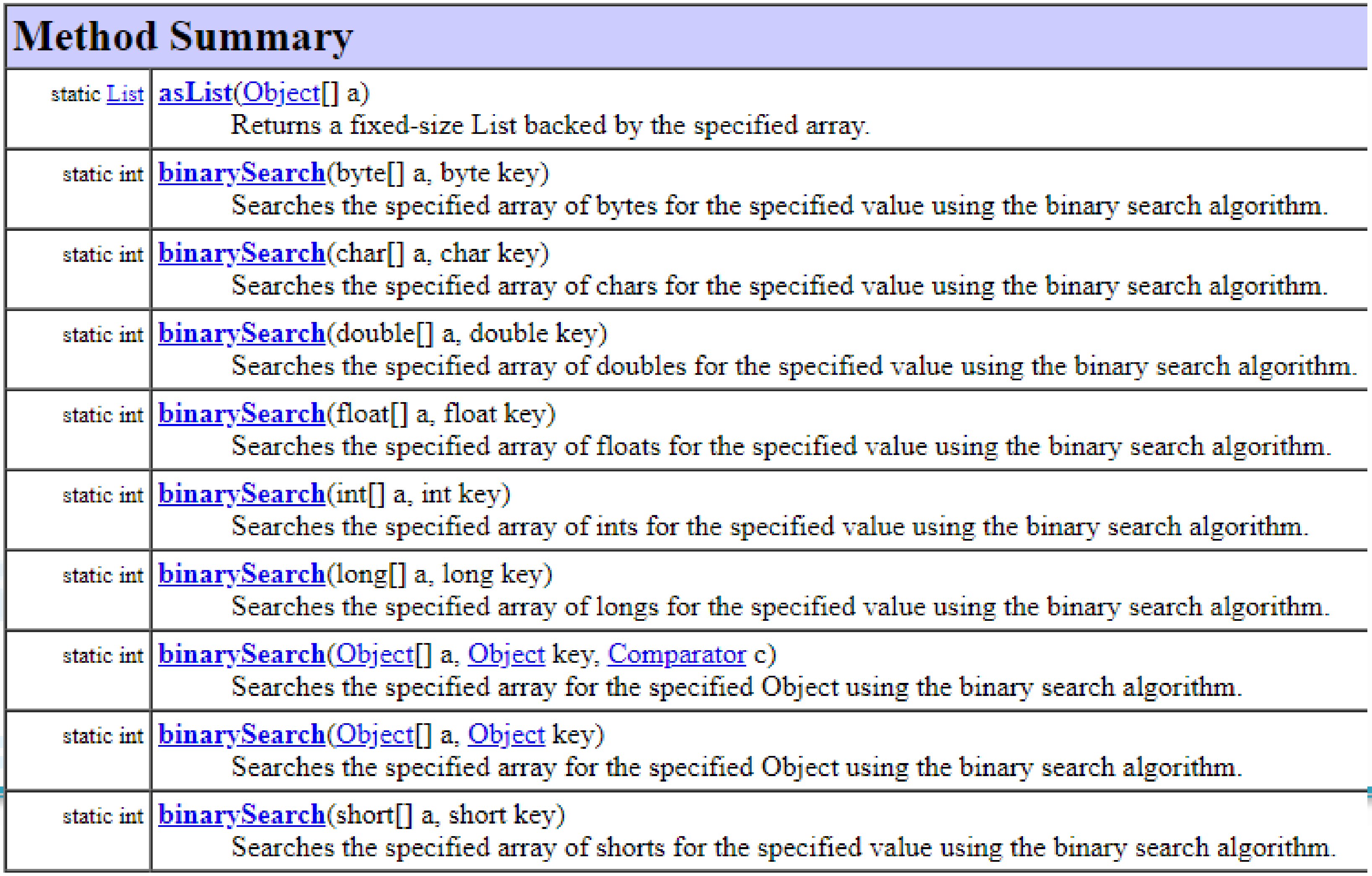
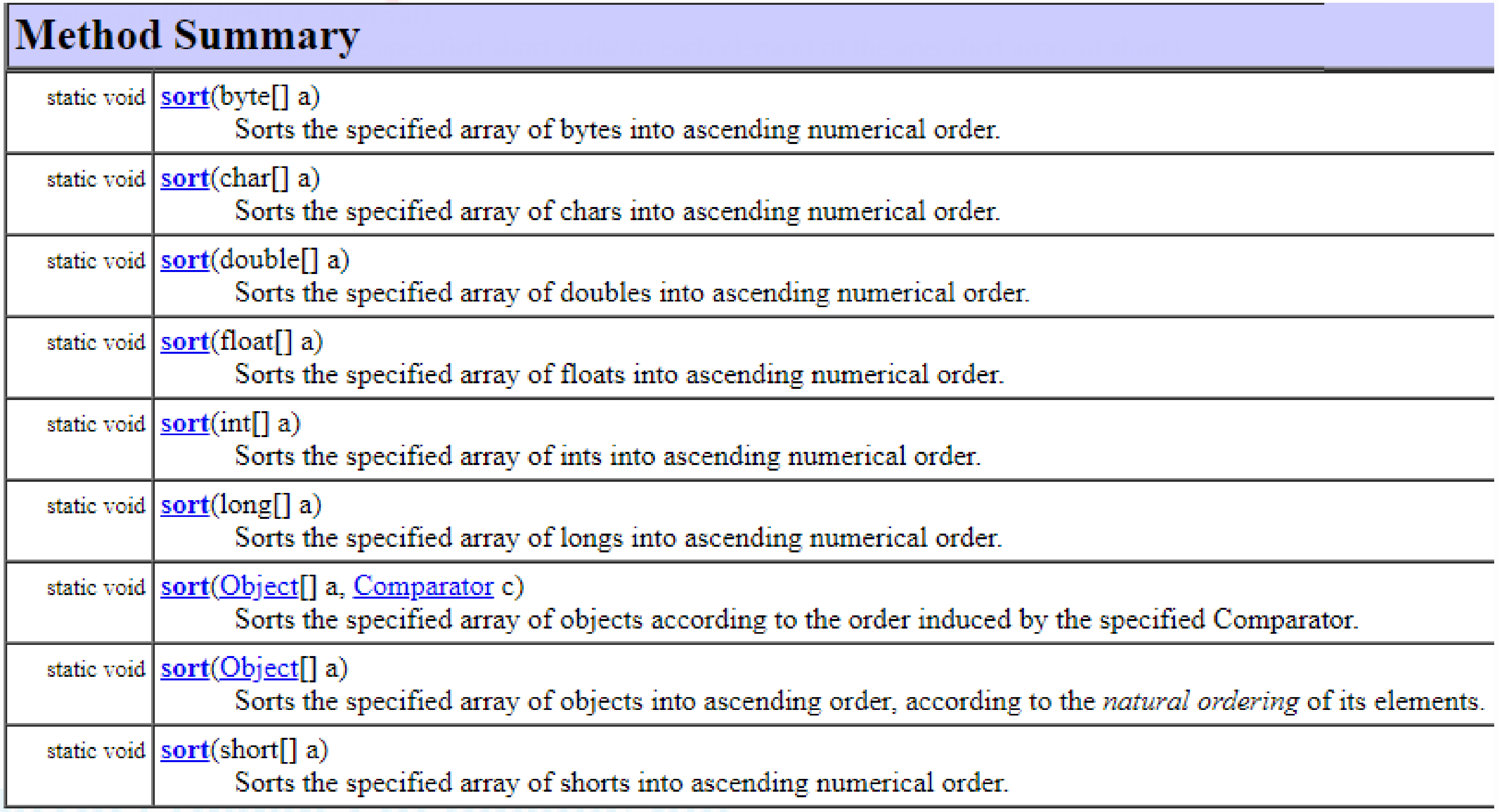
Class java.util.Arrays

- This class contains various methods for manipulating arrays (such as sorting and searching)



Method Summary	
static List	asList(Object[] a) Returns a fixed-size List backed by the specified array.
static int	binarySearch(byte[] a, byte key) Searches the specified array of bytes for the specified value using the binary search algorithm.
static int	binarySearch(char[] a, char key) Searches the specified array of chars for the specified value using the binary search algorithm.
static int	binarySearch(double[] a, double key) Searches the specified array of doubles for the specified value using the binary search algorithm.
static int	binarySearch(float[] a, float key) Searches the specified array of floats for the specified value using the binary search algorithm.
static int	binarySearch(int[] a, int key) Searches the specified array of ints for the specified value using the binary search algorithm.
static int	binarySearch(long[] a, long key) Searches the specified array of longs for the specified value using the binary search algorithm.
static int	binarySearch(Object[] a, Object key, Comparator c) Searches the specified array for the specified Object using the binary search algorithm.
static int	binarySearch(Object[] a, Object key) Searches the specified array for the specified Object using the binary search algorithm.
static int	binarySearch(short[] a, short key) Searches the specified array of shorts for the specified value using the binary search algorithm.

Class java.util.Arrays



Method Summary	
static void	sort(byte[] a) Sorts the specified array of bytes into ascending numerical order.
static void	sort(char[] a) Sorts the specified array of chars into ascending numerical order.
static void	sort(double[] a) Sorts the specified array of doubles into ascending numerical order.
static void	sort(float[] a) Sorts the specified array of floats into ascending numerical order.
static void	sort(int[] a) Sorts the specified array of ints into ascending numerical order.
static void	sort(long[] a) Sorts the specified array of longs into ascending numerical order.
static void	sort(Object[] a, Comparator c) Sorts the specified array of objects according to the order induced by the specified Comparator.
static void	sort(Object[] a) Sorts the specified array of objects into ascending order, according to the *natural ordering* of its elements.
static void	sort(short[] a) Sorts the specified array of shorts into ascending numerical order.

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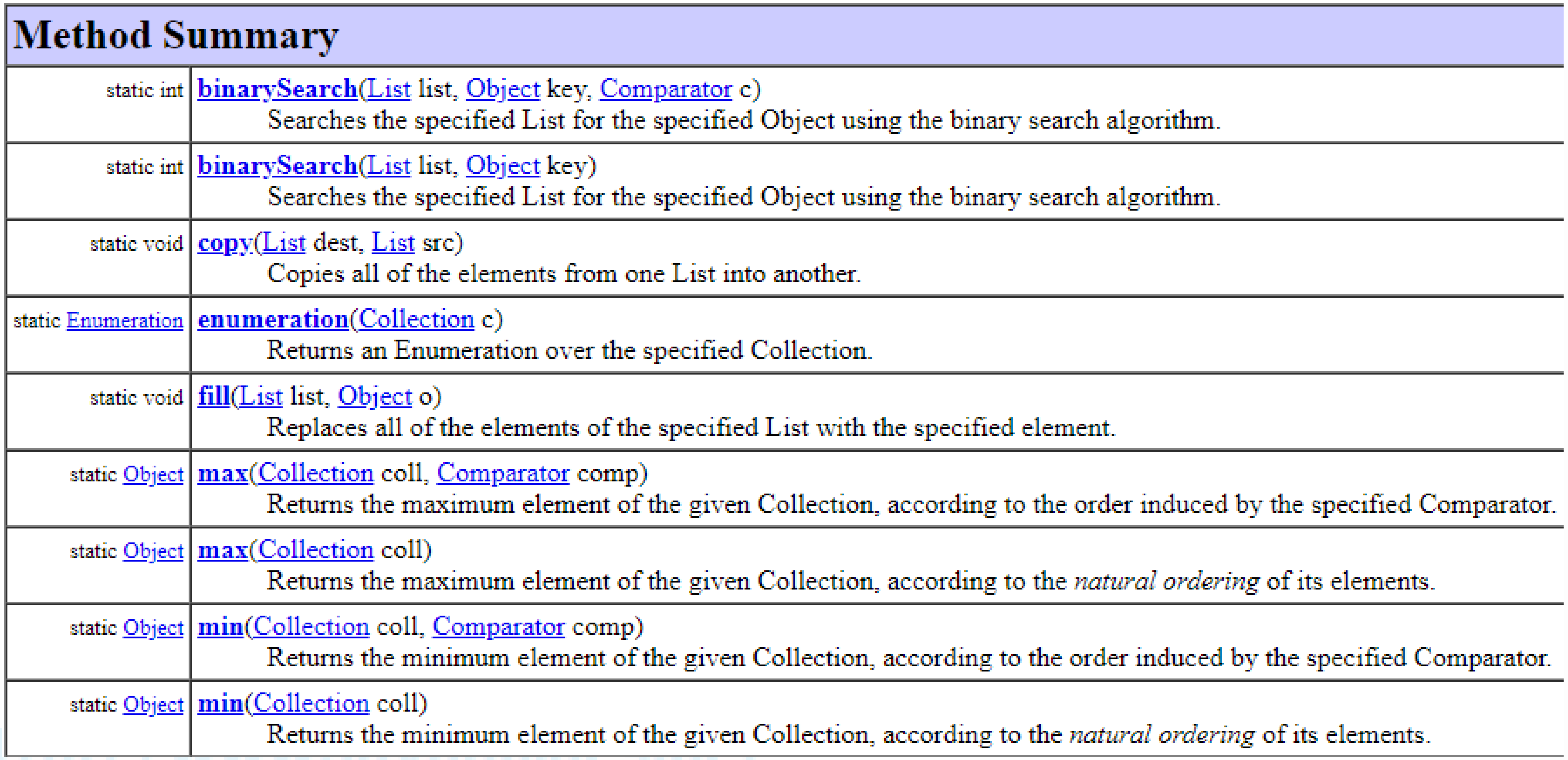
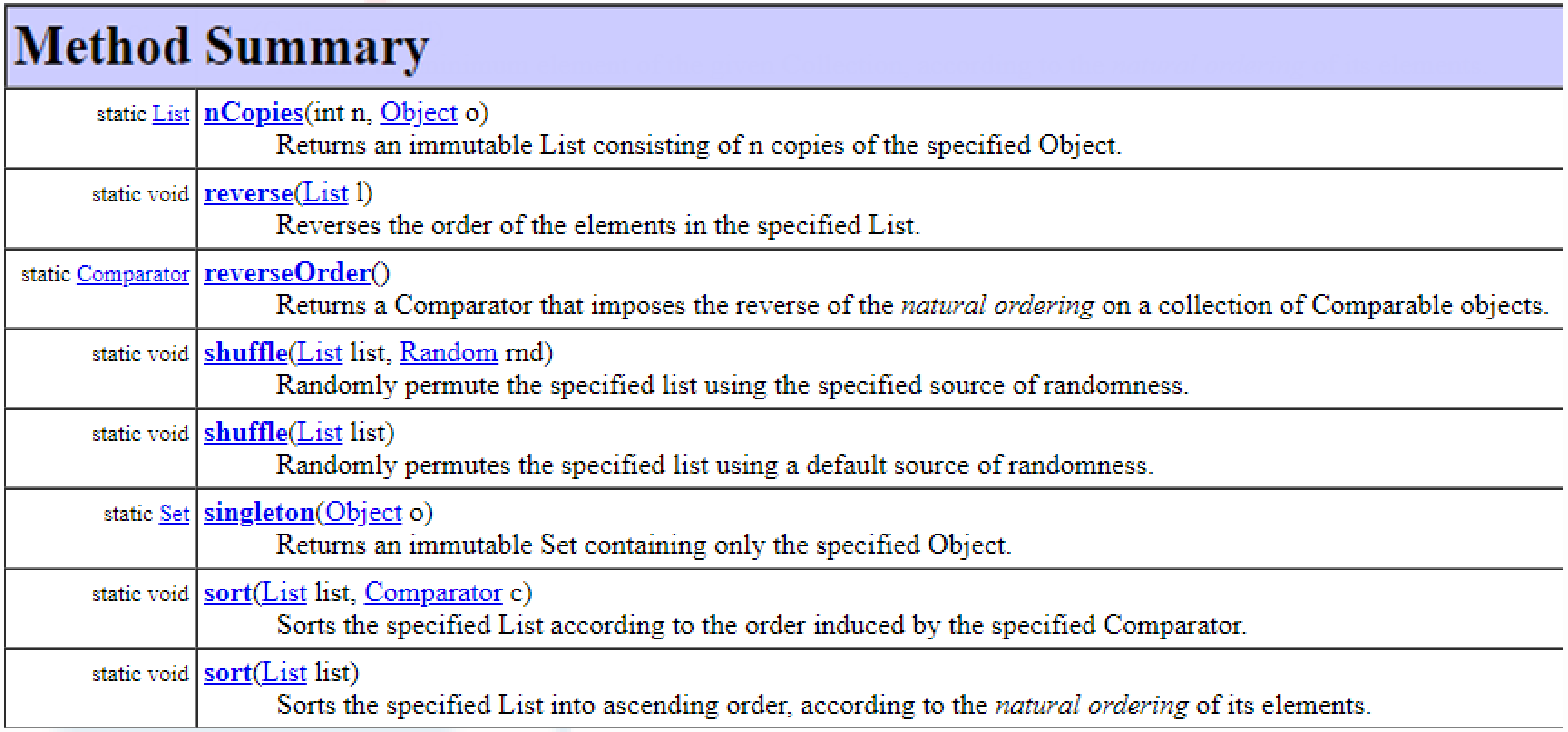
Class java.util.Collections

- This class consists exclusively of static methods that operate on or return Collections.



Method Summary	
static int	**binarySearch**(List list, Object key, Comparator c) Searches the specified List for the specified Object using the binary search algorithm.
static int	**binarySearch**(List list, Object key) Searches the specified List for the specified Object using the binary search algorithm.
static void	**copy**(List dest, List src) Copies all of the elements from one List into another.
static Enumeration	**enumeration**(Collection c) Returns an Enumeration over the specified Collection.
static void	**fill**(List list, Object o) Replaces all of the elements of the specified List with the specified element.
static Object	**max**(Collection coll, Comparator comp) Returns the maximum element of the given Collection, according to the order induced by the specified Comparator.
static Object	**max**(Collection coll) Returns the maximum element of the given Collection, according to the *natural ordering* of its elements.
static Object	**min**(Collection coll, Comparator comp) Returns the minimum element of the given Collection, according to the order induced by the specified Comparator.
static Object	**min**(Collection coll) Returns the minimum element of the given Collection, according to the *natural ordering* of its elements.

Class java.util.Collections



Method Summary	
static List	**nCopies**(int n, Object o) Returns an immutable List consisting of n copies of the specified Object.
static void	**reverse**(List l) Reverses the order of the elements in the specified List.
static Comparator	**reverseOrder**() Returns a Comparator that imposes the reverse of the *natural ordering* on a collection of Comparable objects.
static void	**shuffle**(List list, Random rnd) Randomly permute the specified list using the specified source of randomness.
static void	**shuffle**(List list) Randomly permutes the specified list using a default source of randomness.
static Set	**singleton**(Object o) Returns an immutable Set containing only the specified Object.
static void	**sort**(List list, Comparator c) Sorts the specified List according to the order induced by the specified Comparator.
static void	**sort**(List list) Sorts the specified List into ascending order, according to the *natural ordering* of its elements.

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Objects Comparison

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Comparing objects

- Operators like < and > do not work with objects in Java.
  - But we do think of some types as having an ordering (e.g. `Date`s).

- **natural ordering**: Rules governing the relative placement of all values of a given type.
  - Implies a notion of equality (like `equals`) but also < and > .
  - **total ordering**: All elements can be arranged in $A \leq B \leq C \leq \ldots$ order.

- **comparison function**: Code that, when given two objects *A* and *B* of a given type, decides their relative ordering:
  - A < B,   A == B,   A > B

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Objects Comparison

» Comparable interface

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The Comparable interface

- The standard way for a Java class to define a comparison function for its objects is to implement the `Comparable` interface.

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

- A call of **A**.`compareTo`(**B**) should return:

  a value < 0 if A comes "before" B in the ordering,

  a value > 0 if A comes "after" B in the ordering,

  or exactly 0 if A and B are considered "equal" in the ordering. ➔Consider implementing `Comparable`.

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compareTo example

```
public class Point implements Comparable<Point> {
    // sort by x and break ties by y
    public int compareTo(Point other) {
        if (x < other.x) {
            return -1;
        } else if (x > other.x) {
            return 1;
        } else if (y < other.y) {
            return -1;    // same x, smaller y
        } else if (y > other.y) {
            return 1;     // same x, larger y
        } else {
            return 0;     // same x and same y
        }
    }

    // subtraction trick:
    // return (x != other.x) ? (x - other.x) : (y - other.y);
}
```

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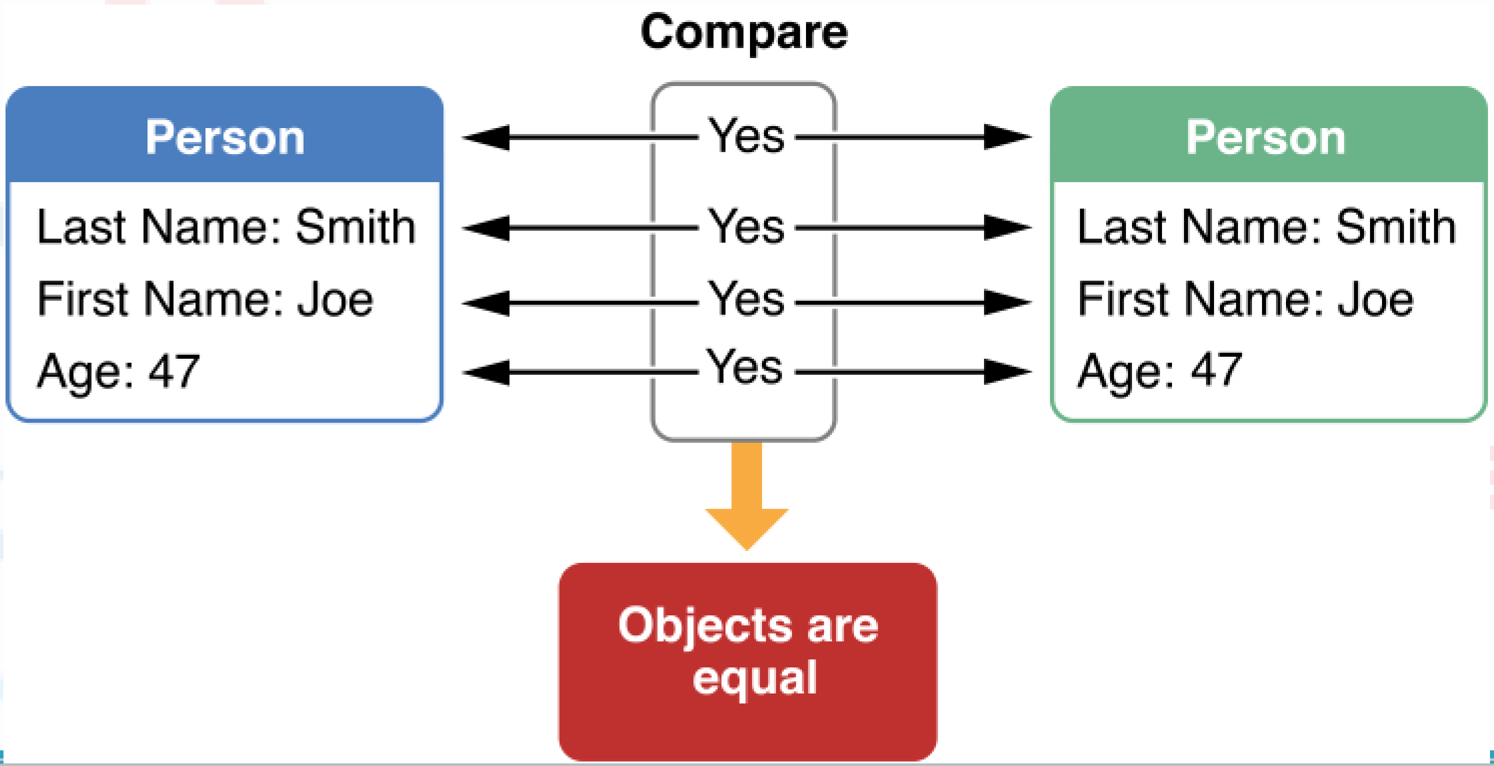
compareTo and equals

- `compareTo` should generally be consistent with `equals`.
  - `a.compareTo(b) == 0` should imply that `a.equals(b)`.



compareTo and equals

- Employee e = new Employee(...);
- e.compareTo(null);//???
- e.equals(null);//???

- Note that null is not an instance of any class, thus:
  - e.compareTo(null) should throw a NullPointerException,
  - even though e.equals(null) returns false.

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What's the "natural" order?

```
public class Rectangle implements Comparable<Rectangle> {
    private int x, y, width, height;

    public int compareTo(Rectangle other) {
        // ...?
    }
}
```

- What is the "natural ordering" of rectangles?
  - By x, breaking ties by y?
  - By width, breaking ties by height?
  - By area? By perimeter?

- Do rectangles have any "natural" ordering?
  - Might we ever want to sort rectangles into some order anyway?

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Objects Comparison

- Comparator interface

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Comparator interface

```
public interface Comparator<T> {
    public int compare(T first, T
  second);
}
```

- Interface `Comparator` is an external object that specifies a comparison function over some other type of objects.
  - Allows you to define multiple orderings for the same type.
  - Allows you to define a specific ordering for a type even if there is no obvious "natural" ordering for that type.

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Comparator examples

```
public class RectangleAreaComparator
        implements Comparator<Rectangle> {
// compare in ascending order by area (WxH)

public int compare(Rectangle r1, Rectangle r2) {
      return r1.getArea() - r2.getArea();
    }
}
```

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Comparator examples (cont.)

```
public class RectangleXYComparator
        implements Comparator<Rectangle> {
    // compare by ascending x, break ties by y
    public int compare(Rectangle r1, Rectangle r2) {
        if (r1.getX() != r2.getX()) {
            return r1.getX() - r2.getX();
        } else {
            return r1.getY() - r2.getY();
        }
    }
}
```

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Using Comparators

- **TreeSet** and **TreeMap** can accept a `Comparator` parameter.

```
Comparator<Rectangle> comp = new
  RectangleAreaComparator();
Set<Rectangle> set = new TreeSet<Rectangle>(comp);
```

- Methods are provided to reverse a `Comparator`'s ordering:

```
Collections.reverseOrder()
Collections.reverseOrder(comparator)
```

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Using Comparators (cont.)

- Searching and sorting methods can accept `Comparator`s.

```
Arrays.binarySearch(array, value, comparator)
Arrays.sort(array, comparator)
Collections.binarySearch(list, comparator)
Collections.max(collection, comparator)
Collections.min(collection, comparator)
Collections.sort(list, comparator)
```

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Using `compareTo`

- `compareTo` can be used as a test in an `if` statement.

```
String a = "alice";
String b = "bob";
if (a.compareTo(b) < 0) {   // true
    ...
}
```

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Using `compareTo`

Primitives	Objects
`if (a < b) { ...`	`if (a.compareTo(b) < 0) { ...`
`if (a <= b) { ...`	`if (a.compareTo(b) <= 0) { ...`
`if (a == b) { ...`	`if (a.compareTo(b) == 0) { ...`
`if (a != b) { ...`	`if (a.compareTo(b) != 0) { ...`
`if (a >= b) { ...`	`if (a.compareTo(b) >= 0) { ...`
`if (a > b) { ...`	`if (a.compareTo(b) > 0) { ...`

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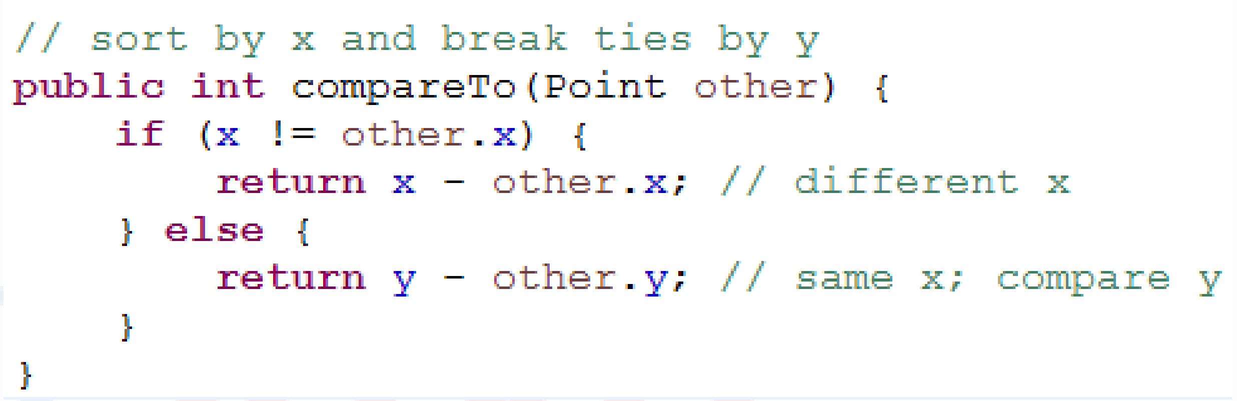
`compareTo` tricks

- *subtraction trick* – Subtracting related numeric values produces the right result for what you want `compareTo` to return:



```
// sort by x and break ties by y
public int compareTo(Point other) {
    if (x != other.x) {
        return x - other.x;  // different x
    } else {
        return y - other.y;  // same x; compare y
    }
}
```

- The idea:
  - if `x > other.x`, then `x - other.x > 0`
  - if `x < other.x`, then `x - other.x < 0`
  - if `x == other.x`, then `x - other.x == 0`

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NOTE: This trick doesn't work for `doubles`

compareTo tricks 2

- *delegation trick* – If your object's fields are comparable (such as strings), use their `compareTo` results to help you:

```
// sort by employee name, e.g. "Jim" < "Susan"
public int compareTo(Employee other) {
    return name.compareTo(other.getName());
}
```

- *`toString` trick* – If your object's `toString` representation is related to the ordering, use that to help you:

```
// sort by date, e.g. "09/19" > "04/01"
public int compareTo(Date other) {
    return toString().compareTo(other.toString());
}
```

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Section complete

Next Section ►►

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Count unique words?

- How to write a program that counts the number of unique words in a large text file?

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Count unique words? (cont.)

- How to write a program that counts the number of unique words in a large text file:
  - Store the words in a collection
  - Report the number of unique words
  - Allow the user to search for a word, and report whether or not the word occurred

➔What **<u>collection</u>** would you use?

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Set

A List Which Each Element just Occurs One Time

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Definition

- A *set*:
  - A collection of elements, without duplicates.
  - Allowed operations: add, remove, search (contains)
  - No indexes – *we cannot get element at index i*
  - Order is unimportant
- Examples:
  - {“PINE”,“APPLE”, “PEN”, “PINE”} => LIST
  - {“PINE”, “APPLE”, “PEN”} => SET
  - {1,2,3,4,5,2,3} => LIST
  - {1,2,3,4,5} => SET

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Set methods

- Fundamental methods:
  - add(e): Adds the element e to S (if not already present).
  - remove(e): Removes the element e from S (if it is present).
  - contains(e): Returns whether e is an element of S.
  - iterator( ): Returns an iterator of the elements of S.

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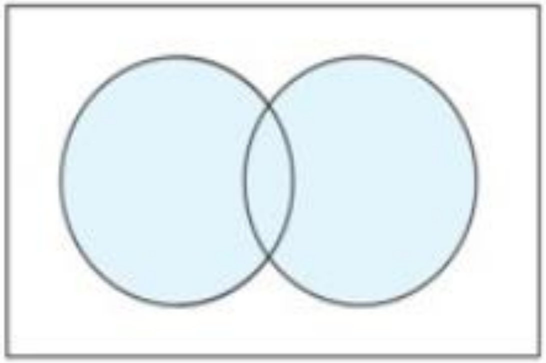
Set operations

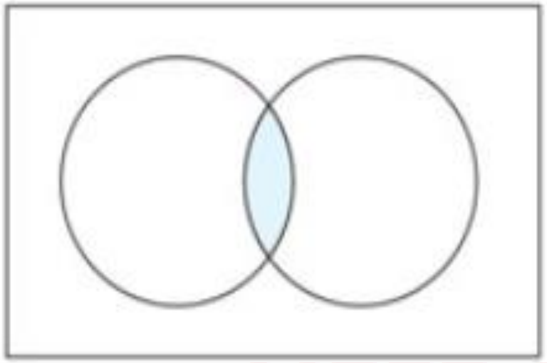
- The traditional mathematical set operations of union, intersection, and subtraction of two sets S and T:

union



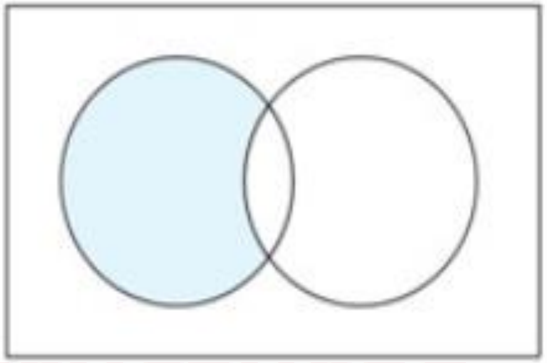
{e: e is in S or e is in T}

intersection



{e: e is in S and e is in T}

subtraction



{e: e is in S and e is not in T}

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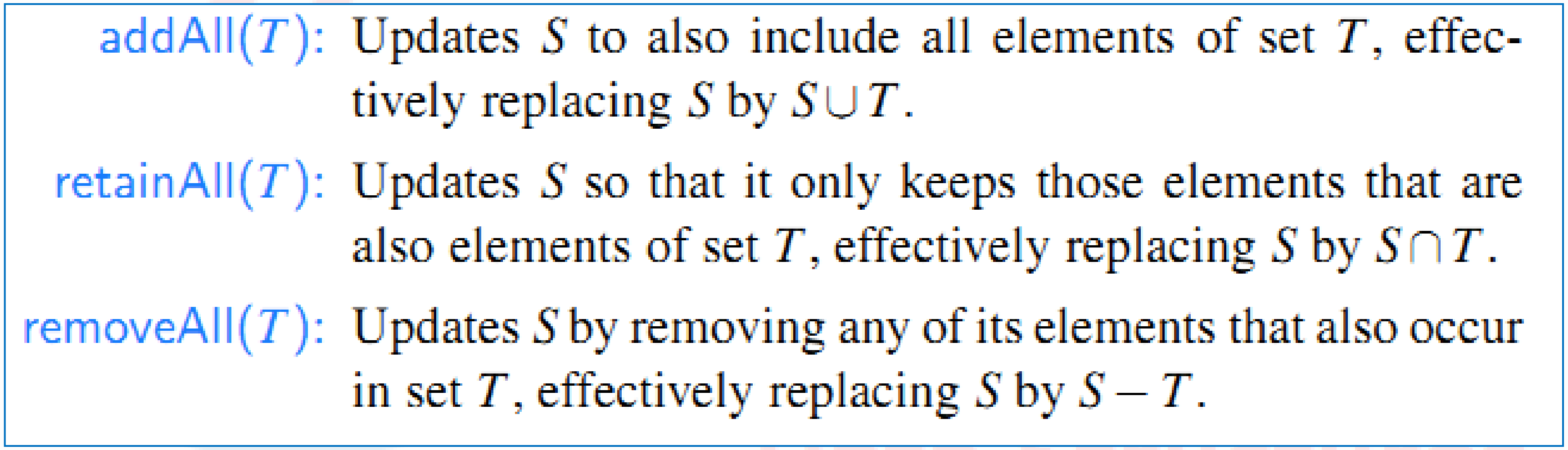
Set operations (cont.)

- These operations are provided through the following methods (Set interface):



addAll(T):	Updates S to also include all elements of set T, effectively replacing S by $S \cup T$.
retainAll(T):	Updates S so that it only keeps those elements that are also elements of set T, effectively replacing S by $S \cap T$.
removeAll(T):	Updates S by removing any of its elements that also occur in set T, effectively replacing S by $S - T$.

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Example

- Testing if s2 is a *subset* of s1
  s1.containsAll(s2)

- Setting s1 to the *union* of s1 and s2
  s1.addAll(s2)

- Setting s1 to the *intersection* of s1 and s2
  s1.retainAll(s2)

- Setting s1 to the *set difference* of s1 and s2
  s1.removeAll(s2)

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Iterators for sets

- A set has a method Iterator iterator( ) to create an iterator over the set
- The iterator has the usual methods:
  - boolean hasNext()
  - Object next()
  - void remove()
- remove() allows you to remove elements as you iterate over the set
- If you change the set in any other way during iteration, the iterator will throw a ConcurrentModificationException

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Set implementation

- In Java, Sets implement the Set interface in java.util package:
  - HashSet implemented using a "hash table" array very fast elements are stored in unpredictable order
  - TreeSet implemented using a "binary search tree“ pretty fast elements are stored in sorted order
  - LinkedHashSet implemented as a hash table with a linked list running through it, it provides *insertion-ordered* iteration (least recently inserted to most recently) and runs nearly as fast as HashSet.

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What is hashing?

- Technique for finding elements without making a linear search through all elements
- Hash function is a function that computes an integer value (called a hash code) from an object (different objects should have different hash codes)
- Object class has a hashCode method
- int h = x.hashCode();

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Hash functions

- Should avoid collisions (two or more different objects with the same hash code)
- If you have your own objects you write:
  - public int hashCode( )
  - When adding x.equals(y) => x.hashCode() == y.hashCode (avoid duplicates)
- E.g. for a circle so that circles of different radii are stored separately.
- Forgetting to implement hashCode means the one assoc with Object is used – not a good idea.

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HashSet

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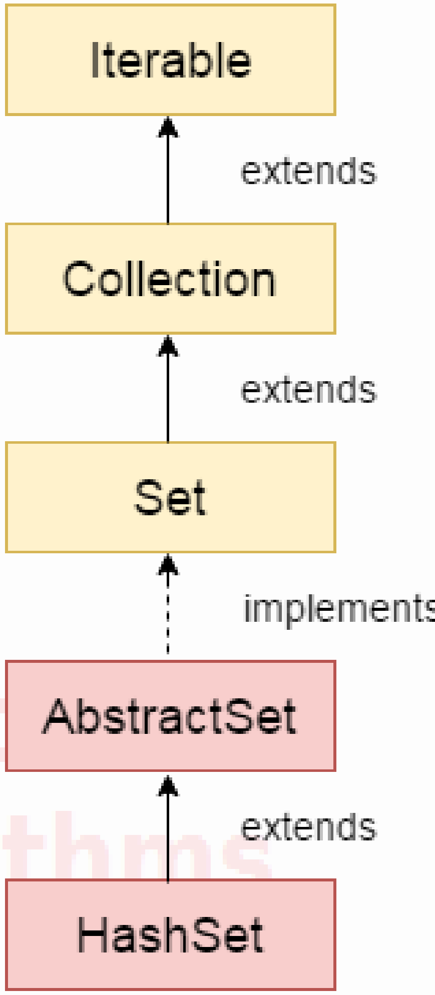
HashSet

- HashSet implements the interface Set.
  - Implemented using a hash table.
  - Storing the elements by using a mechanism called **hashing**.
  - No ordering of elements.
  - add, remove, and contains methods constant time complexity O(c).

→HashSet is the best approach for search operations.



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HashSet (cont.)

- **Constructors**:
  - HashSet():
    - construct a default HashSet (capacity: 16, loadFactor: 0.75).
  - HashSet(int capacity):
    - initialize the capacity of the hash set to the given integer value capacity. The capacity grows automatically as elements are added to the HashSet.
  - HashSet(int capacity, float loadFactor):
    - initialize the capacity of the hash set to the given integer value capacity and the specified load factor.
  - HashSet(Collection<? extends E> c):
    - initialize the hash set by using the elements of the collection c.

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Membership testing in HashSets

- When testing whether a HashSet contains a given object, Java does this:
  - Java computes the hash code for the given object
    - Hash codes are discussed in a separate lecture
    - Java compares the given object, using equals, *only* with elements in the set that have the *same* hash code
- Hence, an object will be considered to be in the set only if *both*:
  - It has the same hash code as an element in the set, *and*
  - The equals comparison returns true
- **Moral:** to use a HashSet properly, you must have a good public boolean equals(Object) and a good public int hashCode() defined for the *elements* of the set

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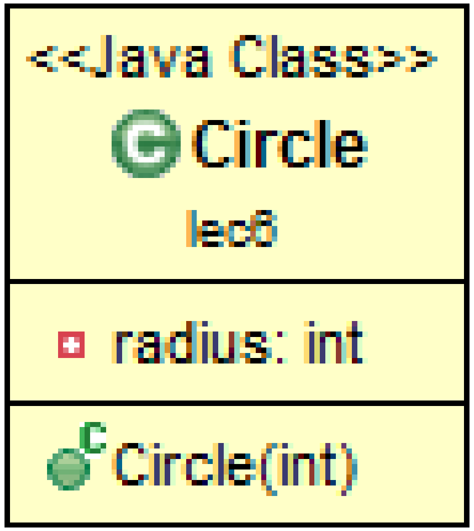
Example

- Consider:



```
Set<Circle> circles = new HashSet<Circle>();
circles.add(new Circle(5));
if (circles.contains(new Circle(5)))
    System.out.println("Circle of radius 5 exists");
else
    System.out.println("Circle of radius 5 does not exists");
```

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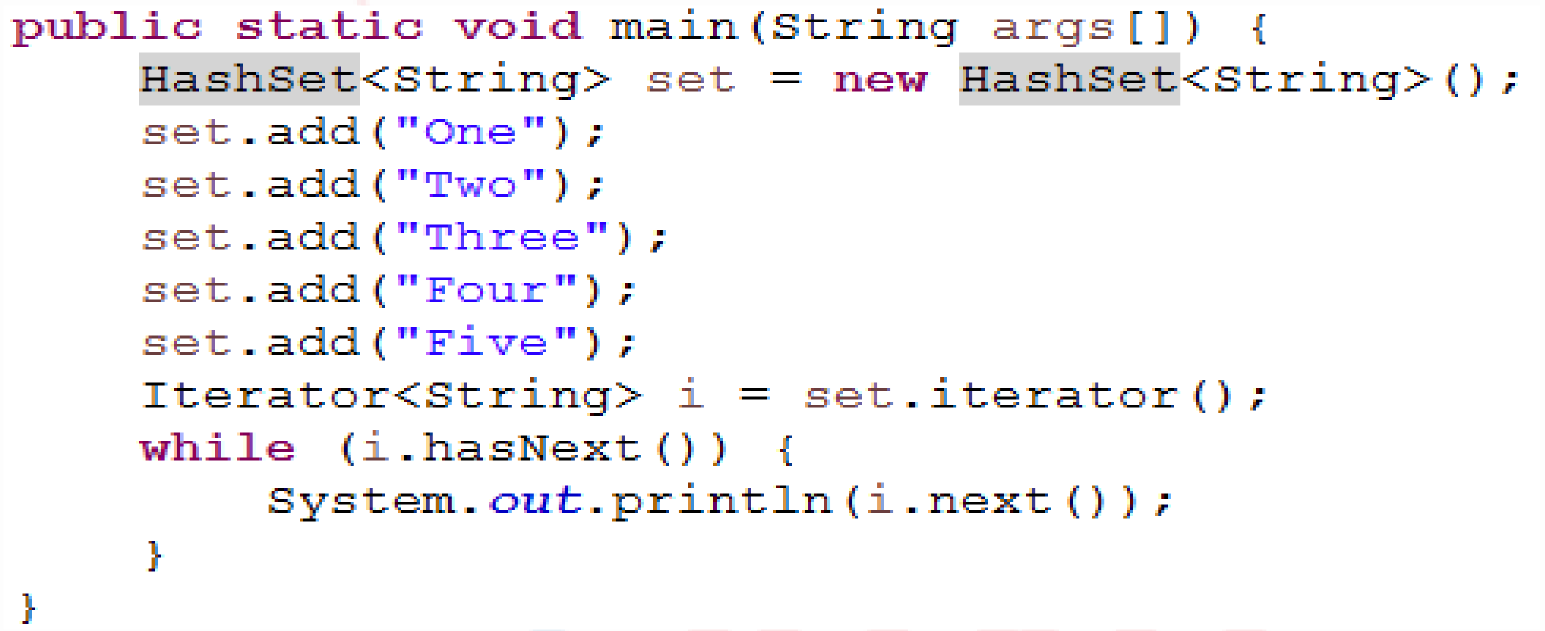
Using HashSet



```
public static void main(String args[]) {
    HashSet<String> set = new HashSet<String>();
    set.add("One");
    set.add("Two");
    set.add("Three");
    set.add("Four");
    set.add("Five");
    Iterator<String> i = set.iterator();
    while (i.hasNext()) {
        System.out.println(i.next());
    }
}
```

- **Output**:

```
Five
One
Four
Two
Three
```

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Notes on foreach/iterator

- For a given set of circles as follows:

```
TreeSet<Circle> set = new TreeSet<Circle>();

set.add(new Circle(1));
set.add(new Circle(2));
set.add(new Circle(3));
set.add(new Circle(2));
```

- How to remove a specific cricle while iterating a set of circles?

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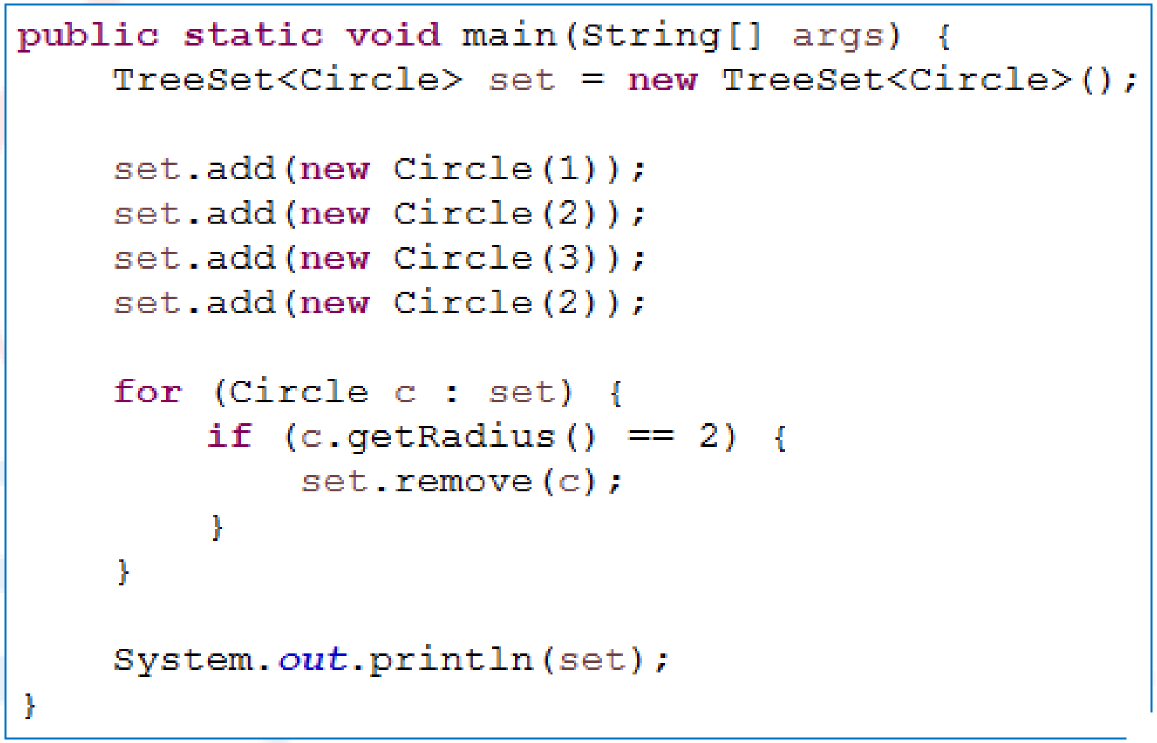
Notes on foreach/iterator

- It’s easy, using foreach approach:

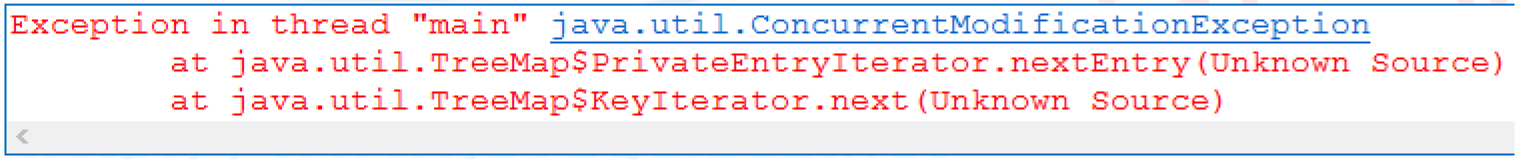


```
public static void main(String[] args) {
    TreeSet<Circle> set = new TreeSet<Circle>();

    set.add(new Circle(1));
    set.add(new Circle(2));
    set.add(new Circle(3));
    set.add(new Circle(2));

    for (Circle c : set) {
        if (c.getRadius() == 2) {
            set.remove(c);
        }
    }

    System.out.println(set);
}
```



```
Exception in thread "main" java.util.ConcurrentModificationException
	at java.util.TreeMap$PrivateEntryIterator.nextEntry(Unknown Source)
	at java.util.TreeMap$KeyIterator.next(Unknown Source)
```

Notes on foreach/iterator

- How about using iterator approach:

```
public static void main(String[] args) {
    TreeSet<Circle> set = new TreeSet<Circle>();

    set.add(new Circle(1));//yes, add ok
    set.add(new Circle(2));//yes, add ok
    set.add(new Circle(3));//yes, add ok
    set.add(new Circle(2));//no, add fail (because of duplication)

    Iterator<Circle> iter = set.iterator();
    while (iter.hasNext()) {
        Circle next = iter.next();
        if (next.getRadius() == 2)
            iter.remove();
    }
    System.out.println(set);
}
```

```
[[Circle: 1], [Circle: 3]]
```

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SortedSet

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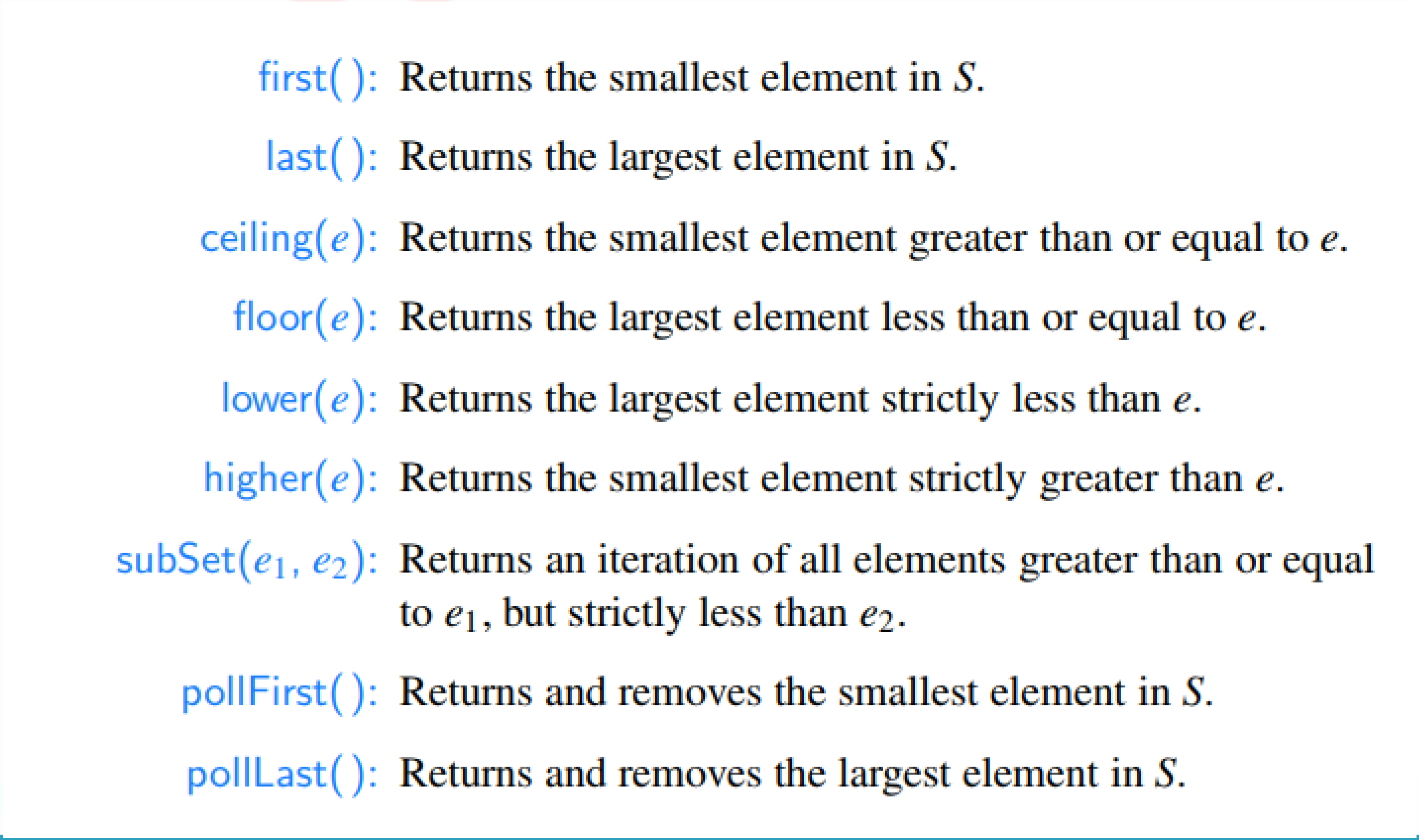
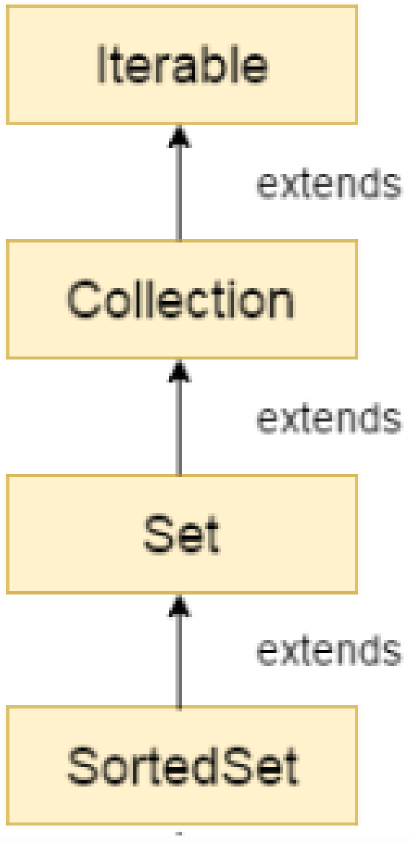
SortedSet

- A SortedSet is just like a Set, except that an Iterator will go through it in **ascending order**
- SortedSet is implemented by TreeSet

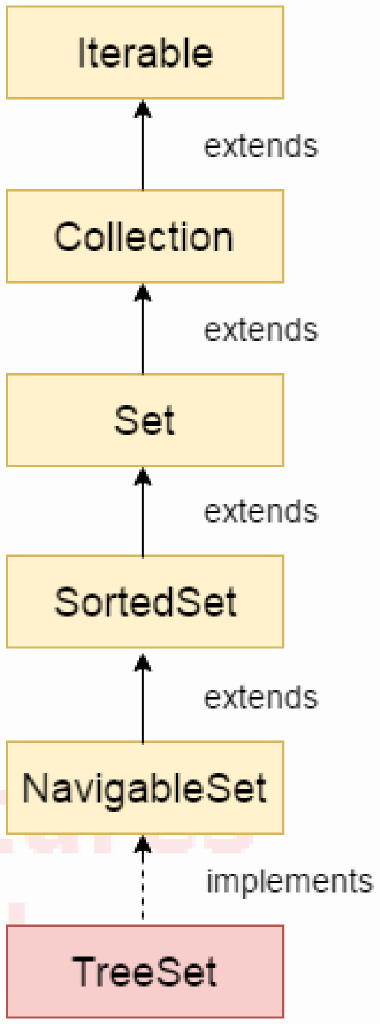


first( ):	Returns the smallest element in S.
last( ):	Returns the largest element in S.
ceiling(e):	Returns the smallest element greater than or equal to e.
floor(e):	Returns the largest element less than or equal to e.
lower(e):	Returns the largest element strictly less than e.
higher(e):	Returns the smallest element strictly greater than e.
subSet(e_1, e_2):	Returns an iteration of all elements greater than or equal to e_1, but strictly less than e_2.
pollFirst( ):	Returns and removes the smallest element in S.
pollLast( ):	Returns and removes the largest element in S.



TreeSet

- TreeSet implements the interface **Set.**
  - Implemented using a tree structure.
  - Guarantees ordering of elements.
  - add, remove, and contains methods logarithmic time complexity O(log (n)), where n is the number of elements in the set.



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TreeSet (cont.)

- TreeSet():
  - construct an empty tree set that will be sorted in ascending order according to the natural order of the tree set.
- TreeSet(Collection<? extends E> c):
  - build a new tree set that contains the elements of the collection c.
- TreeSet(Comparator<? super E> comparator):
  - construct an empty tree set that will be sorted according to given comparator.
- TreeSet(SortedSet<E> s):
  - build a TreeSet that contains the elements of the given SortedSet.

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Membership testing in TreeSets

- In a TreeSet, elements are kept in order
- That means Java must have some means of comparing elements to decide which is “larger” and which is “smaller”
- Java does this by using either:
  - The int compareTo(Object) method of the Comparable interface, or
  - The int compare(Object, Object) method of the Comparator interface
- Which method to use is determined *when the TreeSet is constructed*

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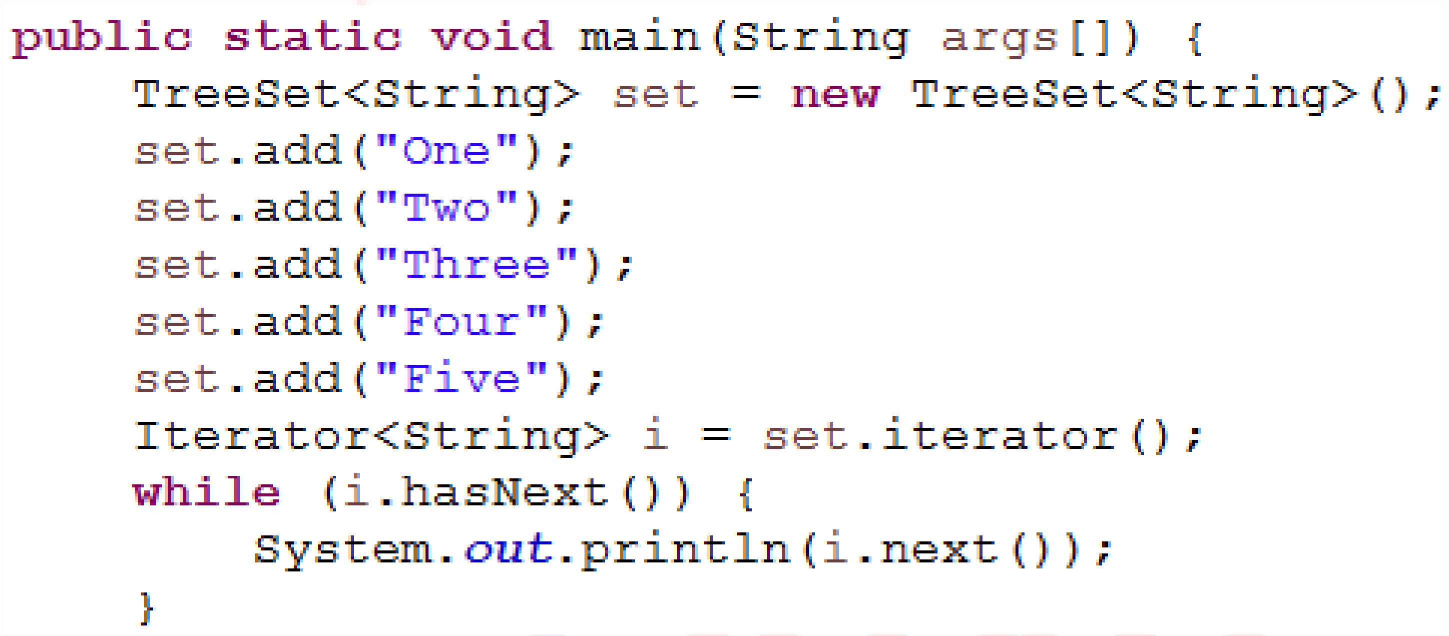
Using TreeSet



```
public static void main(String args[]) {
    TreeSet<String> set = new TreeSet<String>();
    set.add("One");
    set.add("Two");
    set.add("Three");
    set.add("Four");
    set.add("Five");
    Iterator<String> i = set.iterator();
    while (i.hasNext()) {
        System.out.println(i.next());
    }
```

- **Output**:

```
Five
Four
One
Three
Two
```

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LinkedHashSet

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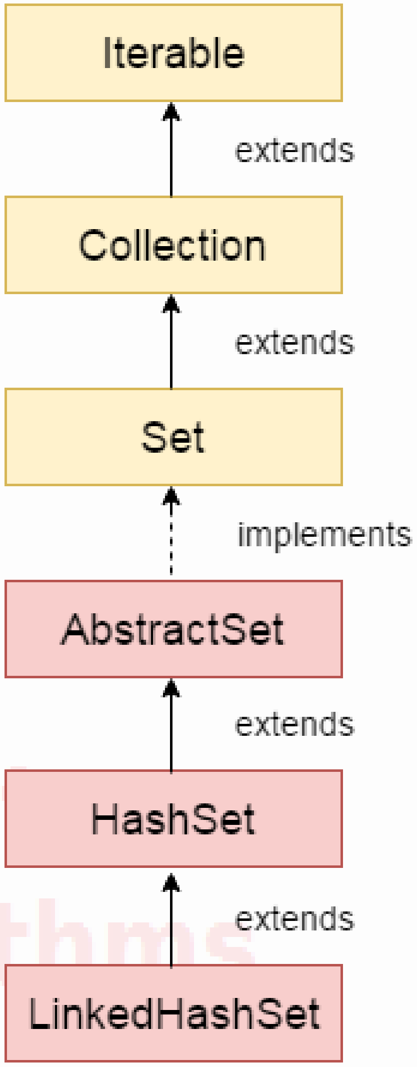
LinkedHashSet

- LinkedHashSet:
  - contains unique elements only like HashSet.
  - provides all optional set operation and permits null elements.
  - is non synchronized.
  - maintains insertion order.



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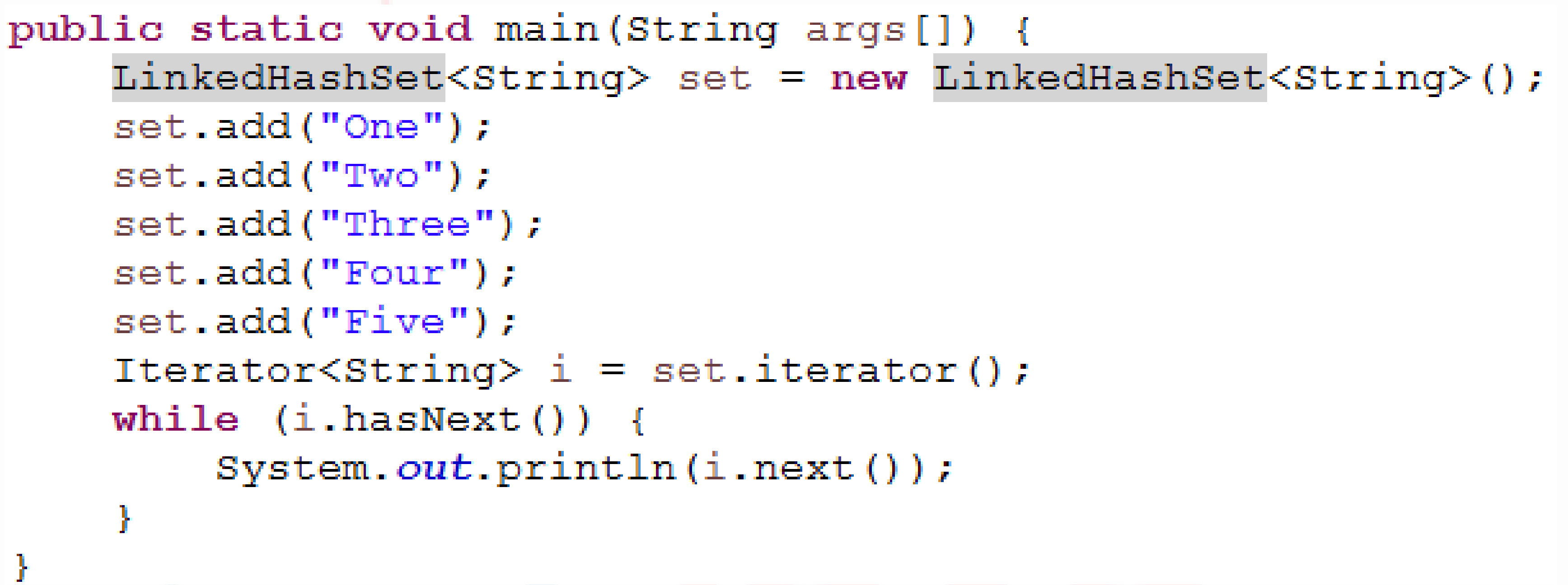
Using LinkedHashSet



```
public static void main(String args[]) {
    LinkedHashSet<String> set = new LinkedHashSet<String>();
    set.add("One");
    set.add("Two");
    set.add("Three");
    set.add("Four");
    set.add("Five");
    Iterator<String> i = set.iterator();
    while (i.hasNext()) {
        System.out.println(i.next());
    }
}
```

- **Output**:

```
One
Two
Three
Four
Five
```

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Flawed compareTo method

```
public class BankAccount implements Comparable<BankAccount> {
    private String name;
    private double balance;
    private int id;

    // ...
    public int compareTo(BankAccount other) {
        return name.compareTo(other.name); // order by name
    }

    public boolean equals(Object o) {
        if (o != null && getClass() == o.getClass()) {
            BankAccount ba = (BankAccount) o;
            return name.equals(ba.name) && balance == ba.balance && id == ba.id;
        } else {
            return false;
        }
    }
}
```

- What's bad about the above?

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Flawed compareTo method (cont.)

```
BankAccount ba1 = new BankAccount("Jim", 123, 20.00);
BankAccount ba2 = new BankAccount("Jim", 456, 984.00);


Set<BankAccount> accounts = new
  TreeSet<BankAccount>();
accounts.add(ba1);
accounts.add(ba2);
System.out.println(accounts);      // [Jim($20.00)]
```

- Where did the other account go?
  - Since the two accounts are "equal" by the ordering of `compareTo`, the set thought they were duplicates and didn't store the second.

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Q
A
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