**Java Collections**

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## **1. What are Java Collections?**

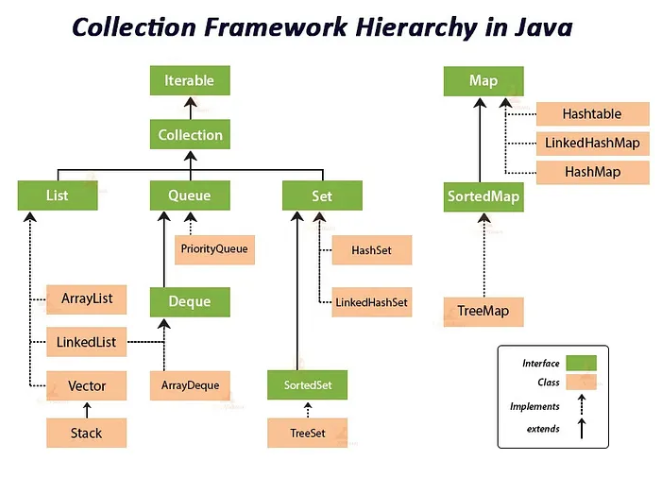
The Java Collections Framework (JCF) is a set of classes and interfaces that provide data structures to store and manipulate groups of objects efficiently. It serves as the foundation for handling collections of data in Java, simplifying many common data manipulation tasks and improving code reusability and performance.

Why Use Collections Instead of Arrays?

Arrays are fixed in size, making them rigid for dynamic data manipulation. Collections provide flexible and efficient ways to manage data that grows or shrinks dynamically. With collections, you get:

* Dynamic Size: Collections grow or shrink in size automatically, while arrays have a fixed size.
* Data Structure Variety: Collections provide a wide range of data structures (lists, sets, maps, queues, etc.).
* Built-in Utility Methods: Collections come with methods to add, remove, search, and manipulate data efficiently.

### # Java Collections Framework Architecture



The JCF has a well-defined architecture of interfaces and classes, making it easy to understand the relationships among different collection types.

Here’s a high-level view of the JCF architecture:

**Core Interfaces:** Define the behavior of collections.

* Iterable
* Collection
* List, Set, Queue, Map, and their variants

**Implementations:** Classes implementing these interfaces.

ArrayList, LinkedList, HashSet, TreeSet, HashMap, etc.

**List:-**

This stores data in ordered collection and can perform index based operations.

|  |  |
| --- | --- |
| ArrayList | Dynamic array, random access, non-synchronized  Example of insertion and deletion |
| Vector | Synchronized version of ArrayList, legacy class  Are thread-safe (should only be use in multithreading environment |
| LinkedList | Doubly linked list, best for frequent insertions and deletions. |

**Set:-**

Unordered collection of object in which no duplicates are allowed.

|  |  |
| --- | --- |
| HashSet | Hash table, no duplicates, allows null |
| LinkedHashSet | Maintains insertion order |
| TreeSet | Sorted order, no duplicates |

**Queue:-**

Maintain order of data in FIFO structure.

|  |  |
| --- | --- |
| Queue and PriorityQueue | FIFO structure, custom priority with comparator |

**Deque:-**

Double-ended queue, supports insertion/removal from both ends

|  |  |
| --- | --- |
| ArrayDeque | Resizable array implementation of the Deque |

**Map:-**

Stores data in key-value pair. Does not extends the Collection Interface.

|  |  |
| --- | --- |
| HashMap | Key-value pairs, hash table, allows one null key |
| LinkedHashMap | Maintains insertion order |
| TreeMap | Sorted map based on natural ordering or comparator |
| HashTable | Synchronized, no null keys/values, legacy class |

Note:-

* All class starting with Linked, means they will maintain insertion order.
* All class starting with Tree, means they are sorted.

### # Iterable Interface

The Iterable interface is the root of the Java Collections Framework. It was introduced in Java 5 to allow collections to be iterated with the enhanced for loop (also known as the for-each loop). It belongs to java.lang package.

**Ways of Iterating**

There are three ways in which objects of **Iterable** can be iterated.

1. Using [enhanced for loop](https://www.geeksforgeeks.org/for-each-loop-in-java/)(for-each loop)
2. Using Iterable [forEach](https://www.geeksforgeeks.org/iterable-foreach-method-in-java-with-examples/) loop
3. Using **Iterator<T>** interface

The methods used while traversing the collections using Iterator to perform the operations are:

* hasNext(): It returns false if we have reached the end of the collection, otherwise returns true.
* next(): Returns the next element in a collection.

import java.util.ArrayList;  
import java.util.Arrays;  
import java.util.Iterator;  
import java.util.List;  
  
public class LearnIterator {  
 public static void main(String[] args) {  
 ArrayList<String> arr = new ArrayList<>(Arrays.*asList*("Apple", "Ball", "Cat"));  
  
 //Iterate using enhanced for-each loop  
 for(String ele : arr){  
 System.*out*.println(ele);  
 }  
  
 //Iterate using ForEach Iterator  
 arr.forEach((ele) -> { System.*out*.println(ele); });  
  
 //Iterate using an Iterator  
 Iterator<String> iterator = arr.iterator();  
 while (iterator.hasNext()) {  
 String element = iterator.next();  
 System.*out*.println(element);  
 }  
 }  
}

### # Collection Interface

The Collection interface extends Iterable and represents a group of objects, known as elements. Collection is the root interface for many other collection types, such as List, Set, and Queue.

Key methods:-

| **Method Signature** | **Description** |
| --- | --- |
| boolean add(E e) | Adds an element to the collection. |
| boolean remove(Object o) | Removes a specified element from the collection. |
| boolean contains(Object o) | Checks if the collection contains the specified element. |
| int size() | Returns the number of elements in the collection. |
| boolean isEmpty() | Checks if the collection is empty. |
| void clear() | Removes all elements from the collection. |
| boolean addAll(Collection<? extends E> c) | Adds all elements from a specified collection to the current collection. |
| boolean containsAll(Collection<?> c) | Checks if the current collection contains all elements from another. |
| boolean removeAll(Collection<?> c) | Removes all elements in the collection that are also in another collection. |

Since Collection is an interface, it supports polymorphism. Any class implementing Collection can be referenced by Collection. This allows flexibility in changing the specific collection type as needed.

Can use this all ways:

ArrayList<String> arr = new ArrayList<>();  
Collection<String> arr2 = new ArrayList<>();  
List<String> arr3 = new ArrayList<>();

## **2. List Interface and its Implementations**

The List interface in Java extends the Collection interface and represents an ordered collection of elements, known as a sequence. Lists allow duplicate elements and provide precise control over the position where elements are inserted or accessed.

Key Characteristics of List

* **Order**: Elements are ordered based on their insertion order, which is preserved.
* **Indexing**: Allows positional access using indexes, starting from 0.
* **Duplicates**: Lists can contain duplicate elements.

**Different List Implementations**

| **Feature** | **ArrayList** | **LinkedList** | **Vector** | **Stack** |
| --- | --- | --- | --- | --- |
| **Underlying DS** | Dynamic Array | Doubly Linked List | Dynamic Array | Dynamic Array |
| **Thread Safety** | No | No | Yes | Yes |
| **Access Speed** | Fast (index-based) | Slow | Fast | Fast |
| **Insert/Delete** | Slow (index-based) | Fast | Slow | Fast |
| **Use Case** | Random access | Frequent inserts | Thread-safe list | LIFO operations |

|  |  |
| --- | --- |
| ArrayList | 1. Dynamic array, random access, non-synchronized 2. Example of insertion and deletion 3. Key Use Cases: Ideal for applications where frequent access to elements is required, with relatively fewer insertions and deletions. |
| Vector | 1. Synchronized version of ArrayList, legacy class 2. Are thread-safe (should only be use in multithreading environment 3. Key Use Cases: Suitable for multithreaded applications where a thread-safe dynamic array is required. |
| LinkedList | 1. Doubly linked list, best for frequent insertions and deletions. 2. Key Use Cases: Ideal for applications where frequent insertions and deletions occur at both ends or in the middle of the list. |
| Stack | 1. Supports last-in-first-out access to elements. 2. Key Use Cases: Useful for LIFO operations like evaluating expressions, tracking call stacks, etc.. |

Key Methods

| **Method Signature** | **Description** |
| --- | --- |
| void add(int index, E element) | Inserts an element at the specified position. |
| E get(int index) | Returns the element at the specified position. |
| E set(int index, E element) | Replaces the element at the specified position with a new element. |
| E remove(int index) | Removes the element at the specified position. |
| int indexOf(Object o) | Returns the index of the first occurrence of the specified element. |
| int lastIndexOf(Object o) | Returns the index of the last occurrence of the specified element. |
| List<E> subList(int fromIndex, int toIndex) | Returns a view of a portion of the list. |

### # ArrayList

import java.util.ArrayList;  
import java.util.Arrays;  
import java.util.Collection;  
import java.util.List;  
  
public class LearnArray {  
 public static void main(String args[]){  
 //Implement arraylist with data  
 Collection<String> array = new ArrayList<>(Arrays.*asList*("Apple","Ball","Cat"));  
  
 //ArrayList without data  
 ArrayList<String> arr = new ArrayList<>();  
 arr.add("Animal");  
 arr.add("Bat");  
 arr.add("Canon");  
  
 //Accessing an element  
 System.*out*.println(arr.get(1)); //Output: Bat  
  
 //get the size  
 System.*out*.println(array.size()); //Output:3  
  
 //Modify an element (Can't do arr[1] = "Banana")  
 arr.set(1, "Banana");  
  
 //remove an element  
 arr.remove(2);  
  
 //Print arrayLists  
 System.*out*.println(array); //[Apple,Ball,Cat]  
 System.*out*.println(arr); //[Animal,Banana]  
  
 //get subList  
 List<Integer> arr2 = new ArrayList<>(Arrays.*asList*(1,2,3,4,5));  
 System.*out*.println(arr2.subList(1,3)); //[2,3]  
 }  
}

### # Stack

import java.util.Stack;  
  
public class LearnStack {  
 public static void main(String[] args) {  
 Stack<String> books = new Stack<>();  
  
 // Adding elements  
 books.push("Java Programming");  
 books.push("Data Structures");  
 books.push("Algorithms");  
  
 // Accessing the top element  
 System.*out*.println("Top book: " + books.peek());  
  
 // Removing an element  
 books.pop();  
  
 System.*out*.println("Stack after pop: " + books);  
 }  
}

## **3. Set Interface and its Implementations**

The Set interface in Java extends the Collection interface and represents an unordered collection of unique elements. Unlike lists, sets do not allow duplicate elements, making them ideal for storing distinct values.

Key Characteristics of Set

* **No Duplicates:** Sets do not allow duplicate elements.
* **No Indexing:** Elements are not stored in a particular order, so they do not support accessing elements by index (except for LinkedHashSet which maintains insertion order).
* **Efficient Search**: Sets are optimized for quick searches, as they use hashing or ordering mechanisms.

Comparison of different implementations of Set

| **Feature** | **HashSet** | **LinkedHashSet** | **TreeSet** |
| --- | --- | --- | --- |
| **Underlying DS** | Hash Table | Hash Table + Linked List | Red-Black Tree |
| **Order** | No | Insertion Order | Sorted Order |
| **Null Values** | Allows one null | Allows one null | Does not allow null |
| **Performance** | O(1) for add/remove/contains | O(1) with ordered iteration | O(log n) for operations |
| **Use Case** | Unique elements with no specific order | Ordered unique elements | Sorted unique elements |

|  |  |
| --- | --- |
| HashSet | 1. Hash table, no duplicates, allows null 2. Key Use Cases: Suitable for storing unique items where order does not matter, such as storing unique IDs or tags. |
| LinkedHashSet | 1. Maintains insertion order 2. Key Use Cases: Useful when the uniqueness of elements is needed, but order is also significant, such as when tracking items recently accessed. |
| TreeSet | 1. Sorted order, no duplicates 2. Key Use Cases: Suitable for storing sorted data and when operations like range queries, min/max retrieval are needed. |

Different methods of set

| **Method Signature** | **Description** |
| --- | --- |
| boolean add(E e) | Adds an element to the set, returning false if it’s already present. |
| boolean remove(Object o) | Removes the specified element if present. |
| boolean contains(Object o) | Checks if the set contains the specified element. |
| int size() | Returns the number of elements in the set. |
| void clear() | Removes all elements from the set. |
| boolean isEmpty() | Checks if the set is empty. |
| boolean addAll(Collection<? extends E> c) | Adds all elements from another collection, ignoring duplicates. |

### # HashSet

import java.util.\*;  
  
public class LearnSet {  
 public static void main(String args[]){  
 Set<String> set = new HashSet<>();  
 set.add("Ajax");  
 set.add("Byte");  
 set.add("Code");  
  
 //Check if element exists  
 System.*out*.println(set.contains("Byte")); //true  
  
 //Add multiple elements  
 set.addAll(Arrays.*asList*("Debug","Eclipse"));  
  
 System.*out*.println(set); //[Eclipse, Byte, Code, Debug, Ajax]  
 }  
}

### # Union of Sets

import java.util.\*;  
  
public class SetUnion {  
  
 public Set<Integer> getUnion(Set<Integer> set1, Set<Integer> set2) {  
 Set<Integer> unionSet = new HashSet<>(set1);  
 unionSet.addAll(set2);  
 return unionSet;  
 }  
  
 public static void main(String args[]){  
 HashSet<Integer> set1 = new HashSet<>(Arrays.*asList*(1,2,4));  
  
 Set<Integer> set2 = new HashSet<>();  
 Integer[] arr = {5,6,3};  
 set2.addAll(Arrays.*asList*(arr));  
  
 SetUnion su = new SetUnion();  
 Set<Integer> set3 = su.getUnion(set1,set2);  
 System.*out*.println(set3); //[1,2,3,4,5,6]  
  
 }  
}

## **4. Queue Interface and its Implementations**

The Queue interface in Java represents a collection designed to hold elements in a sequence, with processing based on the First-In-First-Out (FIFO) principle. It is useful for scenarios where elements are processed in the order they arrive, such as task scheduling.

**Characteristics of Queue**

* **FIFO Order:** The first element added is the first one removed.
* **Addition and Removal:** New elements are added at the end, and elements are removed from the front.
* **Specialized Methods:** Unlike other collections, Queue includes specific methods for handling elements based on their order.

**Queue:-**

|  |  |
| --- | --- |
| PriorityQueue | 1. Special type of queue that orders elements based on priority rather than insertion order. 2. Natural Ordering: Elements are ordered according to their natural order (e.g., numbers from smallest to largest). 3. Custom Comparator: Custom ordering can be specified for more complex priority logic. 4. No Nulls: PriorityQueue does not allow null elements. |

Key methods of queue:

| **Method Signature** | **Description** |
| --- | --- |
| boolean add(E e) | Adds an element to the queue, throwing an exception if full. |
| boolean offer(E e) | Adds an element to the queue, returning false if it fails. |
| E remove() | Removes and returns the head element, throwing an exception if empty. |
| E poll() | Removes and returns the head element, or null if the queue is empty. |
| E element() | Retrieves, but does not remove, the head element. Throws an exception if empty. |
| E peek() | Retrieves, but does not remove, the head element, or returns null if empty. |

The primary implementations of Queue in Java are:

* **LinkedList** - Doubly linked list-based implementation of Queue.
* **PriorityQueue** - Special type of queue that orders elements based on priority rather than insertion order.

### # LinkedList

LinkedList can function as both a List and a Queue. When used as a Queue, it follows the FIFO ordering.

import java.util.LinkedList;  
import java.util.Queue;  
  
public class LinkedListQueueExample {  
 public static void main(String[] args) {  
 Queue<String> queue = new LinkedList<>();  
  
 // Adding elements to the queue  
 queue.add("Alice");  
 queue.add("Bob");  
 queue.add("Charlie");  
 queue.offer("Danny");  
  
 // Displaying the head element  
 System.*out*.println("Head of the queue: " + queue.peek());  
  
 // Removing and displaying each element  
 while (!queue.isEmpty()) {  
 System.*out*.println("Removing: " + queue.poll());  
 }  
 }  
}

### # PriorityQueue

import java.util.PriorityQueue;  
import java.util.Queue;  
  
public class PriorityQueueExample {  
 public static void main(String[] args) {  
 Queue<Integer> priorityQueue = new PriorityQueue<>();  
  
 // Adding elements to the priority queue  
 priorityQueue.add(10);  
 priorityQueue.add(5);  
 priorityQueue.add(15);  
 priorityQueue.add(1);  
  
 // Removing and displaying elements in priority order  
 while (!priorityQueue.isEmpty()) {  
 System.*out*.println("Removing: " + priorityQueue.poll());   
 }  
 //Output: 1 ,5 ,10 ,15  
 }  
}

## **5. Deque Interface and its Implementations**

The Deque (Double Ended Queue) interface extends Queue and allows elements to be added or removed from both ends. It supports both FIFO and LIFO (Last-In-First-Out) operations.

Characteristics of Deque

* **Double-Ended:** Elements can be added/removed from both front and back.
* **Flexible:** Supports both FIFO (as a queue) and LIFO (as a stack).
* **Null Values**: Does not permit null elements to prevent ambiguity in retrieval.

| **Method Signature** | **Description** |
| --- | --- |
| void addFirst(E e) | Adds an element at the front of the deque. |
| void addLast(E e) | Adds an element at the end of the deque. |
| E removeFirst() | Removes and returns the front element of the deque. |
| E removeLast() | Removes and returns the last element of the deque. |
| E getFirst() | Retrieves, but does not remove, the front element. |
| E getLast() | Retrieves, but does not remove, the last element. |
| E pollFirst() | Retrieves and removes the front element, or null if empty. |
| E pollLast() | Retrieves and removes the last element, or null if empty. |

### # ArrayDeque

ArrayDeque is a resizable array-based implementation of Deque. It is more efficient than LinkedList for Deque operations and is the preferred implementation for stacks and queues.

import java.util.ArrayDeque;  
import java.util.Deque;  
  
public class ArrayDequeStackExample {  
 public static void main(String[] args) {  
 Deque<String> stack = new ArrayDeque<>();  
  
 // Using ArrayDeque as a stack (LIFO)  
 stack.push("Java");  
 stack.push("Python");  
 stack.push("C++");  
  
 while (!stack.isEmpty()) {  
 System.*out*.println("Popped: " + stack.pop());  
 }  
 }  
}

## **6. Map Interface and its Implementations**

The Map interface represents a collection of key-value pairs. Each key is unique, and each key maps to exactly one value. Unlike Set or List, Map does not extend the Collection interface, as its structure and behavior differ significantly.

Key Characteristics of Map

* **Key-Value Pairs:** Map stores data as pairs of keys and values.
* **Unique Keys:** Keys must be unique, but values can be duplicated.
* **Efficient Lookup:** Maps provide efficient methods for adding, removing, and retrieving values based on keys.

Different implementations of map

|  |  |
| --- | --- |
| HashMap | 1. Key-value pairs, hash table, allows one null key 2. Does not maintain order of elements 3. Key Use Cases: Efficient when order is not a priority, such as for caching or data lookup tables. |
| LinkedHashMap | 1. Maintains insertion order 2. Key Use Cases: Suitable for caching applications or maintaining an access order where insertion order is essential |
| TreeMap | 1. Sorted map based on natural ordering or comparator 2. Does not allow null keys but allows null values. 3. Provides fast retrieval operations due to sorted order. 4. Key Use Cases: Ideal for applications where sorted order of entries is essential, such as in database indexing. |
| HashTable | 1. Synchronized, no null keys/values, legacy class |

Different methods of map interface

| **Method Signature** | **Description** |
| --- | --- |
| V put(K key, V value) | Adds a key-value pair to the map. Returns the previous value for the key, if any. |
| V get(Object key) | Retrieves the value associated with the specified key. |
| V remove(Object key) | Removes the key-value pair for the specified key. |
| boolean containsKey(Object key) | Checks if the map contains a mapping for the specified key. |
| boolean containsValue(Object value) | Checks if the map contains one or more keys mapped to the specified value. |
| Set<K> keySet() | Returns a set view of the map's keys. |
| Collection<V> values() | Returns a collection view of the map's values. |
| Set<Map.Entry<K, V>> entrySet() | Returns a set view of the map's key-value mappings. |
| void clear() | Removes all mappings from the map. |
| int size() | Returns the number of key-value mappings in the map. |

| **Feature** | **HashMap** | **LinkedHashMap** | **TreeMap** |
| --- | --- | --- | --- |
| **Underlying DS** | Hash Table | Hash Table + Linked List | Red-Black Tree |
| **Order** | No order | Insertion order | Sorted by key |
| **Null Keys** | Allows one null key | Allows one null key | Does not allow null keys |
| **Performance** | O(1) for add/get | O(1) with predictable order | O(log n) for add/get |
| **Use Case** | Lookup tables, caching | Ordered caching, access order | Sorted data collections |

### # HashMap

package LearnCollection;  
  
import java.util.\*;  
public class LearnHashMap {  
 public static void main(String args[]){  
 Map<String,Integer> marks = new HashMap<>();  
 marks.put("Maths",96);  
 marks.put("Physics",92);  
 marks.put("Chemistry",99);  
  
 //retrieve the value(Marks in maths is: 96)  
 System.*out*.println("Marks in maths is: " + marks.get("Maths"));  
  
 //get all key values (Output: Subjects: [Maths, Chemistry, Physics])  
 System.*out*.println("Subjects: " + marks.keySet());  
  
 //DefaultValue (output: Marks in English: 0)  
 System.*out*.println("Marks in English: "+ marks.getOrDefault("Englist",0));  
  
 //Run loop on all values  
 Set<String> keys = marks.keySet();  
 for(String key : keys ){  
 System.*out*.println("Key " + key + " Value " + marks.get(key));  
 }  
 //Key Maths Value 96  
 //Key Chemistry Value 99  
 //Key Physics Value 92  
  
 //other way to loop  
 marks.forEach((k,v)->System.*out*.println("subject : " + k + " marks : " + v));  
 }  
}

## **7. Collection utility class**

The Collections class provides a wide variety of utility methods for manipulating collections, including:

* Sorting and searching
* Reversing and rotating elements
* Shuffling and making collections unmodifiable or thread-safe
* Finding frequency of elements and handling maximum/minimum values

The methods in the Collections class are static and can be used directly without creating an instance of the class.

Important methods

| **Method** | **Description** |
| --- | --- |
| sort(List<T> list) | Sorts the specified list in ascending order. |
| sort(List<T> list, Comparator<? super T> c) | Sorts the specified list according to the specified comparator. |
| reverse(List<?> list) | Reverses the order of elements in the specified list. |
| shuffle(List<?> list) | Randomly shuffles the elements in the specified list. |
| rotate(List<?> list, int distance) | Rotates elements in the list by the specified distance. |
| swap(List<?> list, int i, int j) | Swaps elements at the specified positions in the list. |
| frequency(Collection<?> c, Object o) | Returns the number of occurrences of the specified element in the collection. |
| max(Collection<? extends T> c) | Returns the maximum element in the specified collection. |
| min(Collection<? extends T> c) | Returns the minimum element in the specified collection. |
| binarySearch(List<? extends T> list, T key) | Searches the list for the specified element using binary search. |
| fill(List<? super T> list, T obj) | Replaces all elements of the specified list with the specified element. |
| copy(List<? super T> dest, List<? extends T> src) | Copies elements from the source list to the destination list. |
| unmodifiableList(List<? extends T> list) | Returns an unmodifiable view of the specified list. |
| synchronizedList(List<T> list) | Returns a thread-safe view of the specified list. |

import java.util.\*;  
  
public class LearnCollectionUtility {  
 public static void main(String[] args) {  
 List<Integer> arr = new ArrayList<>(Arrays.*asList*(22,4,16,34));  
  
 //Sort in ascending order  
 Collections.*sort*(arr);  
 System.*out*.println(arr); //[4, 16, 22, 34]  
  
 //Reverse the order  
 Collections.*reverse*(arr);  
 System.*out*.println(arr); //[34, 22, 16, 4]  
  
 List<Integer> arr2 = new ArrayList<>(Arrays.*asList*(19,21,9,15,12));  
  
 //Sort in descending order ( use of comparator)  
 Collections.*sort*(arr2,Comparator.*reverseOrder*());  
 System.*out*.println(arr2); //[21, 19, 15, 12, 9]  
  
 //Get the max value  
 Integer max = Collections.*max*(arr2);  
 System.*out*.println(max); //21  
  
 List<String> arr3 = new ArrayList<>(Arrays.*asList*("Apple","Banana","Apple","Orange"));  
  
 //Get the frequency of element  
 int count = Collections.*frequency*(arr3,"Apple");  
 System.*out*.println(count); //2  
 }  
}