⭐ What is Collection Framework?

The **Collection Framework** in Java is a standardized architecture for storing and manipulating groups of objects.
It provides:

- **Interfaces** (Collection, List, Set, Queue, Deque, Map)
- **Classes** (ArrayList, LinkedList, Vector, Stack, HashSet, LinkedHashSet, TreeSet, PriorityQueue, etc.)
- Utility Classes (Collections, Arrays)
- **Algorithms** (Sorting, Searching, Shuffling, Reversing)

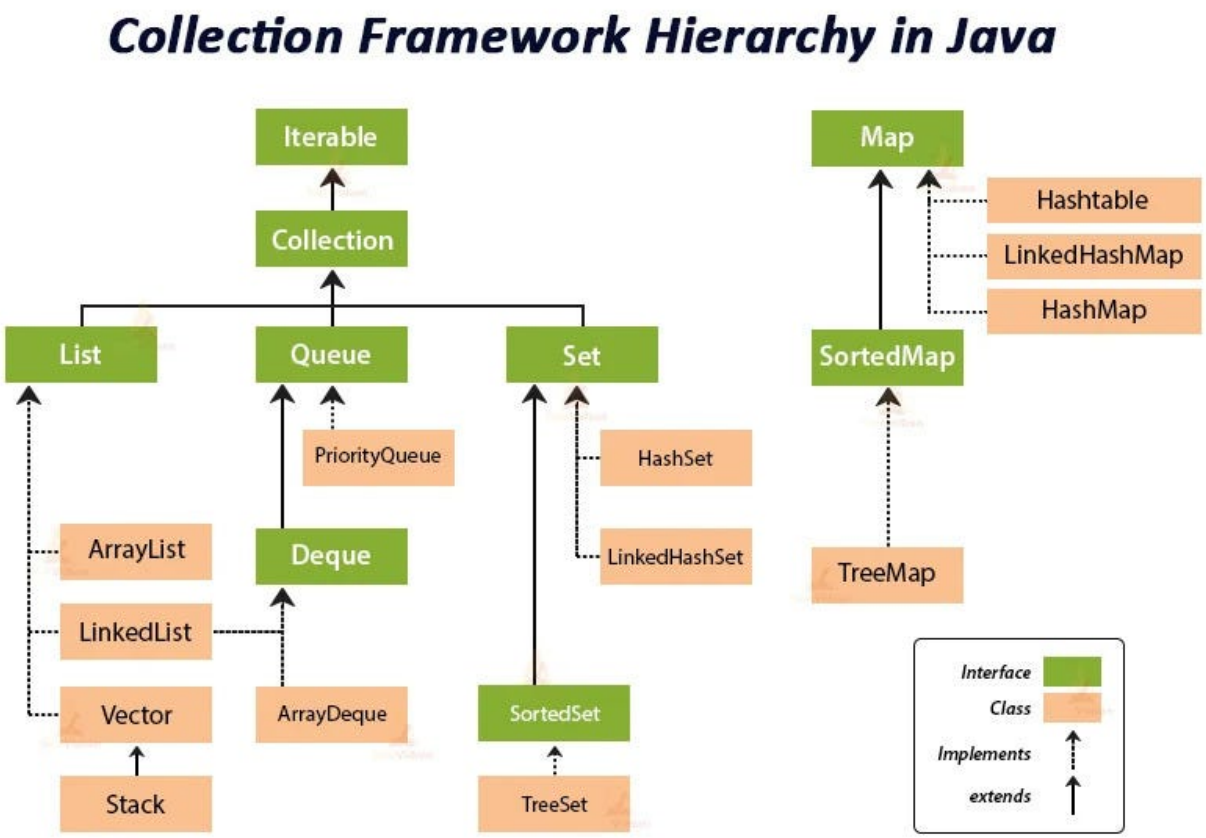
The framework supports operations like insertion, deletion, searching, sorting, updating, iteration, and manipulation of data.

⭐ Difference between Array and ArrayList

Array	ArrayList / Collection
Static size (fixed-length).	Dynamic size (grows/shrinks automatically).
Can store **primitive types** and objects.	Stores **objects only** (wrapper classes for primitives).
Fast and memory efficient for fixed-size data.	More flexible but slightly higher overhead.
Uses direct indexing with a fixed structure.	Built on top of a **dynamic internal array** (`Object[]`).
No built-in methods for manipulation.	Provides many built-in methods (add, remove, contains, etc.).
Supports multi-dimensional arrays.	One-dimensional; can nest lists to simulate multi-dimension.

⭐ Difference between Collection and Collections

Collection	Collections
It is a **interface** in the Collection Framework.	It is a **utility class** in `java.util`.
Represents a group of objects as a single unit.	Provides **static methods** like `sort()`, `reverse()`, `min()`, `max()`, `synchronizedList()`, etc.
Parent of List, Set, Queue.	Works *on* Collection objects.



⭐ List Interface

Definition:

List is a child interface of Collection.

It represents an **ordered collection** that preserves insertion order and allows duplicate elements.

✔ Key Features of List

1. **Maintains Order:** Insertion order is preserved.
2. **Duplicates Allowed:** Multiple identical elements permitted.
3. Index-Based Access: Supports add(index), get(index), set(index), remove(index).
4. **Null Allowed:** List implementations allow null values.
5. Supports Iterators:
    - Iterator (forward)
    - ListIterator (forward + backward)

✔ Implementations of List

1. ArrayList
    - Backed by dynamic array.
    - Fast random access (O(1)).

- Slower for insert/delete in the middle (O(n)).
- Not synchronized.

2. LinkedList
   - Backed by doubly linked list.
   - Fast insert/delete operations (O(1) at ends).
   - Slow random access (O(n)).
   - Also implements Queue/Deque.

3. **Vector** (Legacy)
   - Similar to ArrayList but synchronized.
   - Slower due to synchronization.
   - Rarely used today.

4. **Stack** (Legacy)
   - Extends Vector.
   - LIFO structure (push, pop, peek).
   - Modern replacement: ArrayDeque.

⭐1. ArrayList

Definition:
ArrayList is a **dynamic array implementation** of the List interface.
It can grow or shrink automatically as elements are added or removed.

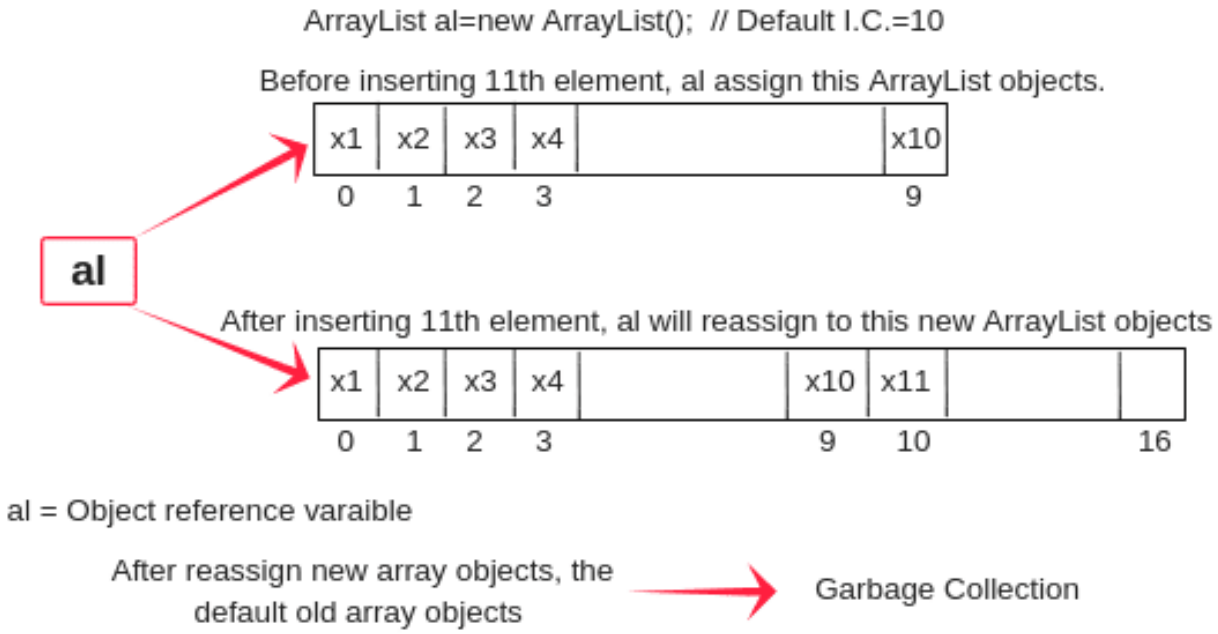
✔ Key Features of ArrayList

1. **Dynamic Array:** Automatically resizes.
2. Maintains Insertion Order: Index-based access.
3. **Allows Duplicates:** Same values can be inserted.
4. **Allows Null Values:** Can store one or more nulls.
5. Fast Random Access: get(index) is O(1).
6. **Not Synchronized:** Not thread-safe by default.
   - Thread-safe options:
     - Collections.synchronizedList(list)
     - CopyOnWriteArrayList
7. **Default Capacity:** 10 (auto-expands by 1.5×).
8. Resizable Underlying Array: Uses Object[] internally.

✔ Common Methods in ArrayList

- add(E e)
- add(int index, E e)
- get(int index)
- set(int index, E e)
- remove(int index) / remove(Object o)
- contains(Object o)

- size()
- clear()
- indexOf() / lastIndexOf()
- iterator() / listIterator()
- addAll(Collection c)



Initially, when we declare `ArrayList<Integer> al = new ArrayList<>();`

`al`

```
┌──┬──┬──┬──┬──┬──┬──┬──┬──┬──┐
│  │  │  │  │  │  │  │  │  │  │   ← 10 empty slots
└──┴──┴──┴──┴──┴──┴──┴──┴──┴──┘

 Index: 0  1  2  3  4  5  6  7  8  9
```

After first add → `al.add(10);`

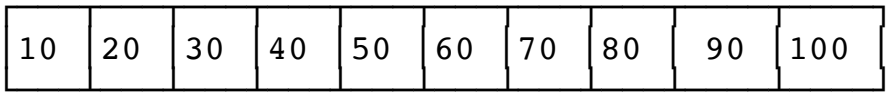
```
al
```


```
 Index: 0   1   2   3   4   5   6   7   8   9
```

```
After adding all initial elements (10 elements total)
```

```
al.add(10);
al.add(20);
al.add(30);
al.add(40);
al.add(50);
al.add(60);
al.add(70);
al.add(80);
al.add(90);
al.add(100);
```

```
al   (Initial capacity full)
```



Now add a new element → `al.add(110);`
➡ Capacity is full → ArrayList **resizes by 50%**
➡ New capacity = **15**

```
al     (Resized by 50%)
```


```
 Capacity: 15
 Size: 11
```

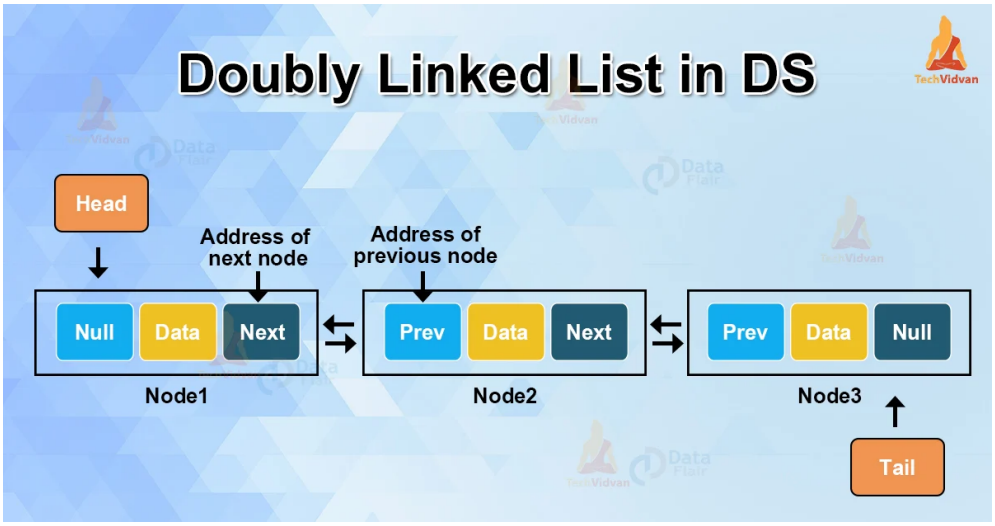
✔ Default Capacity = 10
✔ Resize happens by 1.5× (50%)
✔ Array grows only when full
✔ After removing elements, capacity does NOT shrink automatically

2. LinkedList

The LinkedList class in Java is part of the Java Collection Framework and implements the List, Deque, and Queue interfaces.
It represents a doubly-linked list internally and provides efficient insertion and deletion operations compared to ArrayList.

⭐ Key Features of LinkedList

1. **Doubly Linked List:**
   Each element (node) contains references to both its **previous** and **next** nodes.
2. **Efficient Insertions and Deletions:**
   Adding or removing elements—especially at the **beginning** or **middle**—is faster than ArrayList
   because no shifting of elements is required.
3. **Maintains Insertion Order:**
   Preserves the order in which elements are added.
4. **Allows Duplicates and Nulls:**
   Supports duplicate elements and can store null values.
5. Implements Queue and Deque Interfaces:
   Can be used as a Queue (FIFO) or as a Deque (Double-Ended Queue) using methods like offer(), poll(), offerFirst(), offerLast(), etc.



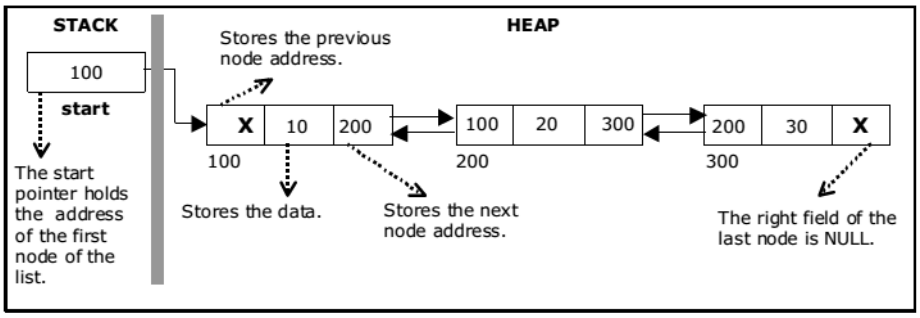


Figure 3.3.1. Double Linked List

🎯 When to Use LinkedList?

Use LinkedList when:
✔ You perform **frequent insertion/deletion**
✔ You need **Queue/Deque** implementation
✔ Order of elements matters
✔ You don't need fast random access

When NOT to Use LinkedList?

Avoid LinkedList when:
You frequently access elements by index
You need fast data reading
Memory is constrained (because nodes take more memory)

Why LinkedList is Faster for Insert/Delete?
Because only **pointers** change — no shifting of elements.

Why LinkedList is Slow for Accessing Elements?

Diff b/w arrayList And LinkedList

Aspect	ArrayList	LinkedList
Data Structure	Dynamic Array (contiguous memory)	Doubly Linked List (nodes: data + next + prev)
Random Access Performance	**Fast (O(1))** → direct index access	**Slow (O(n))** → must traverse nodes
Insertion/Deletion Performance	**Slow (O(n))** → shifting required	**Fast (O(1))** at beginning/end
Memory Usage	Less memory	More memory (extra pointers)
Thread-Safety	Not synchronized	Not synchronized
Growth	Increases capacity by **50%** (old * 1.5)	Adds nodes dynamically (**no fixed capacity**)
Best Use Case	Frequent read/search operations	Frequent add/delete operations
Allows Null	Yes	Yes
Maintains Order	Yes	Yes
Duplicates Allowed	Yes	Yes
Access by Index	Fast (O(1))	Slow (O(n))
Resizing	Automatic	Automatic

✅ 3. Vector

The **Vector** class in Java is part of the **Java Collection Framework** and is located in the java.util package. It implements the **List** interface and stores elements in a **dynamic, resizable array**.
Unlike ArrayList, **Vector is synchronized**, which makes it **thread-safe** for multi-threaded environments.

⭐ Key Features of Vector

1. **Resizable Array:**
   Automatically grows or shrinks as elements are added or removed.
2. **Synchronized:**
   All methods in Vector are synchronized, making it thread-safe but slightly slower than ArrayList.
3. **Maintains Insertion Order:**
   Elements remain in the order they are added.
4. **Allows Duplicates:**
   Duplicate elements are permitted.
5. Allows Null Elements:
   Can store one or more null values.
6. **Legacy Class:**
   Introduced in **JDK 1.0** and later retrofitted to implement the **List** interface.

Diff b/w arrayList and vector

Aspect	ArrayList	Vector
Thread-Safety	Not synchronized	**Synchronized (thread-safe)**
Performance	Faster	Slower (synchronization overhead)
Synchronization	Must be done manually	All methods synchronized
Growth	Grows by **50%** (old * 1.5)	Grows by **100%** (doubles capacity)
Memory Overhead	Less	More (sync + internal overhead)
Access Time	Fast	Slower
Resize Behavior	Automatic	Automatic (double size)
Null Elements Allowed	Yes	Yes
Insertion/Deletion Performance	Slower (shifting)	Slower than LinkedList but OK
Legacy Class	JDK 1.2	**JDK 1.0 (Legacy)**
Initial Capacity	10	10
Duplicates Allowed	Yes	Yes