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        - Example: ArrayList
    - Equality in OOP
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        - The hashing concept
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        - does two object with the same hashcode equal?
        - What is hashcode for?
    - Object ordering
        - Comparison
        - Comparable interface
        - why the return type is `int` ?
        - Return values
        - Implementing the Comparable interface
        - sorting
        - Custom comparators
        - Comparable vs Comparator
        - Sort method
    - Collection interface
        - `Collections` vs `Collection` interface
            - `Collections` is a static utility class
            - `Collection` is an interface
        - Lowest comman denominator
            - To support all collections
            - Implements the `Iterable` interface
        - `Collection` is the root interface in the collection hierarchy.
        - No direct implementation in the JDK
        - Sub interfaces for collection types
    - List
        - Common usecases
            - Storing items in order with index based access
        - List interface
            - Add
            - Remove
            - Replace
            - Inspect

Collections

Defintion

- Language API to manage "groups" of things

Agenda

- Understanding the overall Collection API
- Learning individual types of collections
- When to use what? What's the fifference?

Concept

- Coding to interfaces
- Iterator pattern
- Efficency discussions
- Equality and hash code
- Natual ordering and comparisons

Collections

- Set
    - HashSet
    - TreeSet
- Lists
    - ArrayList
    - LinkedList
- Maps
    - HashMap

Roadmap

- Pre-Collection API
- Diffent Collection needs
- Introducing ArrayList
- Concepts and fundamentals
- Zoom up to Collections interface
- Tackle individual collections types
- Lear the collection type, usages and code examples

Pre-Collection API

arrays

```
int[] numbers;
numbers = new int[10];
numbers[0] = 1;
System.out.println(numbers[0]);
```

work with primitive types and object references

```
Date[] dates = new Date[10];
dates[0] = new Date();
```

The problem with arrays

```
* Limited data structure
* Does not have methods on its own
* Have to use `Arrays` class to do things
```

Arrays class

- `Arrays.asList()`
- `Arrays.compare()`
- `Arrays.copyOf()`

```
// String[] names = {"John", "Jane", "Joe"};
String[] names = new String[10];
Arrays.fill(names, "name ");
for(int i = 0; i < names.length; i++) {
  names[i] = names[i] + i;
}
Arrays.binarySearch(names, "name 4");
```

Vector

Hashtable

The diffrent collection needs

Arrays and the Arrays class

- Isn't that enough?

Position based access

- Strorage and retrieval by index
- Needs sorting methods
- Ordered vs Unordered

Uniqueness

- Are duplicates allowed?
- Affects adding behavior
- No need for position based access

Retrieval mechanisms

- Index based retrieval
- Key based retrieval
- Presence-only retrieval

Others

- Mutability

- Concurrency requirements

Collection Types

Collections types

- Define the contract of the collection
  - List
  - Set
  - Map Queue

Implementations

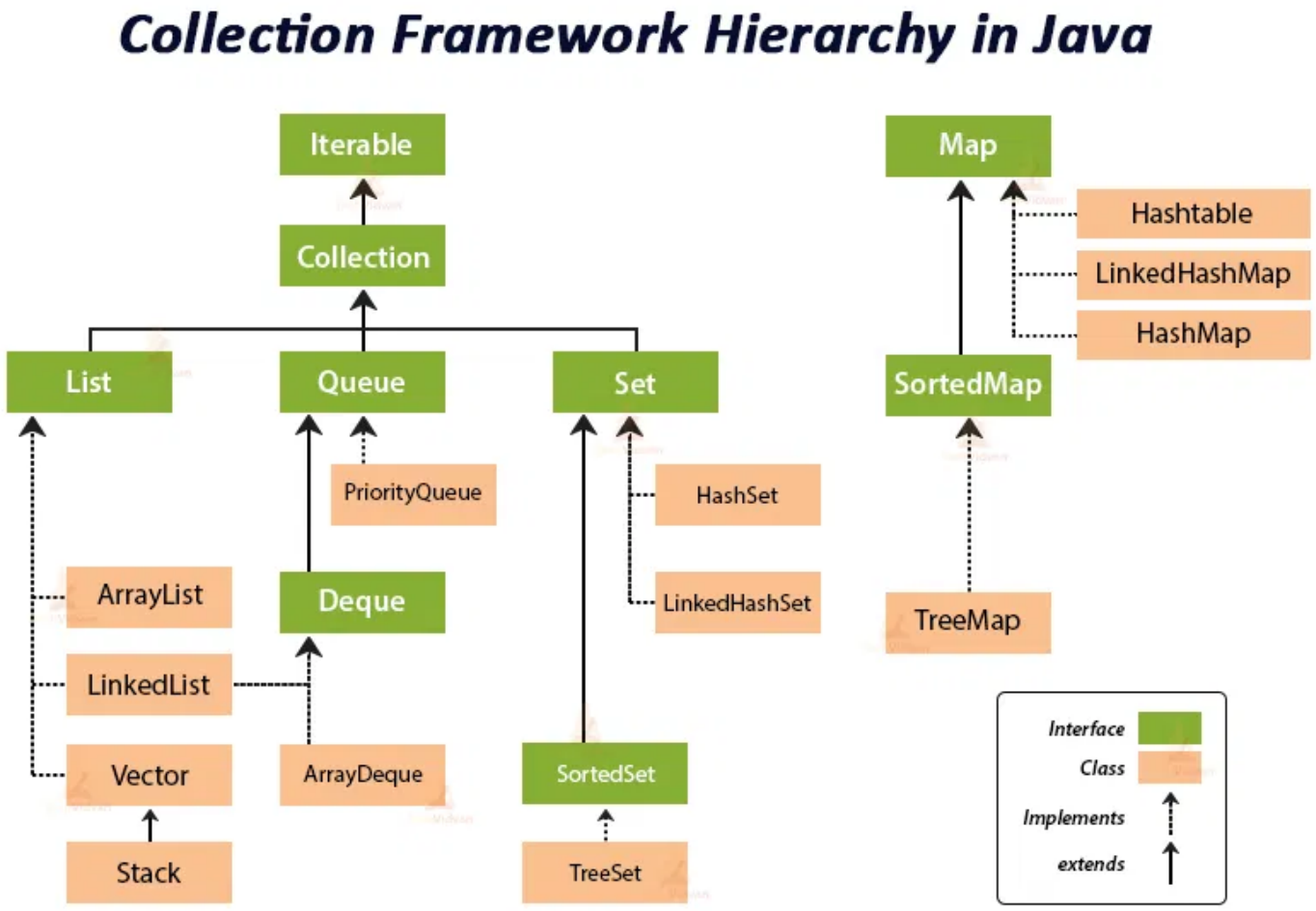
- How it acturally works behind the scenes

Examples

- **List**
  - Defines the contract/behavior
- **ArrayList**
  - An implementation of List contract
- **LinkedList**
  - Another implementation of List contract
- **Set**
  - HashSet
  - LinkedHashSet
  - TreeSet
- Q
- **Map**
  - HashMap
  - TreeMap

- **Queue**
  - PriorityQueue
- **Tradeoffs**
  - finding what is the right tool for the job

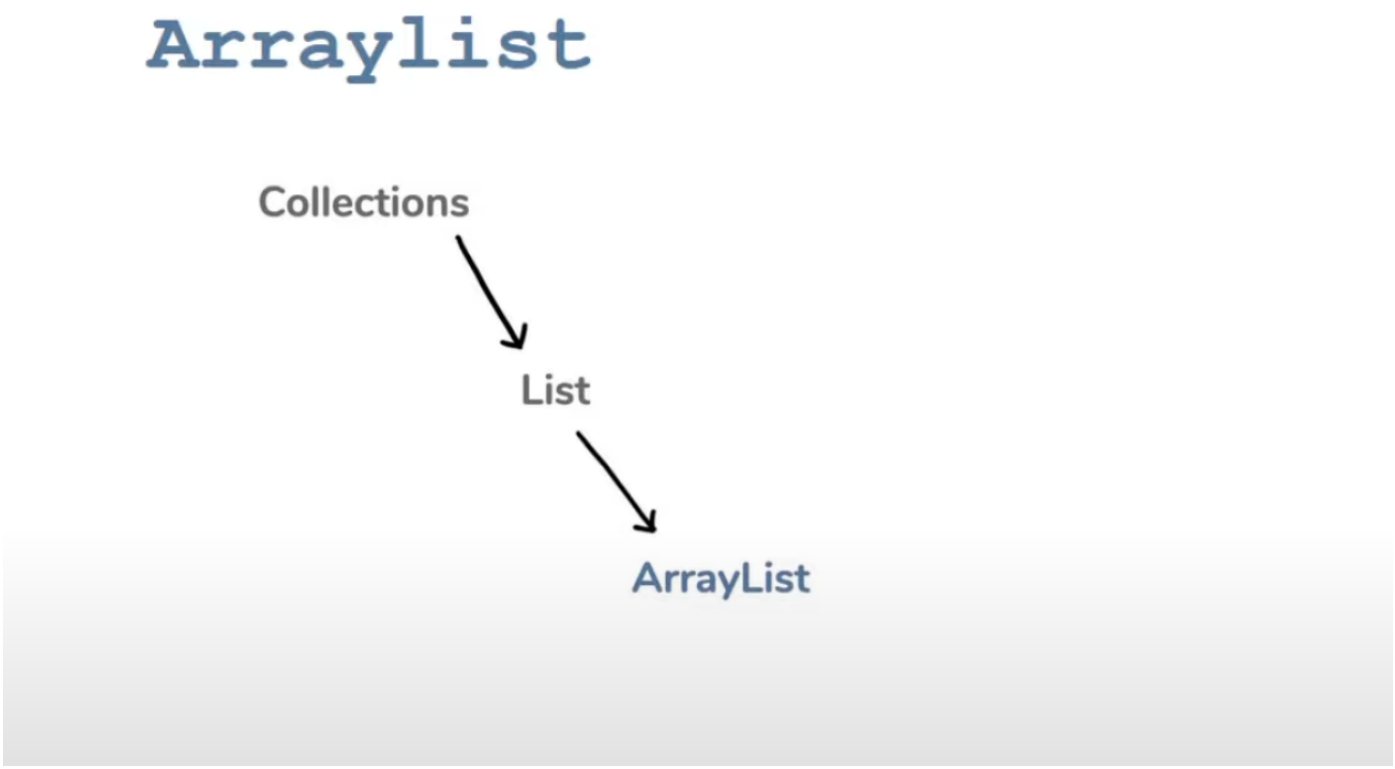
Hierarchy of Collections



https://github.com/seaboyz/coding-interview/blob/990a49ddc8d6e9c2b4744faa95eecc8ec95f158e/Sanbox/src/App.java#L6

ArrayList

- "Replacement" for arrays




```
ArrayList<String> names = new ArrayList<>();
for(int i = 0; i < 20; i++){
    names.add("name " + i);
}
for(int i = 0; i < 20; i++){
    System.out.println(names.get(i));
}
```

O notation

Tradeoffs

- Feature requirements
- Efficiency
    - Time
    - Space
        - Usualy proportional to size to be stored.

Time Effieciency

- How long does it take?

- Storage time - single item
- Retrieval time - sigle item
- Retrival time - search

How do you measure time efficiency?

- Bigger collecion = longer times
- A factor of N (number of elements)

O(N)

- Big O notation
- How good / bad is the depencency on N?
- Rough imprecise measurement/classification
- Broad buckets
- it assumes the worst case estimate
- Rough/board estimate

Linear Time

- O(N) - depends on number of elements

Constant Time

- O(1)

Logarithmic Time

- O(log N)
- Binary search
    1. Look at the middle
    2. if greater, take first half
    3. if lesser, take second half
    4. Repeat
- has to be sorted first
- Time doesn't linearly increase with size of N

Quadratic Time

- find duplecated element
- $O(N^2)$

How O-Notation matters

- Inherent performance characteristics
  - Search a list(not sorted)
- Implementation-based characteristics
  - Looking up by index(ArrayList vs LinkedList)
- Underlying factor

How iterators work?

Feature

- each iterator has its own state(every time you get a iterator form .iterator(), it returns a new iterator)
- iterator does not like the collection to be modified

for each loop

```
for(String name : names){
    System.out.println(name);
}
```

Iterator vs Iterable

Iterator

```
public interface Iterator<E> {
  boolean hasNext();// Are there more elements?
  E next();// Get the next element in the iteration
  void remove();// Remove the last element returned by iterator
  default void forEachRemaining(Consumer<? super E> action)
}
```

Iterable

```
public interface Iterable<E> {
  Iterator<E> iterator();
  default Spliterator<E> spliterator() {
    return Spliterators.spliteratorUnknownSize(iterator(), 0);
  }
  default void forEach(Consumer<? super E> action) {
    Objects.requireNonNull(action);
    Spliterator<E> spliterator = spliterator();
    while (spliterator.tryAdvance(action)) {
      // Empty
    }
  }
}
```

Example: ArrayList

```
ArrayList<String> names = new ArrayList<>();
for(int i = 0; i < 20; i++){
    names.add("name " + i);
}
Iterator<String> iterator = names.iterator();
// String element = iterator.next();

while(iterator.hasNext()){
    element = iterator.next();
    System.out.println(element);
}
```

Equality in OOP

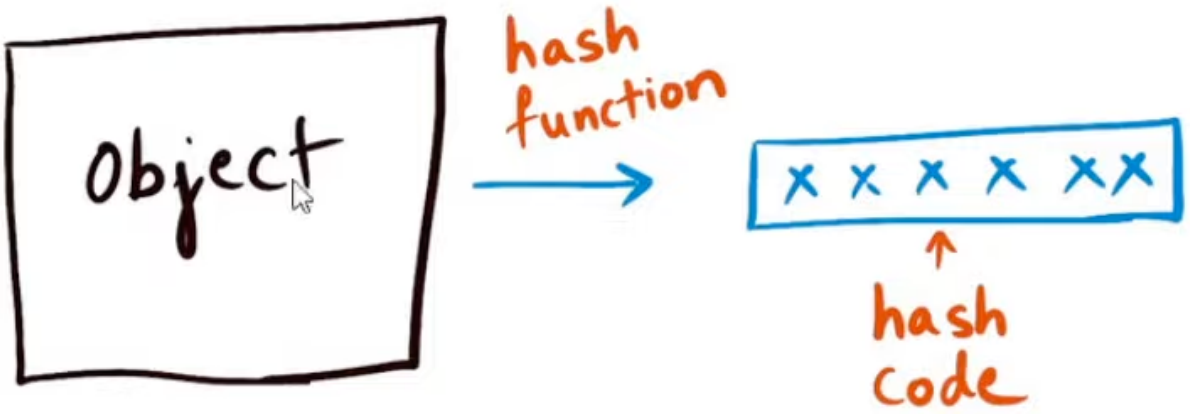
- `==`
- `equals()`
- Equality with objects(You have to define it)
- Only you know what equivalence means
- The `equals()` method is used to compare objects
- The `==` operator is used to compare references

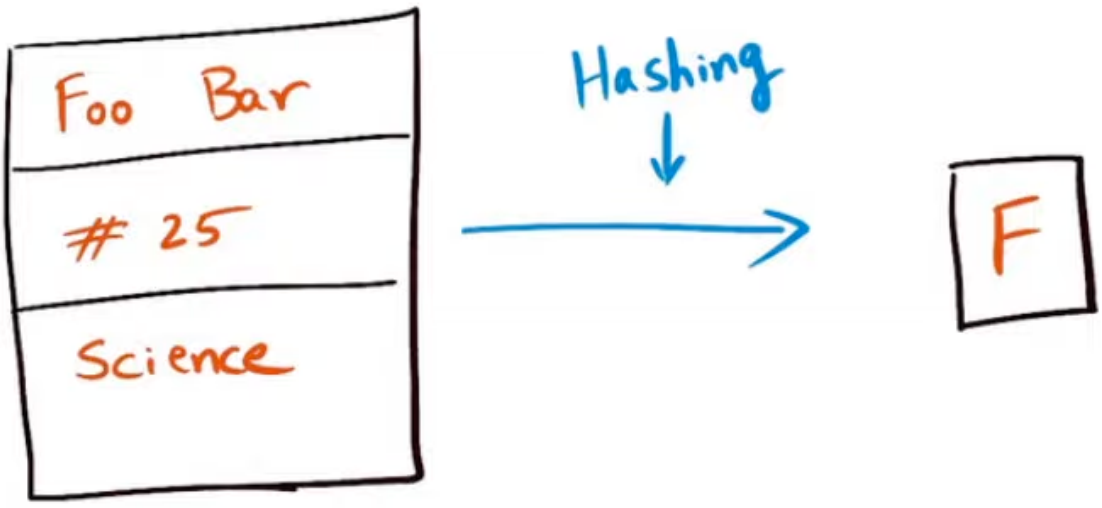
```java
public class Students {
  private String name;
  private int age;
  public Students(String name, int age){
    this.name = name;
    this.age = age;
  }
  public String getName(){
    return name;
  }
  public int getAge(){
    return age;
  }
  public boolean equals(Object o){
    if(o == null){
      return false;
    }
    if(o == this){
      return true;
    }
    if(!(o instanceof Students)){
      return false;
    }
    Students s = (Students) o;
    return s.getName().equals(this.getName()) && s.getAge() == this.getAge();
  }
  public int hashCode(){
    return Objects.hash(name, age);
  }
}
```

Hashing and hash codes

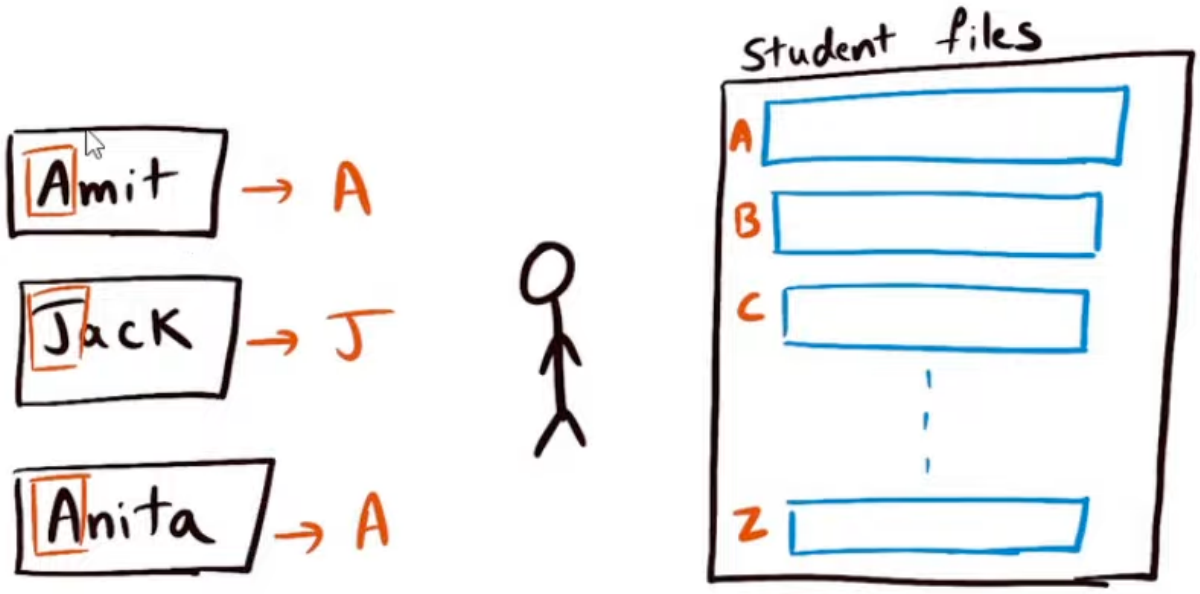
The hashing concept

- using hash function to convert a object to a string value





- hash mapping is not one-to-one, it is one-to-many, but it could be one



hashcode in java

```
public int hashCode(){
  return Objects.hash(name, age);
}
```

does two object with the same hashcode equal?

- No.
- It dependes the implementation of `equals()`

What is hashcode for?

*The purpose of the hashCode() method is to provide a numeric representation of an object's contents so as to provide an alternate mechanism to loosely identify it. By default the hashCode() returns an integer that represents the internal memory address of the object

Object ordering

Comparison

- what to compare?
- there is object state in two objects
- there is a clear definition of comparison of those values
- Individual values or combination of values
- not all objects are comparable
    - two database connection instances are not comparable
- comparison is not defaut

Comparable interface

- Indicates that an object is comparable

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

why the return type is `int` ?

- Argument object is greater than this object
- Argument object is lesser than this object
- They are both the same(things that are compared are same)

Return values

- Negative value
    - object `o` is greater than `this` object.
- Positive value
    - object `o` is lesser than `this` object.
- Zero
    - they are both the same.

Implementing the Comparable interface

```
public class Student implements Comparable<Student> {

  @Override
  public int compareTo(Student o){
    if(this.id > o.getId()){
      return 1;
    }
    if(this.id < o.getId()>){
      return -1;
    }
    return 0;
  }

  // another way
  public int compareTo(Student o){
    return this.id - o.getId();
  }

}
```

sorting

```
Student s1 = new Student(1,"john","doe","science");
Student s1 = new Student(2,"tom","cat","history");
Student s1 = new Student(3,"jane","doe","arts");
ArrayList<Student> students = new ArrayList<>();
students.add(student1);
students.add(student2);
students.add(student3);

students.sort(null);
```

https://github.com/seaboyz/java-collection/blob/1483adbbbf89aeb3e4b26770065c8edd9d2f3d15/Sanbox/src/Student.java#L14

Custom comparators

- By cource enrollment
- But this is only one `compareTo()` method
- Compartor here to sovle the problem

Comparable vs Comparator

- Comparable
  - means I am a object that can be compared

    - please compare me to other objects
- Comparator
    - for creating the object instance for `Comparable` to use

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

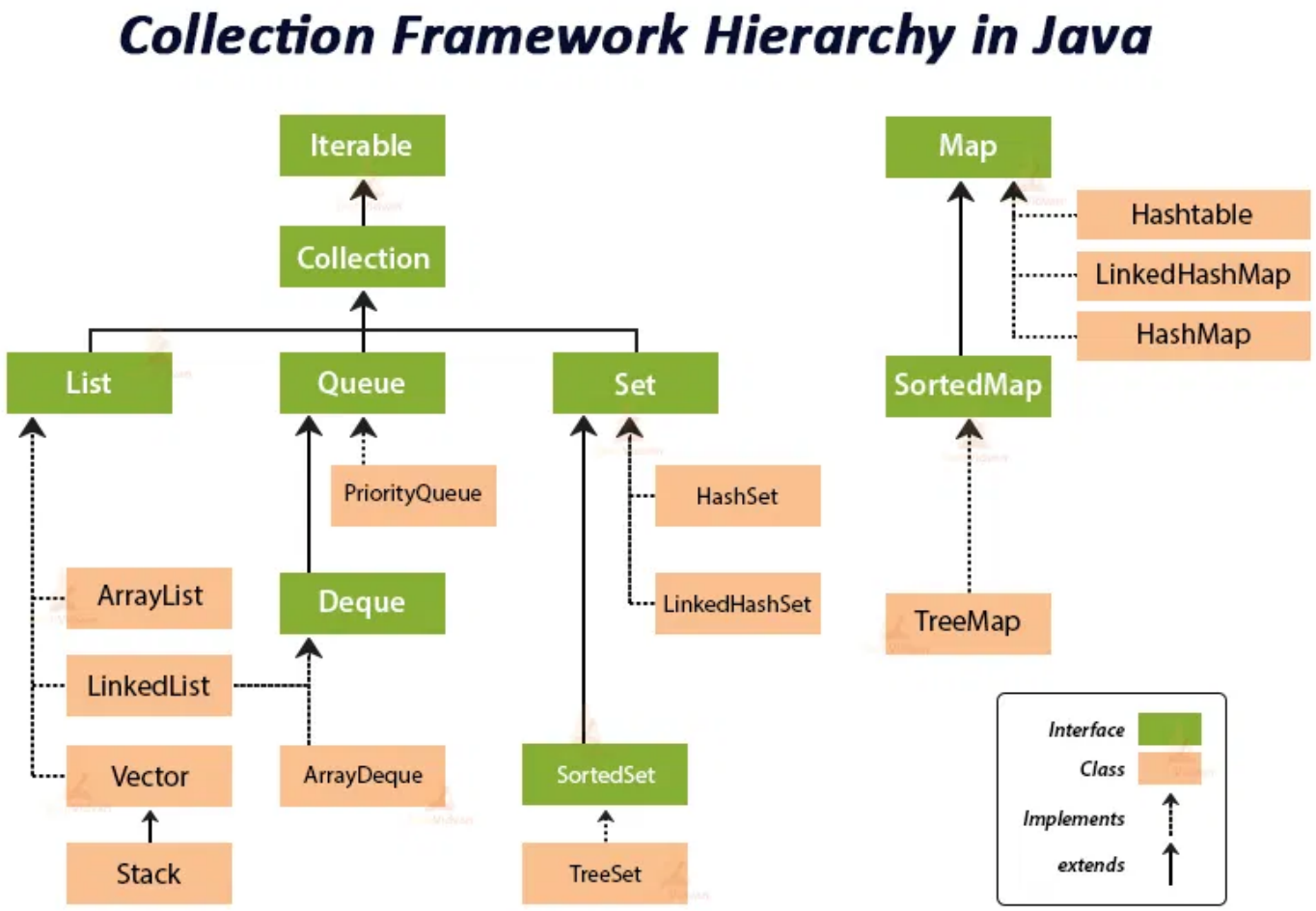
```
import java.util.Comparator;

public class StudentLastNameComparator implements Comparator<Student> {
    @Override
    public int compare(Student s1, Student s2) {
        return s1.getLastname().compareTo(s2.getLastname());
    }
}
```

Sort method

- Tkes comparator instance as argument

```
students.sort(new StudentLastNameComparator());
```

Collection interface



- `Map` interface is not inherited from the `Collection` interface

`Collections` vs `Collection` interface

`Collections` is a static utility class

```
Collections.sort(students, new StudentLastNameComparator());
```

`Collection` is an interface

```
public interface Collection<E>{
  public int size();
  public boolean isEmpty();
  public boolean contains(Object o);
  public Iterator<E> iterator();
  public Object[] toArray();
  public <T> T[] toArray(T[] a);
  public boolean add(E e);
  public boolean remove(Object o);
  public boolean containsAll(Collection<?> c);
  public boolean addAll(Collection<? extends E> c);
  public boolean removeAll(Collection<?> c);
  public boolean retainAll(Collection<?> c);
  public void clear();
}
```

Lowest comman denominator

To support all collections

Implements the `Iterable` interface

```
Interface Queue<E> extends Collection<E>{
  public boolean offer(E e);
  public E poll();
  public E peek();
}
Interface List<E> extends Collection<E>{
  public E get(int index);
  public E set(int index, E element);
  public void add(int index, E element);
  public E remove(int index);
  public int indexOf(Object o);
  public int lastIndexOf(Object o);
  public ListIterator<E> listIterator();
  public ListIterator<E> listIterator(int index);
  public List<E> subList(int fromIndex, int toIndex);
}
Interface Set<E> extends Collection<E>{
  public boolean add(E e);
  public boolean remove(Object o);
  public boolean containsAll(Collection<?> c);
  public boolean addAll(Collection<? extends E> c);
  public boolean removeAll(Collection<?> c);
  public boolean retainAll(Collection<?> c);
  public void clear();
}
```

`Collection` is the root interface in the collection hierarchy.

- Add
  - add()
  - addAll()
- Remove
  - remove()
  - removeAll()
  - retainAll()
  - clear()
- Inspect
  - isEmpty()
  - size()
- Process
  - iterator()
  - stream()
  - toArray()
  -

No direct implementation in the JDK

Sub interfaces for collection types

- Set
- List
- Queue

List

- An ***ordered*** collection of elements

Common usecases

Storing items in order with index based access

- List of students in the school
- List of students with IDs
  - Add (enroll) new students
  - Process all students in order

        - By ID for sending notifications
        - By name for attendance
        - By grade for scholarships
    - Access a student's record given ID

List interface

Add

```
boolean add(E e);
boolean AddAll(Collection<? extends E> c);
void add(int index, E element);
boolean addAll(int index, Collection<? extends E> c);
```

Remove

```
E remove(int index);
boolean remove(Object o);
boolean removeAll(Collection<?> c);
boolean retainAll(Collection<?> c);
void clear();
```

Replace

```
E set(int index, E element);
default void replaceAll(UnaryOperator<E> operator);
```

Inspect

```
boolean isEmpty();
int size();
boolean contains(Object o);
boolean containsAll(Collection<?> c);
int indexOf(Object o);
int lastIndexOf(Object o);
```

Retrieve

```
E get(int index);
// returns a view of the portion of this list between the specified fromIndex, inclusive
List<E> subList(int fromIndex, int toIndex);
```

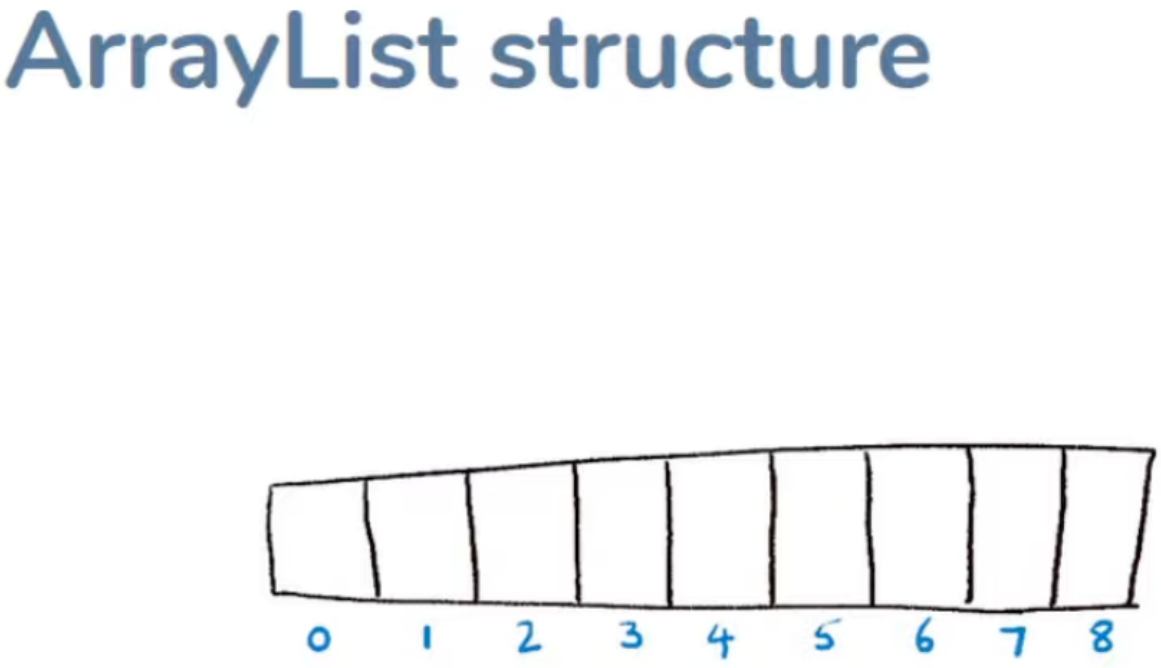
Process

```
Iterator<E> iterator();
ListIterator<E> listIterator();
ListIterator<E> listIterator(int index);
default Spliterator<E> spliterator();
```

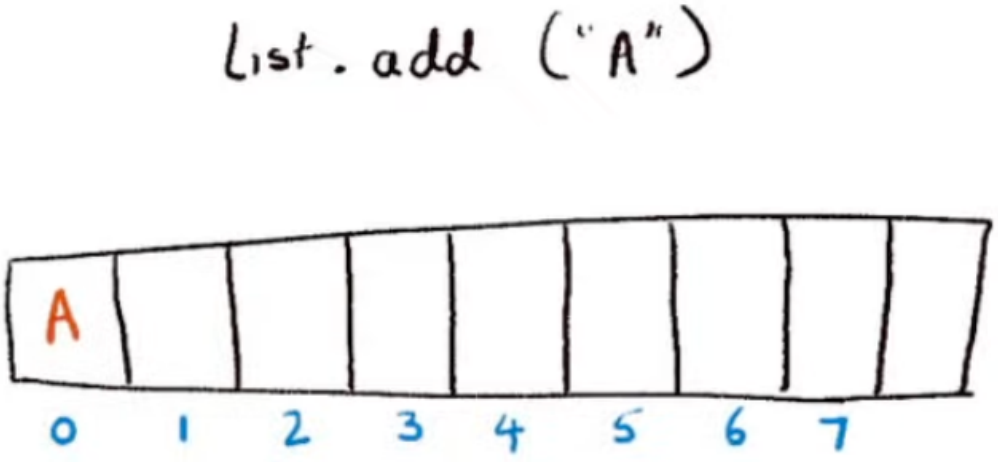
ArrayList

- A list that is implemented as an array
- The array is resized automatically when the list grows
- The array is resized automatically when the list shrinks
- The array is resized automatically when the list is cleared

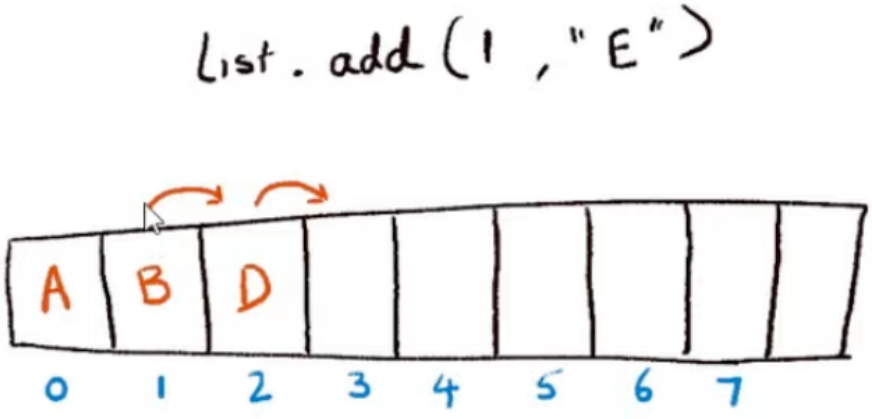
```
ArrayList<E> arrayList = new ArrayList<>();
```



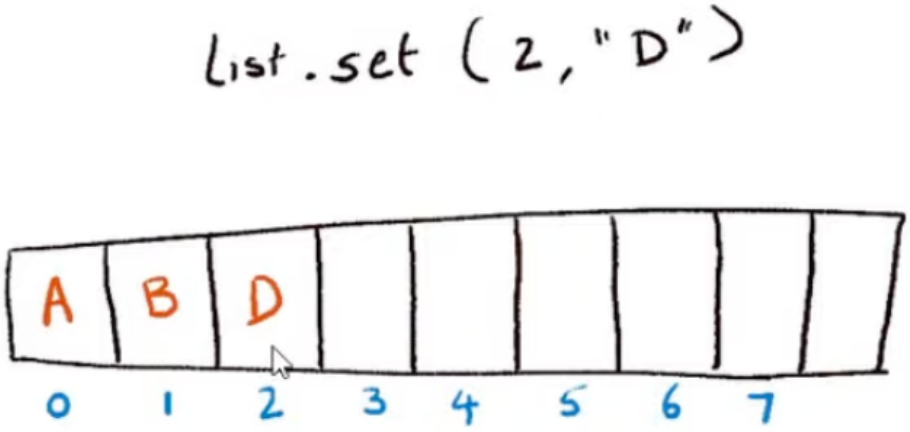
ArrayList - Add



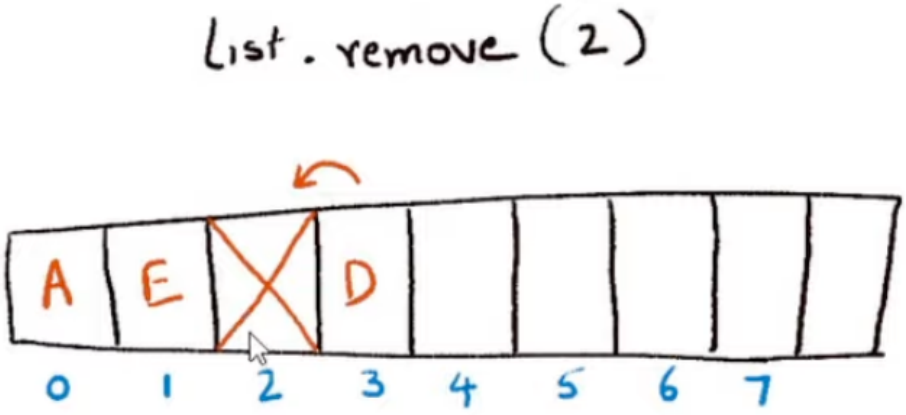
ArrayList - Add at index



ArrayList - Set

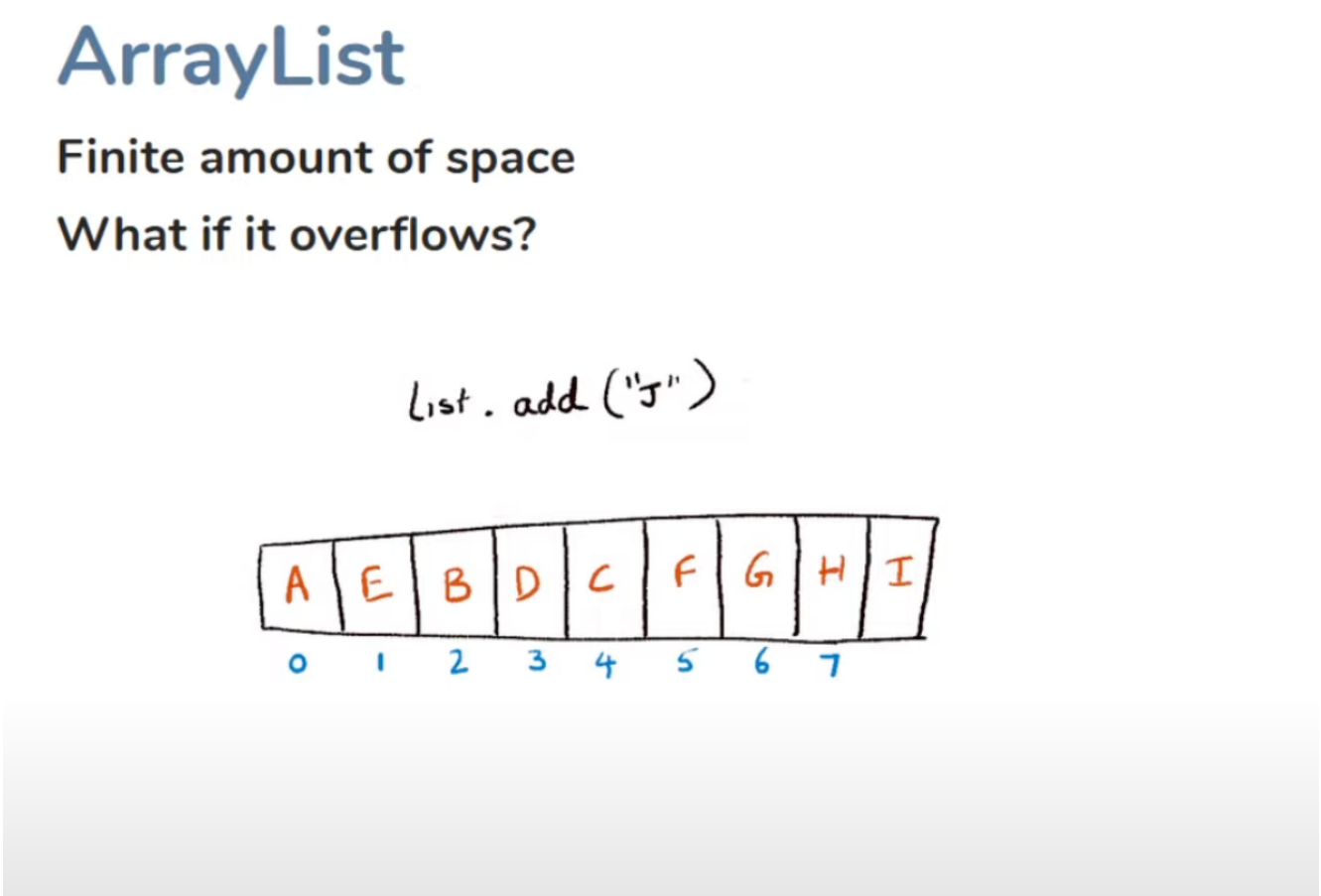


ArrayList - Remove



ArrayList performance

- get() - O(1)
- set() - O(1)
- contains - O(n)
- remove(0) - O(n)
    - 1. remove first element (1)
    - 2. shift all other elements to the left (n-1)
- add(0) - O(n)
- add(Object o) to the end - ???
    - Best case - O(1)
    - Worst case - O(N)
    - Most cases - O(1)
    - Finite amount of space
    - doubles space when it runs out
    -



    - copy over all the existing element to the new arraylist
    - Add new object to the position after the last element