teamnet transforming technology

# An introduction to the Java Collections Framework

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## Outline

1. General concepts
2. Containers in Java
3. ~~Container utility classes~~[1]

1 = As further self-study materials: see `java.util.Arrays` and `java.util.Collections`
See Java SE Documentation: http://docs.oracle.com/javase/8/docs/

# 1

## General concepts

## General concepts

- Every programming language makes use of some **base data structures** to assist in developer productivity.

- In programming literature these are known as **compound data types** – and are especially useful for dynamicity at run-time.

- They are split into three categories, which we'll henceforth call *containers*:
    1. Tuples
    2. Lists
    3. Dictionaries

# 2

## Containers… the Java way

# 2

**But first, a word about Tuples!**

## Tuples

- They represent **ordered** (not sorted!) sequences of elements.
- They are **immutable** (i.e. they cannot be changed at element level).
- **Not part of Java**, by default.
- Their purpose: ???

Let's find out… ☺

# **Tuples** – Quick example

Problem formulation:

```
public static void main(String[] args) {
    Sample samplesA = generateRandomSample(10);
    Sample samplesB = generateRandomSample(10);

    System.out.println(samplesA);
    System.out.println(samplesB);
}
```

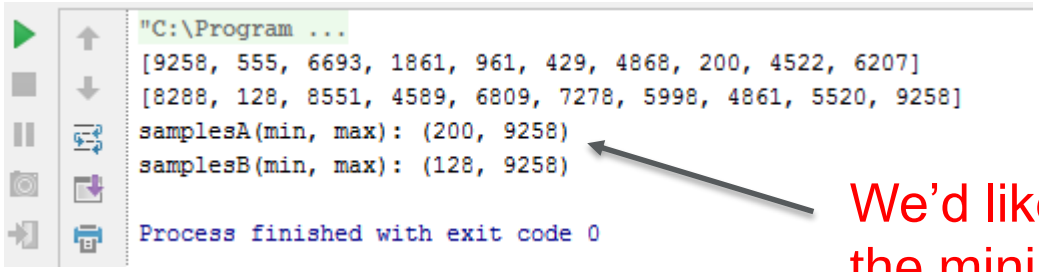
Given multiple batches of experimental data

```
"C:\Program ...
[9258, 555, 6693, 1861, 961, 429, 4868, 200, 4522, 6207]
[8288, 128, 8551, 4589, 6809, 7278, 5998, 4861, 5520, 9258]

Process finished with exit code 0
```

# **Tuples** – Quick example (2)

Problem formulation:

```
public static void main(String[] args) {
    Sample samplesA = generateRandomSample(10);
    Sample samplesB = generateRandomSample(10);

    System.out.println(samplesA);
    System.out.println(samplesB);
}
```




We'd like *to* compute both
the minimum
and the maximum…

using a single method!

# **Tuples** – Quick example (3)

We define a 2-Tuple to hold our data:

```
public class TwoTuple<A, B> {
    public final A first;
    public final B second;

    public TwoTuple(A first, B second) {
        this.first = first;
        this.second = second;
    }

    public String toString() { return "(" + first + ", " + second + ")"; }
}
```

*public access* holders for 1st and 2nd element

In the future, we might need 3 items? No problem!

```
public class ThreeTuple<A, B, C>
        extends TwoTuple<A, B> {

    public final C third;

    public ThreeTuple(A first, B second, C third) {
        super(first, second);
        this.third = third;
    }

    public String toString() {
        return "(" + first + ", "
                + second + ", "
                + third + ")";
    }
}
```

add a 3rd holder item using inheritance

# **Tuples** – Quick example (3)

We define a 2-Tuple to hold our data:

```
public class TwoTuple<A, B> {
    public final A first;
    public final B second;

    public TwoTuple(A first, B second) {
        this.first = first;
        this.second = second;
    }

    public String toString() { return "(" + first + ", " + second + ")"; }
}
```

*public access* holders for 1st and 2nd element

Build our algorithm, using above type

```
public static TwoTuple<Integer, Integer>
computeBatchCharacteristics(Sample sampleBatch) {
    // Compute minimum and maximum
    return tuple(min(sampleBatch),  // and return
                 max(sampleBatch)); // as a 2-tuple
}
```

return a 2-tuple

## **Tuples** – Conclusions

- They represent ordered (not sorted!) sequences of elements.
- They are immutable (they cannot be changed at element level).
- **Not part of Java**, by default.
- Their purpose: they allow **multi-return** in methods/functions.

# 2.1

## Arrays in Java

# **Array**(s)

- The most basic (primitive) “containers” of any statically typed programming language.

Declaration (two alternatives):

```
// Declaration through initializer
int[] arrayOfIntegers = new int[] { 1, 3, 5, 7, 9, };
```

type — variable name — “new” operator — type[desired_size] — initializer

Setting values explicitly:

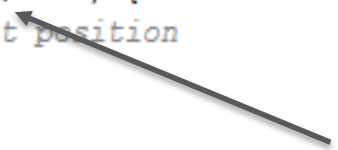
```
// Explicitly setting values
arrayOfIntegers[0] = 1; // Notice: the first entry always starts at position '0' !!!
arrayOfIntegers[1] = 3;
```

explicit position — explicit value

# **Array**(s) – Adding and retrieving values

Adding values (most often done way):

```
// Automate addition by iterating over array
for (int i = 2; i < arrayOfIntegers.length; i++) {
    // Double the value and set on explicit position
    arrayOfIntegers[i] = i * 2;

    // Other processing steps
    // could follow here
    // ...
}
```




Retrieval (explicit):

```
// Retrieving values explicitly
int firstValue = arrayOfIntegers[0]; // Access first value, save its reference
int secondValue = arrayOfIntegers[1]; // Access second value, save its reference
```

- They offer the best **random access performance** compared with any other containers (for both *addition* and *retrieval* of data).

## **Array**(s) – Further notes on retrieval

- Their main issue? They (must) have a (known) fixed size; generally very expensive to expand, to accommodate other items.

Retrieval (***classic*** *vs.* ***foreach*** iteration):

```
// --- Does it contain number '5'?
// A flag to denote discovery
boolean containsFive = false;
// Automate retrieval by iterating over array
for (int arrayOfInteger : arrayOfIntegers) {
    // Validate each retrieved value against '5'
    if (arrayOfInteger == 5) {
        // Set flag to true
        containsFive = true;
        break; // No need to proceed any further
    }
}
// Print conclusion
System.out.println(containsFive ? "Five's in here!" : "Sorry buddy, no five for you!");
```

Using "foreach"

Simpler access to references instead of "i"-based values

# **Array**(s) – Printing

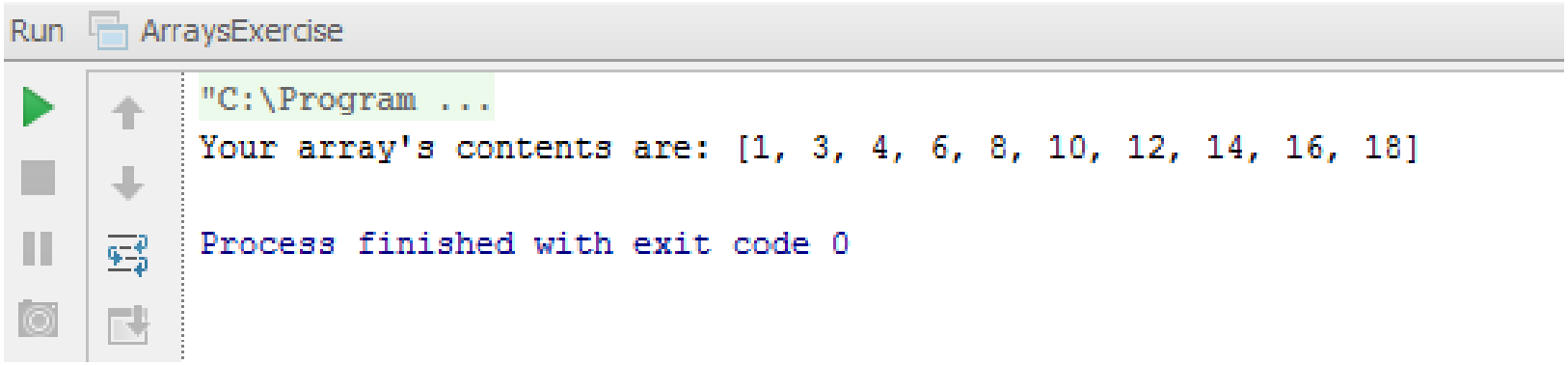
## Printing (user friendly way):

```
// Finally, let's print it out
System.out.println("Your array's contents are: " +
        java.util.Arrays.toString(arrayOfIntegers));
```

A-ha, what's this?!

First contact with container utilities! ☺

## Print results:



## Changing requirements

- What if we want to deal with any known number of “items”, dynamically at run-time?
- What if we had some kind of utility that could hold elements and expand in *a natural sort of way*, if needed?

How about we take a look at what’s inside the `java.util` **package**?

# The java.util “toolbox”

Here’s an overview of the most often used Java containers:

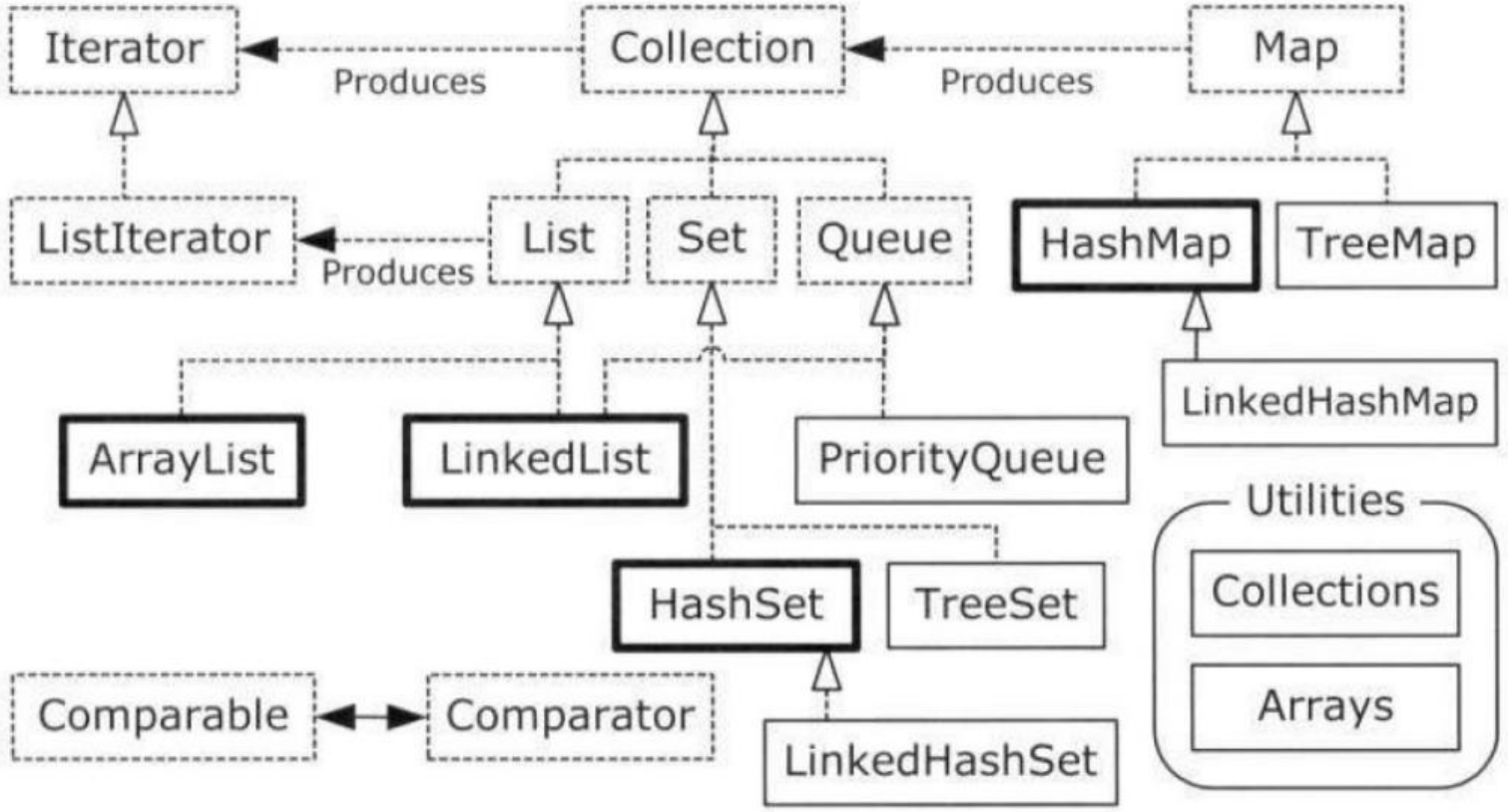





Image source: Thinking in Java (4th Edition), Bruce Eckel

## A first word about Java containers

Categories:

1. **Collections** – *sequences* which can hold **individual** elements based on one or more rules.

2. **Maps** – a group of **associated pairs** of elements (also known as a *dictionary*, in programming literature).

Container utilities: `java.util.`**`Arrays`** & **`Collections`** classes

# java.util.Collection(s)

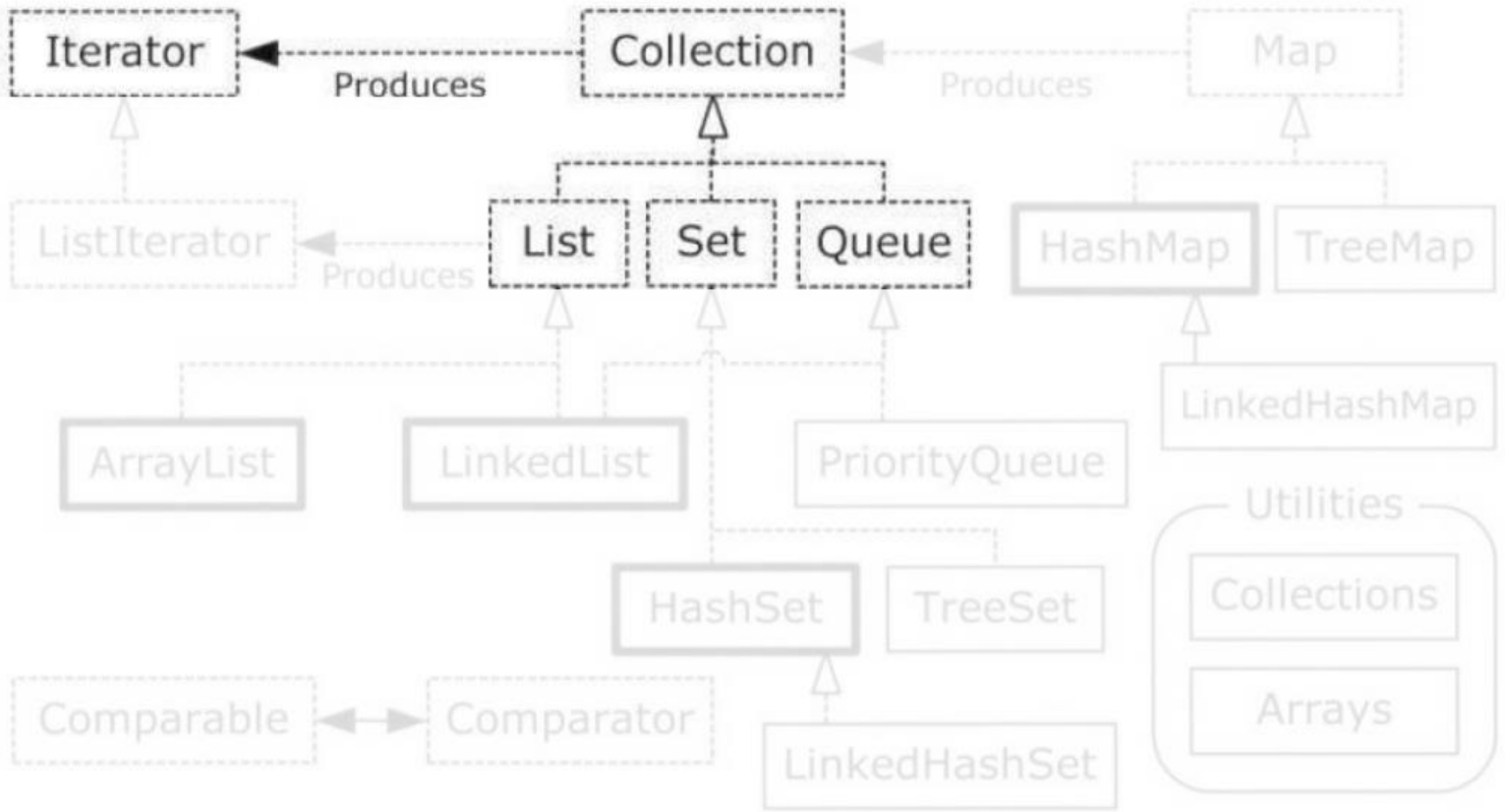
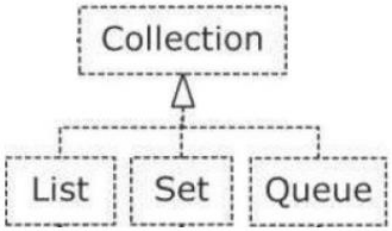





Image source: Thinking in Java (4th Edition), Bruce Eckel

# **java.util.Collection**(s)




The basic single-item containers in Java are known as **collections**.

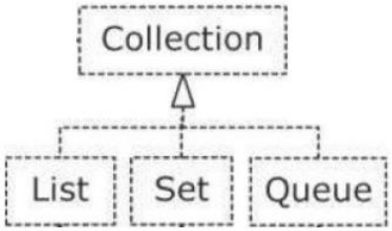
The `Collection` interface generalizes the idea of a sequence – a way of holding a group of objects.

*Crudely* put, a collection is a **container** that can **hold** any number of **objects** (possibly taking into account some *rules*).



Image source: Thinking in Java (4th Edition), Bruce Eckel

# java.util.Collection(s)




## Why would one use such data structures?

**Advantages**:

- No expansion limits

  (making them *perfect* for dynamic memory management)

**Disadvantages**:

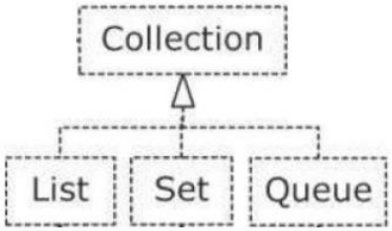
- None

  (sort of - because they are task specific - this illustrates that they have weaknesses of their own, which you need to be aware of) ☺



Image source: Thinking in Java (4th Edition), Bruce Eckel

# java.util.Collection(s)




Java collections can *initially* be split into:

- `Lists`
- `Sets`
- `Queues`

(these are all just *root* interfaces)

Each comes with strengths and weaknesses, and is suitable for a specific task, as we'll see.



Image source: Thinking in Java (4th Edition), Bruce Eckel

# 2.2

## Lists in Java

# java.util.List(s)

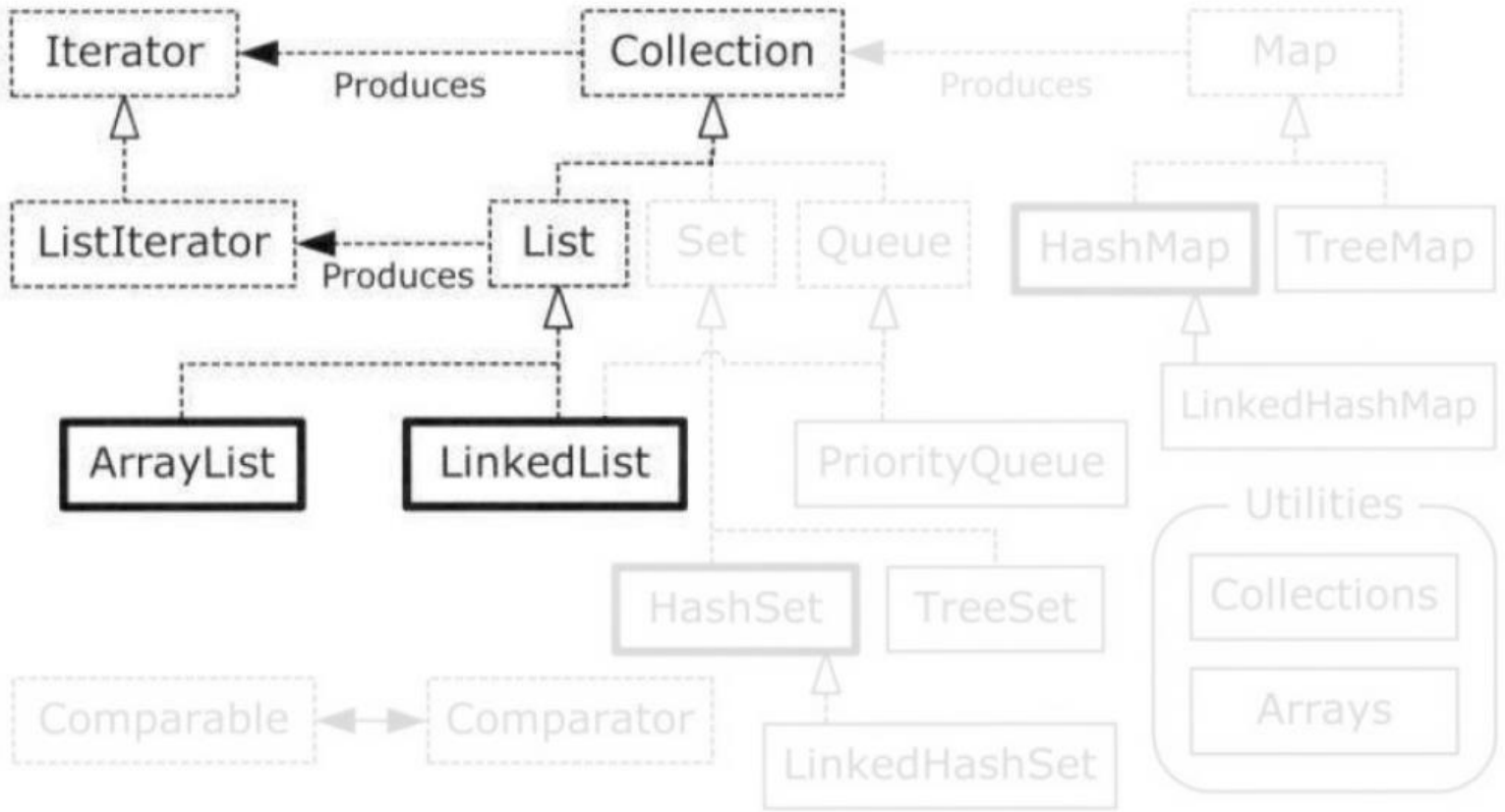





Image source: Thinking in Java (4th Edition), Bruce Eckel

## **java.util.List**(s) – Notes

- They can hold single elements.
- They **allow** duplicates to be inserted.
- They are **ordered**, by default (**not sorted** – careful here!).
- Adequate for FIFO and LIFO behavior (as **stack**s & **queue**s – later on this).

# **java.util.List**(s) – Quick example

Given the following:

```
class Motherboard {

    private final String serialNumber;

    public Motherboard() { this.serialNumber = generateSerialNumber("MBD"); }

    public void listPartDetails() {
        System.out.println("I'm a " + this.getClass().getSimpleName()
                + "\nS/N: " + this.serialNumber);
    }
}
class CPU {

    private final String serialNumber;

    public CPU () {
        this.serialNumber = generateSerialNumber("CPU");
    }

    public void listPartDetails() {
        System.out.println("I'm a " + this.getClass().getSimpleName()
                + "\nS/N: " + this.serialNumber);
    }
}
```

# **java.util.List**(s) – Quick example (2)

Let's put them into practice:

```
@SuppressWarnings("unchecked")
public static void main(String[] args) {

    // A quick declaration
    ArrayList partsList = new ArrayList();
    // Add some parts to our list
    partsList.add(new CPU());
    partsList.add(new CPU());
    partsList.add(new Motherboard());

    for (int i = 0; i < partsList.size(); i++) {
        // Retrieve and cast to CPUs
        ((CPU)partsList.get(i)).listPartDetails();
    }
}
```

Simple declaration

Adding elements

Retrieval

```
Run  ListsExercise
"C:\Program ...
I'm a CPU
Exception in thread "main" java.lang.ClassCastException: lists.ListsExercise$Motherboard cannot be cast to lists.ListsExercise$CPU
    at lists.ListsExercise.main(ListsExercise.java:132) <5 internal calls>
S/N: CPU-128430
I'm a CPU
S/N: CPU-644387

Process finished with exit code 1
```

*How could we solve this problem?*

# **java.util.List**(s) – Quick example (3)

## Fix by adding a rule: establish *bounds*

```java
@SuppressWarnings("unchecked")
public static void main(String[] args) {

    // A quick declaration
    ArrayList partsList = new ArrayList();
    // Add some parts to our list
    partsList.add(new CPU());
    partsList.add(new CPU());
    partsList.add(new Motherboard());

    for (int i = 0; i < partsList.size(); i++) {
        // Retrieve and cast to CPUs
        ((CPU)partsList.get(i)).listPartDetails();
    }
}
```

```java
@SuppressWarnings("unchecked")
public static void main(String[] args) {

    // A bounded list (can hold only CPU)
    ArrayList<CPU> partsList = new ArrayList<CPU>();
    // Add some parts to our list
    partsList.add(new CPU());
    partsList.add(new CPU());
    // ! partsList.add(new Motherboard()); // Not allowed anymore

    for (CPU part : partsList) {
        // Easier retrieval as well
        part.listPartDetails();
    }
}
```

```
"C:\Program ...
I'm a CPU
S/N: CPU-307516-CP815915-
I'm a CPU
S/N: CPU-859552-CP59231-

Process finished with exit code 0
```

*Hey, what about the poor Motherboard? ☹*

# **java.util.List**(s) – Quick example (4)

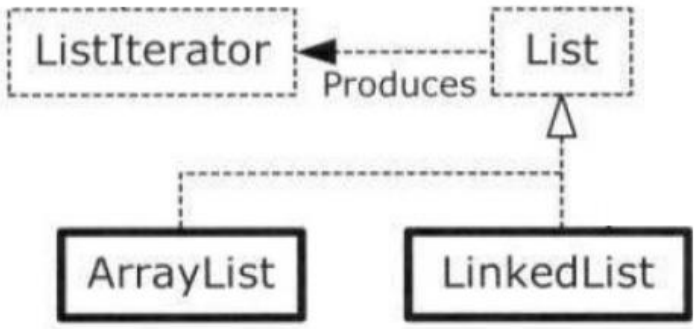
## Easy fix: *lowering* the *bounds*, through *polymorphism*

```
public static void main(String[] args) {

    // A bounded list (can hold any Part)
    ArrayList<Part> partsList = new ArrayList<Part>();
    // Add some parts to our list
    partsList.add(new CPU());
    partsList.add(new CPU());
    partsList.add(new Motherboard()); // Allowed now
    partsList.add(new Motherboard());

    for (Part part : partsList) {
        // Easier retrieval as well
        part.listPartDetails();
    }
}
```

Both **CPU** and **Motherboard** are some kind of **Part**

```
"C:\Program ...
I'm a CPU
S/N: CPU-385229-CP62893-
I'm a CPU
S/N: CPU-73361-CP811429-
I'm a Motherboard
S/N: MBD-36526-CP22908-
I'm a Motherboard
S/N: MBD-603444-CP97315-

Process finished with exit code 0
```

# java.util.List(s)




Most often used **Lists** are:

- `ArrayList`
- `LinkedList`

Legacy:

- `Vector`

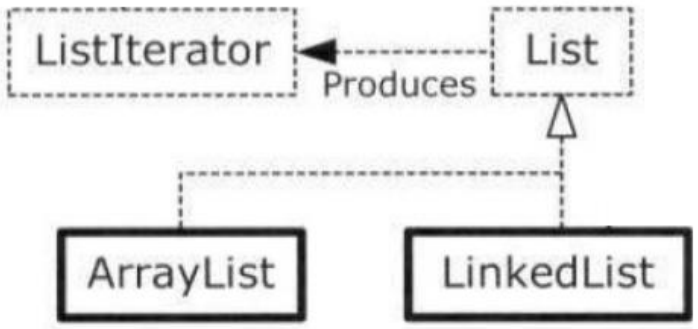
(may be old school, but it offered thread-safety – replaced by `CopyOnWriteArrayList`)

When and why would one use such data structures?



Image source: Thinking in Java (4th Edition), Bruce Eckel

# java.util.ArrayList




The most basic type of sequence.

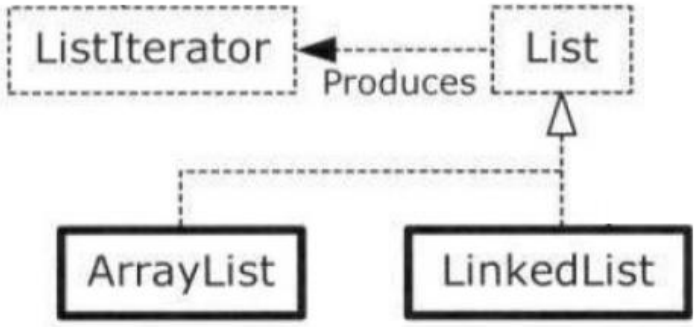
Excels at **random**ly **access**ing elements.

The drawback: **slower** when **insert**ing elements in the **middle**.



Image source: Thinking in Java (4th Edition), Bruce Eckel

# java.util.LinkedList




A general purpose sequence: can be used as a **stack**, as a **queue** and **de-queue**.

Larger feature set than an `ArrayList`.

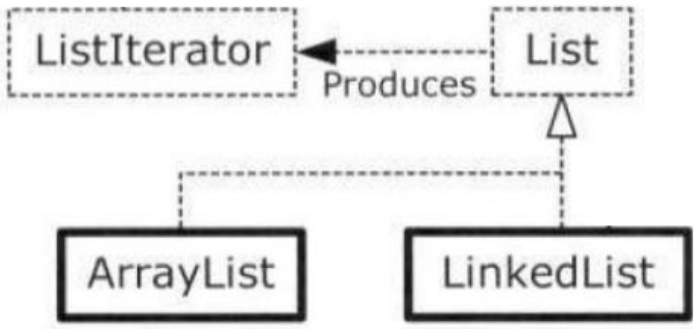
Best for *sequential* access; **inexpensive insertions** and **deletions** in the middle.

The drawback: **slow** for **random access**.



Image source: Thinking in Java (4th Edition), Bruce Eckel

# java.util.List(s)




The most **common operations** you will do with/on a **List** are:

- `add(obj)` (at the end)
- `addAll(collection)`
- `insert(atPosition)`
- `contains(obj)`
- `get(position)`
- `remove(position/obj)`
- `iterator()`



Image source: Thinking in Java (4th Edition), Bruce Eckel

# 2.2.1

## A case for Iterators

# java.util.Iterator

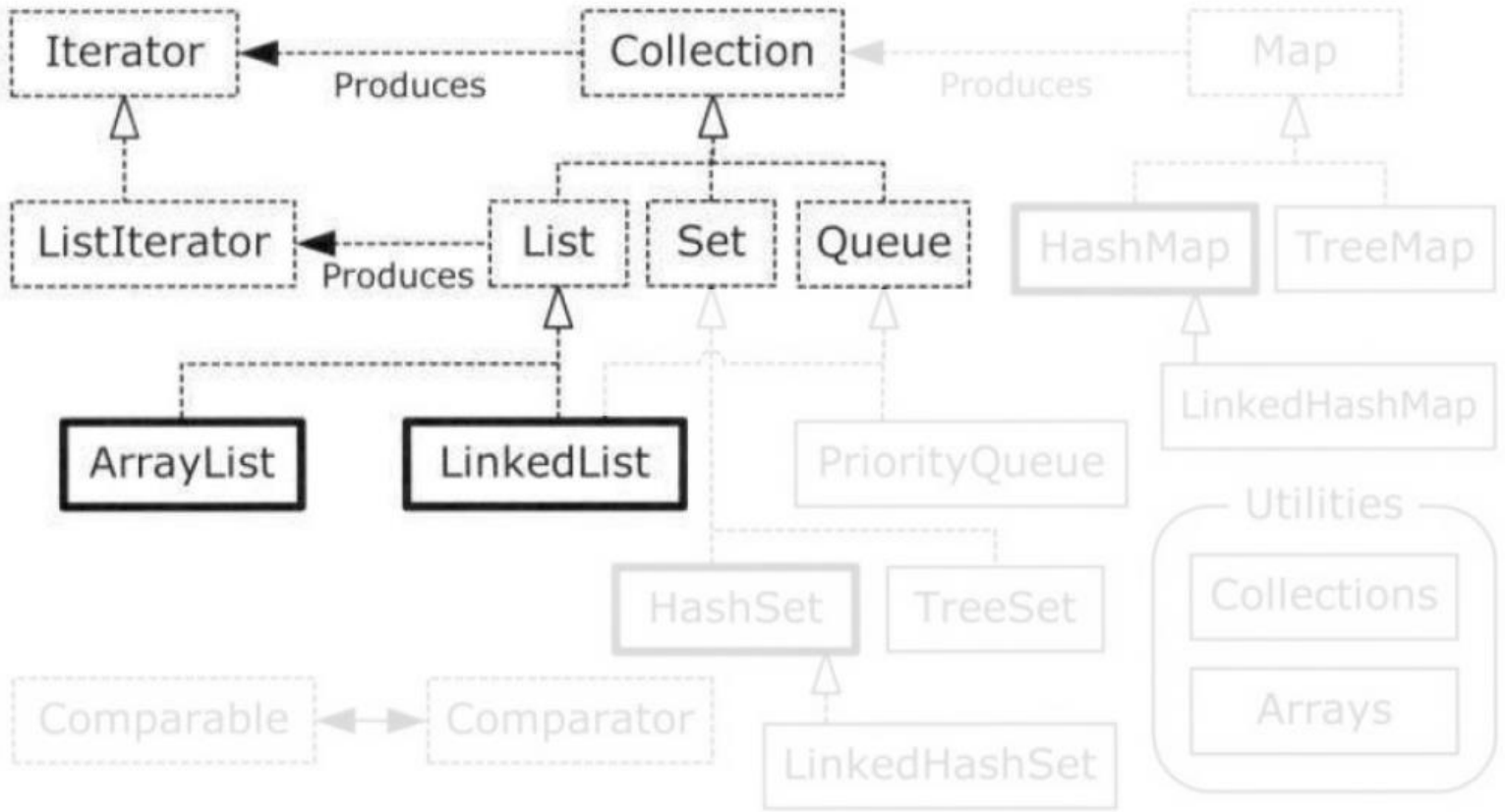





Image source: Thinking in Java (4th Edition), Bruce Eckel

## **java.util.Iterator** – Notes (1)

- Any container must be able to accept as well as retrieve items.

(Thus you could say, well, we have **add()** and **get()** for exactly that.)

- However, the idea is to think at a higher-level, and thus, there is a drawback using the previous approach: **you need to program to the exact type of container**.

(What if we write code for a `List` and later decide it would apply to a `Set` as well – since both are containers after all ?)

(Or what if, we want, from the beginning, to write general purpose code that applies to every container, no matter the underlying type?)

- The concept of an `Iterator` (a design pattern) can be used to achieve this abstraction.

## **java.util.Iterator** – Notes (2)

- An **iterator** is a *lightweight object* that **moves** through a **sequence**.
- It **selects each element** of that **sequence** without having the programmer worrying about the underlying type (i.e. enforces *loose coupling*).
- A usual interaction with an iterator would look like:
  1. Ask a `Collection` for an `Iterator`, by calling `iterator()`
  2. Get the next object in the sequence using `next()`
  3. See if there are more elements with `hasNext()`
  4. Remove the last element returned using `remove()`

# **java.util.Iterator** – Quick example

```
public static void main(String[] args) {
    List<Pet> pets = Pets.arrayList(12);
    // Iteration via iterator
    Iterator<Pet> it = pets.iterator();
    while (it.hasNext()) {
        Pet p = it.next();
        System.out.print(p.id() + ":" + p + " ");
    }
    System.out.println();
    // A simpler approach, when possible:
    for (Pet p : pets)
        System.out.print(p.id() + ":" + p + " ");
    System.out.println();
    // An Iterator can also remove elements:
    it = pets.iterator();
    for (int i = 0; i < 6; i++) {
        it.next();
        it.remove();
    }
    System.out.println(pets);
}
```

ask for the collection's Iterator

if there are elements in the sequence

retrieve an element

use *foreach* when *reading*

remove the current element



Code source: Thinking in Java (4th Edition), Bruce Eckel

# **java.util.Iterator** – A (better) typical use case

```
public class CrossContainerIteration {
    public static void display(Iterator<Pet> it) {
        while (it.hasNext()) {
            Pet p = it.next();
            System.out.print(p.id() + ":" + p + " ");
        }
        System.out.println();
    }

    public static void main(String[] args) {
        ArrayList<Pet> pets = Pets.arrayList(8);
        LinkedList<Pet> petsLL = new LinkedList<Pet>(pets);
        HashSet<Pet> petsHS = new HashSet<Pet>(pets);
        TreeSet<Pet> petsTS = new TreeSet<Pet>(pets);
        display(pets.iterator());
        display(petsLL.iterator());
        display(petsHS.iterator());
        display(petsTS.iterator());
    }
}
```

if there are elements in the sequence

retrieve an element via next()

ask for each container's Iterator



Code source: Thinking in Java (4th Edition), Bruce Eckel

# java.util.ListIterator

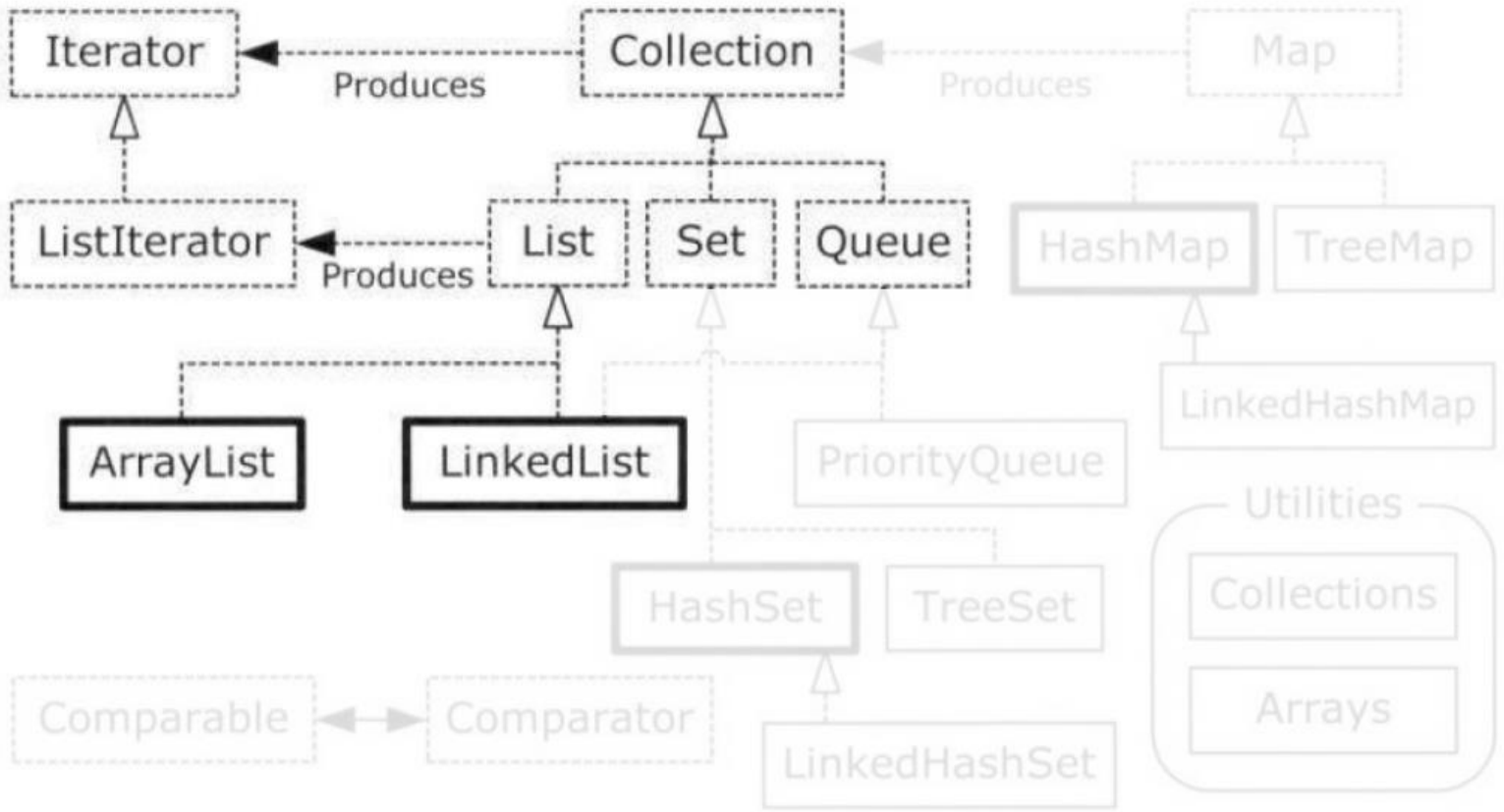





Image source: Thinking in Java (4th Edition), Bruce Eckel

## java.util.ListIterator

- A more *powerful* iterator produced only by List implementations.
- Apart from the forward version of the general implementation, a `ListIterator` is bidirectional; traversal can be done both ways.
- Can also produce **indexes** of the **next** and **previous** elements, relative to where the iterator is pointing in the list.
- It can replace the last element visited, using the `set()` method.

# **java.util.ListIterator** – Quick example

```
public static void main(String[] args) {
    List<Pet> pets = Pets.arrayList(8);
    ListIterator<Pet> it = pets.listIterator();
    while (it.hasNext())
        System.out.print(it.next() + ", " + it.nextIndex() +
                ", " + it.previousIndex() + "; ");
    System.out.println();
    // Backwards:
    while (it.hasPrevious())
        System.out.print(it.previous().id() + " ");
    System.out.println();
    System.out.println(pets);
    it = pets.listIterator(3);
    while (it.hasNext()) {
        it.next();
        it.set(Pets.randomPet());
    }
    System.out.println(pets);
}
```

ask for the collection's Iterator

forward *facing*

access indexes

reverse direction

change an element using set()

## **java.util.List**(s) – Conclusions

- They can associate numerical indexes to objects – thus, like arrays they are **ordered**.
- Automatic resizing to accommodate new items, if needed.
- `ArrayLists` excel at **random access** (direct retrieval).
- `LinkedLists` are **multi-purpose** lists; they offer **optimal sequential access**, as well as **insertions** and **deletions** in the middle.
- **Iterator**s *unify access to containers* because they separate traversal of a sequence from underlying implementations.

# 2.3

## Sets in Java

# java.util.Set(s)

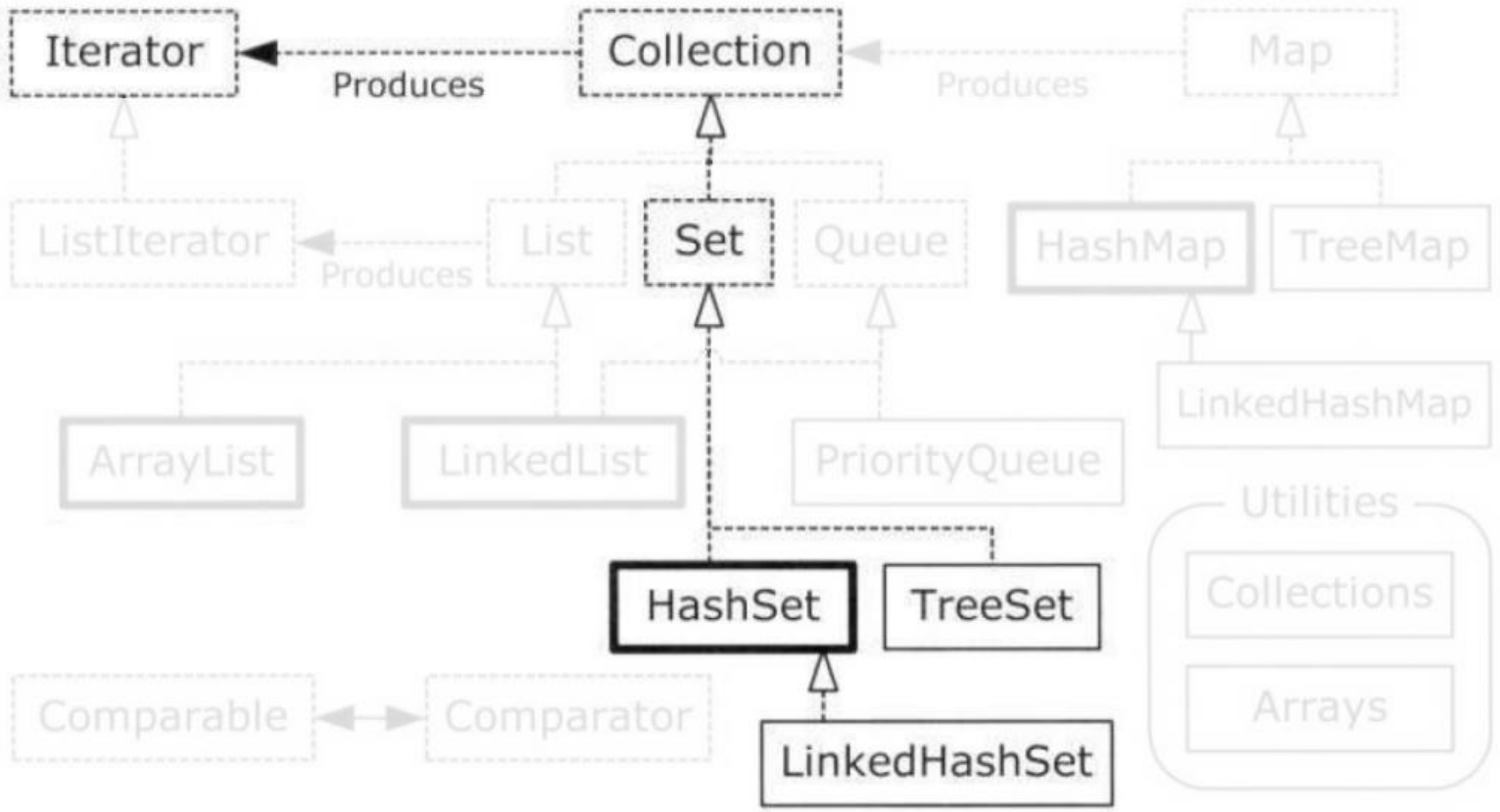





Image source: Thinking in Java (4th Edition), Bruce Eckel

## **java.util.Set**(s) – Notes

- Like lists, they can hold single elements.
- They **DO NOT** allow duplicates.
- Used for *querying* held elements, via `contains(obj)` method (e.g. *test for membership*).
- Because of this, lookup is typically the most important operation for a `Set`.

# **java.util.Set**(s) – Quick example

```
public static void main(String[] args) {
    Random rand = new Random(47);

    Set<Integer> intSet = new HashSet<Integer>();

    for (int i = 0; i < 10000; i++)
        intSet.add(rand.nextInt(30));
    System.out.println(intSet);

}
```

typical declaration

add an integer between 0 and 30

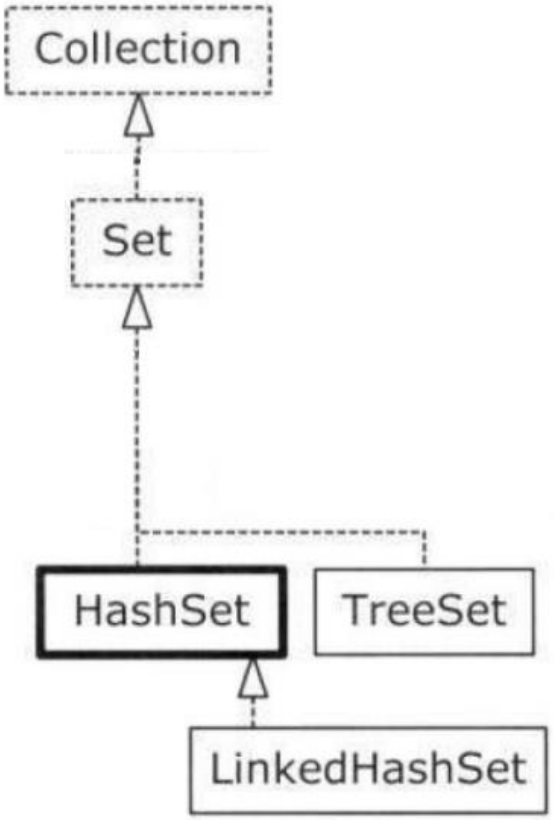
```
"C:\Program ...
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 16, 19, 18, 21, 20, 23, 22, 25, 24, 27, 26, 29, 28]

Process finished with exit code 0
```

*No duplicates, although 10,000 integers were added.*



Image source: Thinking in Java (4th Edition), Bruce Eckel

# java.util.Set(s)




**Sets** are available in many flavors. The **three** most used are:

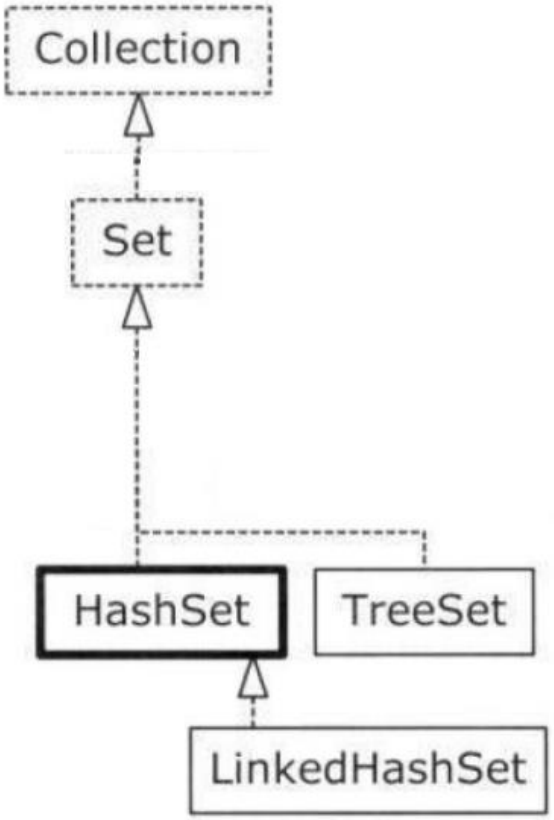
- `HashSet`
- `LinkedHashSet`
- `TreeSet`

When and why would one use such data structures?



Image source: Thinking in Java (4th Edition), Bruce Eckel

# java.util.HashSet




Used when fast lookup time is important.

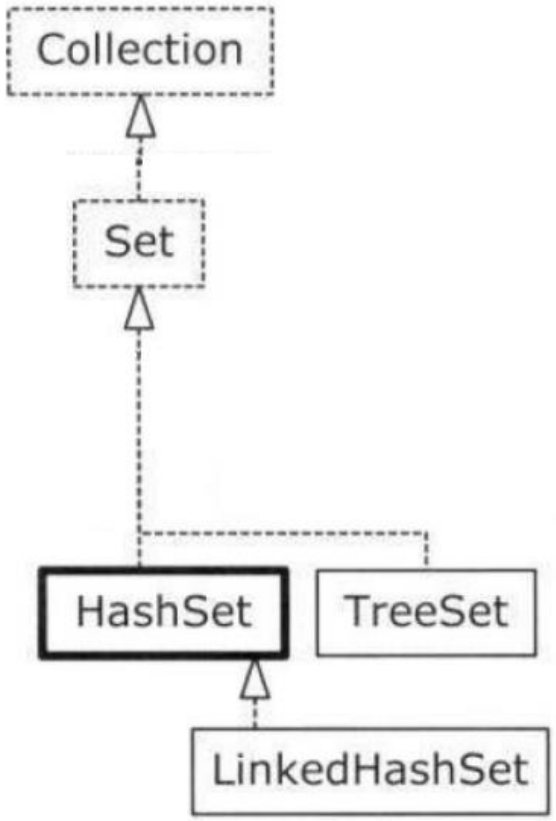
Utilizes a hashing function for speed.

Order of elements appears to be maintained through custom heuristics.



Image source: Thinking in Java (4th Edition), Bruce Eckel

# java.util.LinkedHashSet




Typically as fast as HashSet, in matters of lookup speed.

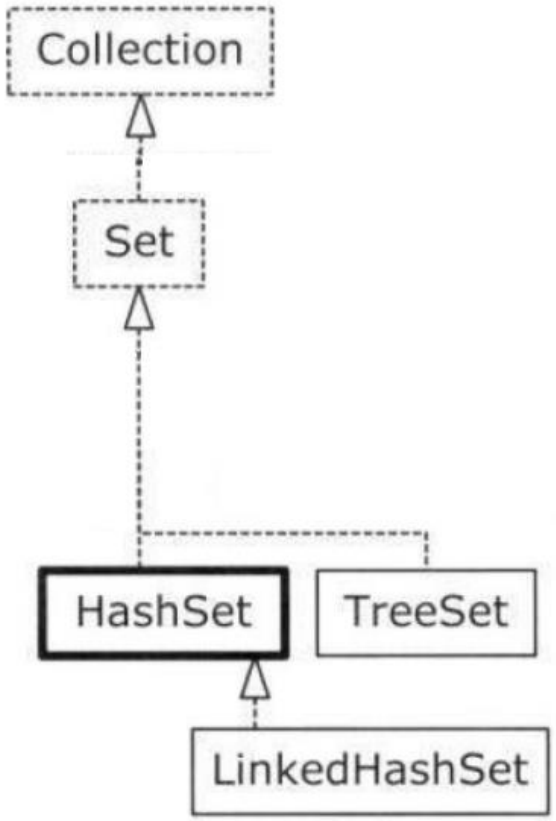
Elements held, **appear to be ordered** based on **insertion order**.

This is because the ordering is based on an **underlying linked list.**



Image source: Thinking in Java (4th Edition), Bruce Eckel

# java.util.TreeSet




Totally different paradigm than the previous two.

An importance is placed strictly on the principle of sorting of elements.

Sorting is made possible because of the underlying data structure: a **red-black tree**.



Image source: Thinking in Java (4th Edition), Bruce Eckel

# **java.util.TreeSet** – Quick example

```
public class SortedSetOfStrings {

    private static final  String poem =
            "It matters not how strait the gate,\n"+
            "How charged with punishments the scroll.\n"+
            "I am the master of my fate:\n"+
            "I am the captain of my soul.";

    public static void main(String[] args) {
        SortedSet<String> words =
                new TreeSet<String>(String.CASE_INSENSITIVE_ORDER);
        words.addAll(Arrays.asList(poem.split("\\W+")));
        System.out.println(words);
    }
}
```

Notice the use of `SortedSet` interface

A comparator is given; not mandatory

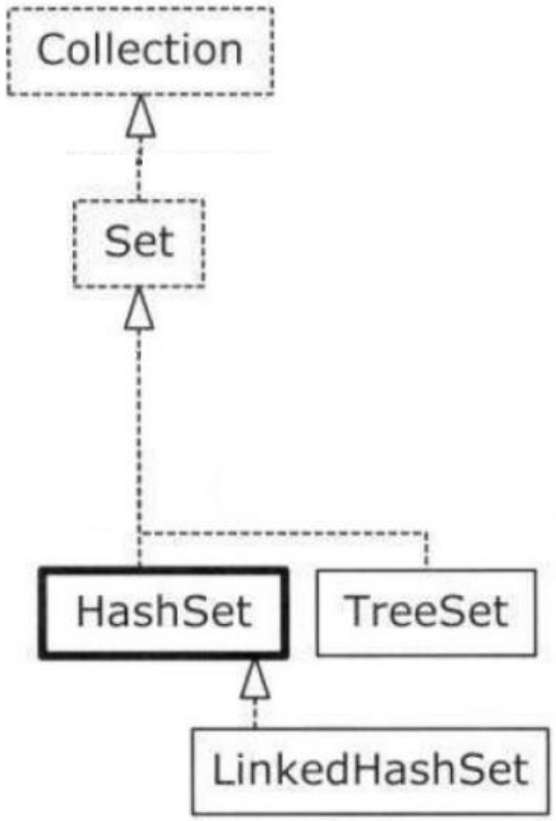
Quick collection building via Arrays.asList(…) utility

```
"C:\Program ...
[am, captain, charged, fate, gate, how, I, It, master, matters, my, not, of, punishments, scroll, soul, strait, the, with]

Process finished with exit code 0
```



Image source: Thinking in Java (4th Edition), Bruce Eckel

# java.util.TreeSet




Thus, the elements in a `SortedSet` are guaranteed to be in **sorted order**.

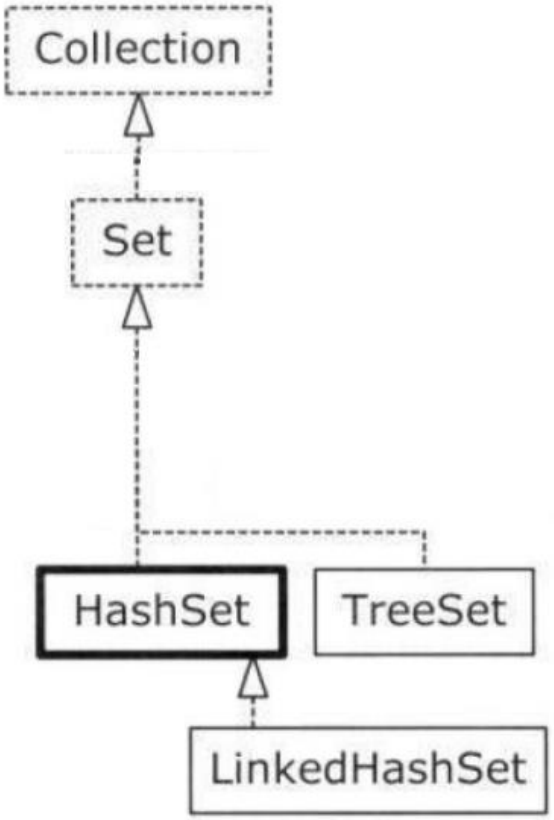
This allows for the following interesting methods:

- `comparator()`
- `first()`
- `last()`
- `subSet(from, to)`
- `headSet(uptoElement)`
- `tailSet(fromElement)`



Image source: Thinking in Java (4th Edition), Bruce Eckel

# java.util.Set(s)




The most **common operations** you will do with/on a **Set** are:

- `add(obj)`
- `addAll(collection)`
- `contains(obj)`
- `iterator()`
- `remove(obj)`



Image source: Thinking in Java (4th Edition), Bruce Eckel

## **java.util.Set**(s) – Conclusions

- A `Set` **only accepts one** of each type of objects (no duplicates).
- **Automatic resizing** to accommodate new items, if needed.
- `HashSet(s)` are best used for **fast lookup time**.
- `LinkedHashSet(s)` have similar lookup time, and maintain an **order** based on **insertion**.
- `TreeSet(s)` are a breed apart, focusing on a **sorting order** for held elements.

# 2.4

## Maps in Java

# The java.util “toolbox”

Here’s an overview of the most often used Java containers:

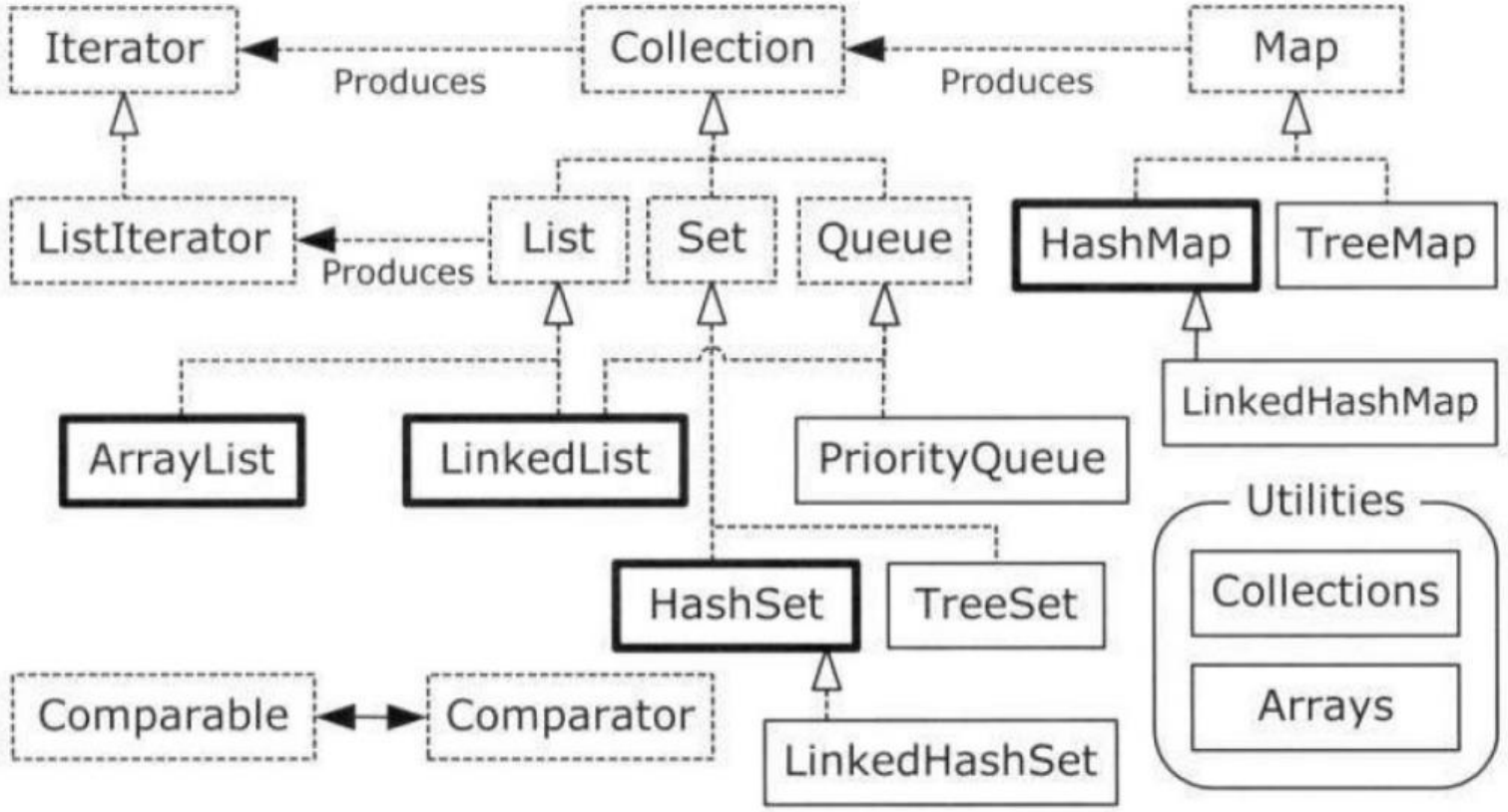





Image source: Thinking in Java (4th Edition), Bruce Eckel

# java.util.Map(s)

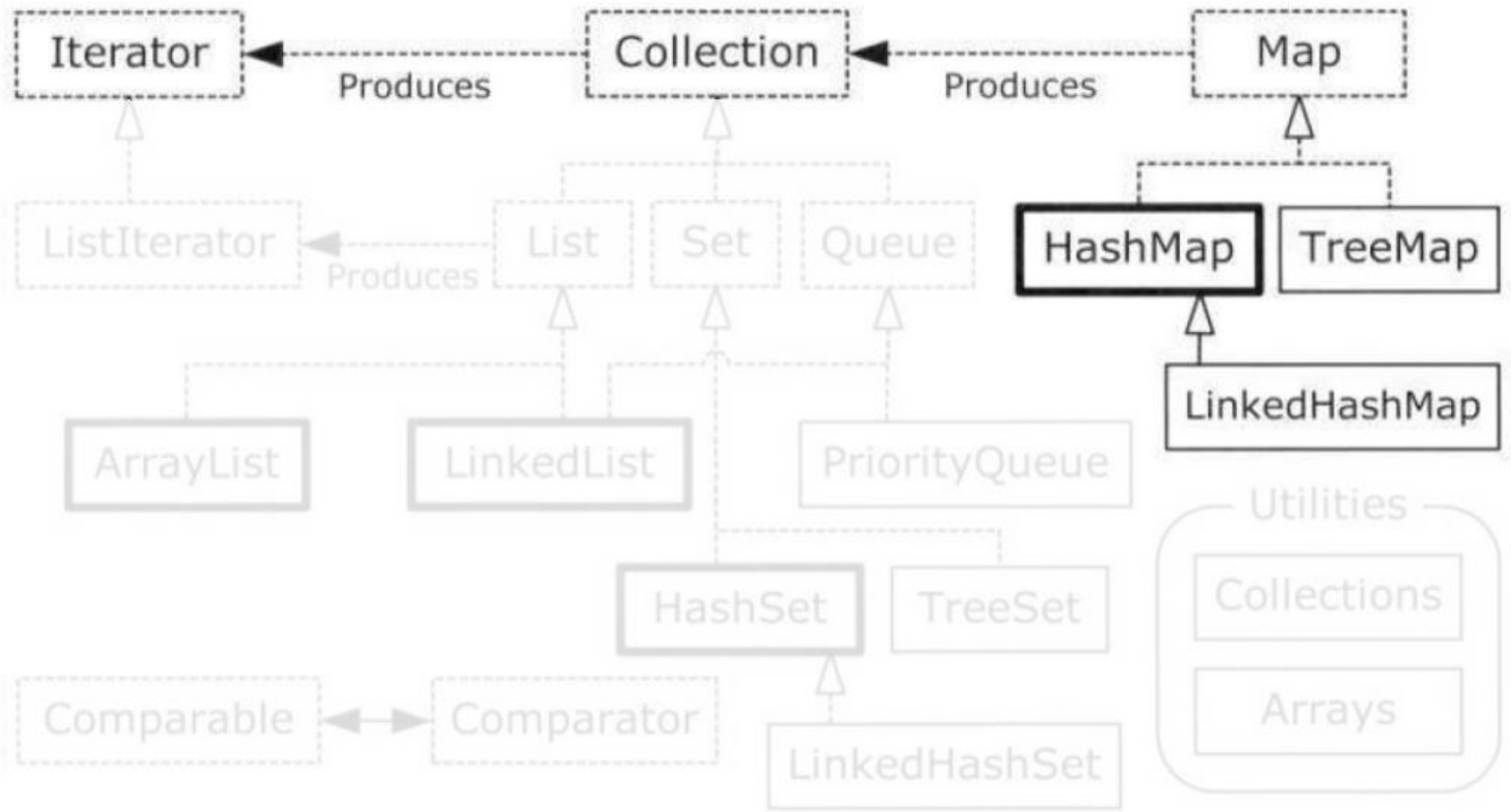





Image source: Thinking in Java (4th Edition), Bruce Eckel

## **java.util.Map**(s) – Notes

- Allows for a way to easily **associate objects with** other **objects**.
- It works on the principle of a **dictionary**: a **key maps** to one (or more) **associated value**(s).
- A **Map** can **return** a **`Set`** of its **keys**, a **`Collection`** of its **values** or a **`Set`** of its pairs (i.e. **entries**).
- **Automatic resizing** to accommodate new keys, if needed.

# **java.util.Map**(s) – Quick example

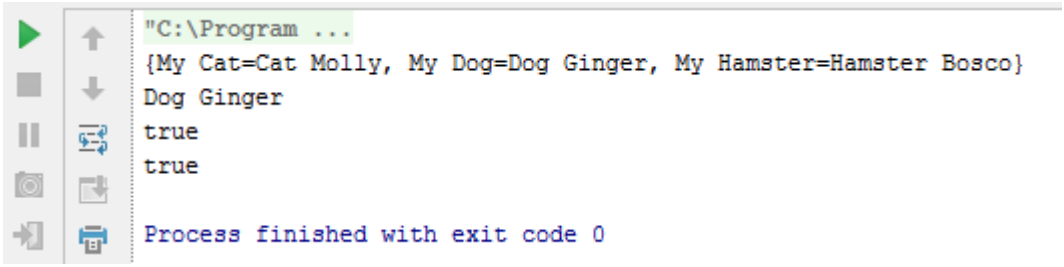
```
public static void main(String[] args) {
    Map<String, Pet> petMap = new HashMap<String, Pet>();

    petMap.put("My Cat", new Cat("Molly"));
    petMap.put("My Dog", new Dog("Ginger"));
    petMap.put("My Hamster", new Hamster("Bosco"));

    System.out.println(petMap);
    Pet dog = petMap.get("My Dog");
    System.out.println(dog);

    System.out.println(petMap.containsKey("My Dog"));
    System.out.println(petMap.containsValue(dog));
}
```

declaration establishes bounds on `<Key, Value>`

insert items via `put(key, value)`

retrieve an item via `get(key)`

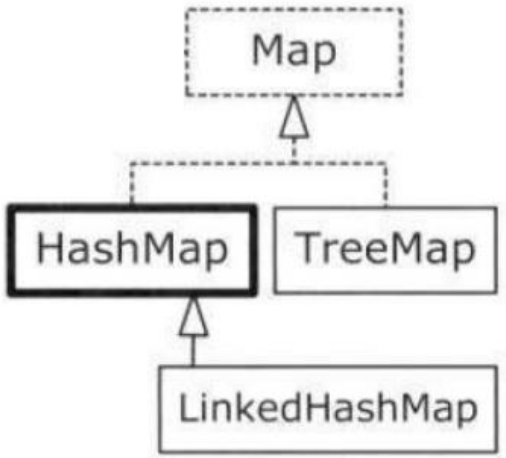
keys are stored as a `Set`
values as a `Collection`






Code source: Thinking in Java (4th Edition), Bruce Eckel

# java.util.Map(s)




**Maps** are available in **many** flavors. The **three** most used are:

- `HashMap`
- `LinkedHashMap`
- `TreeMap`

Legacy:

- `Hashtable`

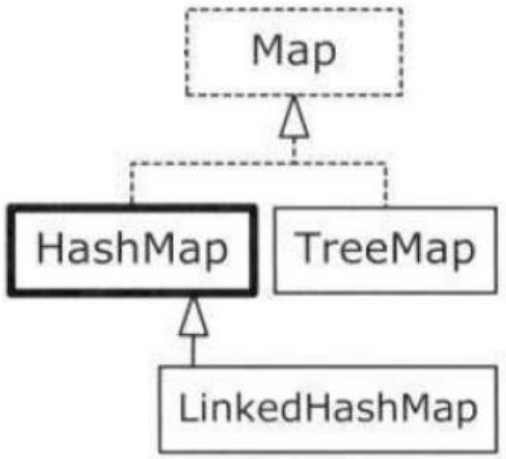
  (old school, but offers **thread-safety**; **replaced** by `ConcurrentHashMap`)

When and why would one use such data structures?



Image source: Thinking in Java (4th Edition), Bruce Eckel

# java.util.HashMap




Implementation is based on the concept of a **hashtable**.

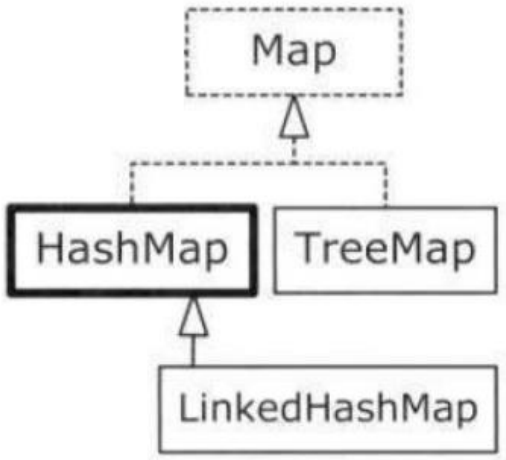
Insertion and locating of held pairs is done in near constant time – favors **lookup speed**.

Elements *appear* in no apparent **order**, because of hashing.



Image source: Thinking in Java (4th Edition), Bruce Eckel

# java.util.LinkedHashMap




Similar to a `HashMap`, but keys are stored based on **insertion order**.

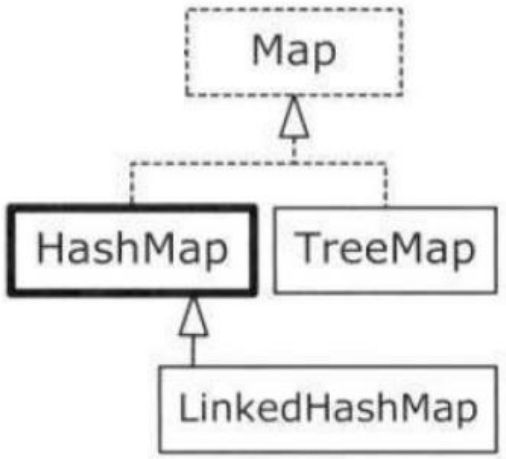
Can be tweaked (through a constructor param) to permit LRU behavior – useful for building *caches*.

**Faster** when **iterating** than a `HashMap`, because of underlying linked list used to keep internal order.



Image source: Thinking in Java (4th Edition), Bruce Eckel

# java.util.TreeMap




Underlying implementation is a **red-black tree** (holds entries, or *pairs*).

The pairs are stored in **sorted order**, based on a `Comparator`.

Slower than `HashMap` and `LinkedHashMap`.



Image source: Thinking in Java (4th Edition), Bruce Eckel

# **java.util.TreeMap** – Quick example

```
public static void printKeys(Map<Integer, String> map) {
    System.out.println("Size = " + map.size() + ", ");
    System.out.println("Keys: ");
    System.out.println(map.keySet()); // Produce a Set of the keys
}

public static void test(Map<Integer, String> map) {
    System.out.println(map.getClass().getSimpleName());
    // Map has 'Set' behavior for keys:
    map.putAll(new CountingMapData(25));
    // Thus, no duplicate keys are added
    map.putAll(new CountingMapData(25));
    printKeys(map);
    // Producing a Collection of the values:
    System.out.println("Values: ");
    System.out.println(map.values());

    // Operations on the Set change the Map:
    Set<Integer> keySet = map.keySet();
    keySet.removeAll(map.keySet()); // A goofy alternative to map.clear() :)
    System.out.println("map.isEmpty(): " + map.isEmpty());
}

public static void main(String[] args) {
    test(new TreeMap<Integer, String>());
}
```

a method that prints the key set nicely (works w/ any Map implementation)

retrieve implementation name

we try to add duplicate keys

retrieve values as a collection

retrieve underlying key set and modify it



Code source: Thinking in Java (4th Edition), Bruce Eckel

# **java.util.TreeMap** – Quick example

```
public static void printKeys(Map<Integer, String> map) {
    System.out.println("Size = " + map.size() + ", ");
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    System.out.println("map.isEmpty(): " + map.isEmpty());
}

public static void main(String[] args) {
    test(new TreeMap<Integer, String>());
}
```
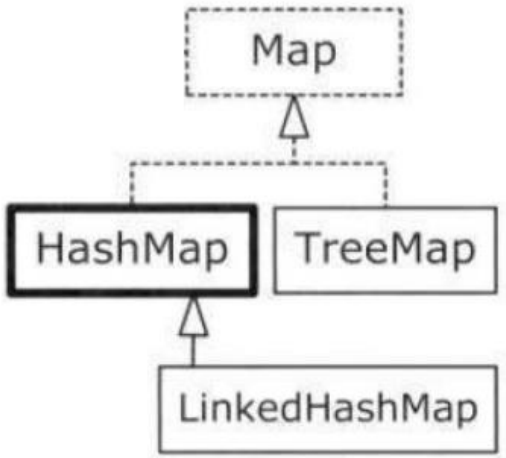

```
"C:\Program ...
TreeMap
Size = 25,
Keys:
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24]
Values:
[A0, B0, C0, D0, E0, F0, G0, H0, I0, J0, K0, L0, M0, N0, O0, P0, Q0, R0, S0, T0, U0, V0, W0, X0, Y0]
map.isEmpty(): true

Process finished with exit code 0
```



Code source: Thinking in Java (4th Edition), Bruce Eckel

# java.util.Map(s)




The most **common operations** you will do with/on a **Map** are:

- put(key, value)
- `get(key)`
- `entrySet().iterator()`
- `keySet()`
- `values()`
- `containsKey()`
- `containsValue()`



Image source: Thinking in Java (4th Edition), Bruce Eckel

## **java.util.Map** – Conclusions

- Work on the principle of a **dictionary**: a **key maps** to one (or more) **associated value**(s).
- `HashMap(s)` are best used for **fast lookup time**.
- `LinkedHashMap(s)` have similar lookup time, and maintain an **order** based on **insertion**.
- `TreeMap(s)` focus on maintaining a **sorting order** for held keys.
- *Be aware, that the above* (`HashMap, LinkedHashMap, TreeMap`) *are not thread-safe!*

# 2.4.1

## A word about `equals()` and `hashCode()`

## `equals()` **method**

- Is inherited by all object instances,from `java.lang.Object`
- Indicates whether some other object is "*equal to*" the current object, whose method is called.
- **Returns** `true` if the object is "equal to" the object that calls it and `false` otherwise

```
String s1 = "Pet";
String s2 = "Pet";
String s3 = "Pets";

System.out.println(s1.equals(s2)); // returns true
System.out.println(s1.equals(s3)); // returns false
```

## `equals()` method constraints

- A proper implemented `equals()` method **must satisfy** the following **five conditions**:
  1. **Reflexive**: For any **`x`**, `x.equals(x)` should return `true`.
  2. **Symmetric**: For any **`x`** and **`y`**, `x.equals(y)` should return `true` if and only if `y.equals(x)` returns `true`**.**
  3. **Transitive**: For any **`x`**, **`y`**, and **`z`**, if `x.equals(y)` returns `true` and `y.equals(z)` returns `true`, then `x.equals(z)` should return `true`.

## `equals()` method constraints (2)

4. **Consistent:** For any **x** and **y**, multiple invocations of `x.equals(y)` **consistently return `true`** or **consistently return `false`**, provided no information used in equals comparisons on the object is modified.

5. For any **non-null x**, `x.equals(null)` should **return `false`.**

## Alright, alright enough theory!

- As you can see, a proper implementation of `equals()` is essential for your own classes to work well with the Java Collection classes. So how do you implement `equals()` "properly"?

- So, when are two objects equal? That depends on your application, the classes, and what you are trying to do.

## `equals()` and `hashCode()` example

```
public class WeekDay {

    private final int id;
    private final String name;

    private static String[] daysNames = new String[]{"MON", "TUE", "WED", "THU", "FRI", "SAT", "SUN"};

    public WeekDay(int id) {...}

    public String getName() { return name; }

    @Override
    public String toString() { return name; }
}
```

- You could decide that two `WeekDay` objects are equal to each other if only their `id`s are *equal*.
- Or, you could decide that all fields must be used to establish equality (i.e. `id` and name) provided they are immutable/unchangeable (i.e. `final`).

## `equals()` example (2)

```
@Override
public boolean equals(Object o) {
    if (this == o) return true;
    if (o == null || getClass() != o.getClass()) return false;

    WeekDay weekDay = (WeekDay) o;

    if (id != weekDay.id) return false;
    if (!name.equals(weekDay.name)) return false;

    return true;
}
```

## `hashCode()` **method**

- Is inherited by all objects instances, from java.lang.Object
- Used when you insert an Object into a `HashSet`, `LinkedHashSet`, `HashMap` or `LinkedHashMap` to identify appropriate underlying bucket to store an entry.
- Returns an `int`, representing the `hash code` or `hash` value for the Object for which this method was called upon.

```
Integer i = 7;
Double d = 4.25;
String s = "Pets";

System.out.println(i.hashCode()); // prints 7
System.out.println(d.hashCode()); // prints 1074855936
System.out.println(s.hashCode()); // prints 2484052
```

## `hashCode()` **method (2)**

- When inserting an object into a `HashSet`, `LinkedHashSet`, `HashMap` or `LinkedHashMap` you use a key.
- The hash code of this key is calculated, and used to determine where to **store** the object internally (which bucket).
- Later, when you need to lookup an object you also use a key – the same key as before.
- The hash code of this key is calculated and used to determine where to **search** for the object, in the list internal storage.

## `hashCode()` **rules**

1. If `object1` and `object2` are equal according to their `equals()` method, they must also have the same hash code.

2. If `object1` and `object2` have the **same hash code**, they **do NOT have to be equal too**.

## `hashCode()` **recipe:**

1. Store some constant nonzero value, say *17*, in an `int` variable called `result`.
2. For each significant field in your object (that is, each field taken into account by the `equals()` method), calculate an `int` hash code `c` for the field:
3. For each `c`, combine the hash code(s) computed above:

```
result = 31 * result + c;
```

4. Return **result**.
5. Test/Use the resulting hash code in your code

# hashCode() example

```java
@Override
public int hashCode() {
    int result = id;
    result = 31 * result + name.hashCode();

    return result;
}
```

# hashCode() recipe (2)

| Field type | Calculation |
|---|---|
| **boolean** | **c = ( f ? 0 : 1)** |
| **byte, char, short,** or **int** | **c = (int)f** |
| **long** | **c = (int)(f ^ (f>>>32))** |
| **float** | **c = Float.floatToIntBits(f);** |
| **double** | **long l = Double.doubleToLongBits(f);**<br>**c = (int)(l ^ (l>>>32))** |
| **Object,** where **equals( )** calls **equals( )** for this field | **c = f.hashCode( )** |
| Array | Apply above rules to each element |

lower-case “L”

# 2.5

## Queues in Java

# java.util.Queue(s)

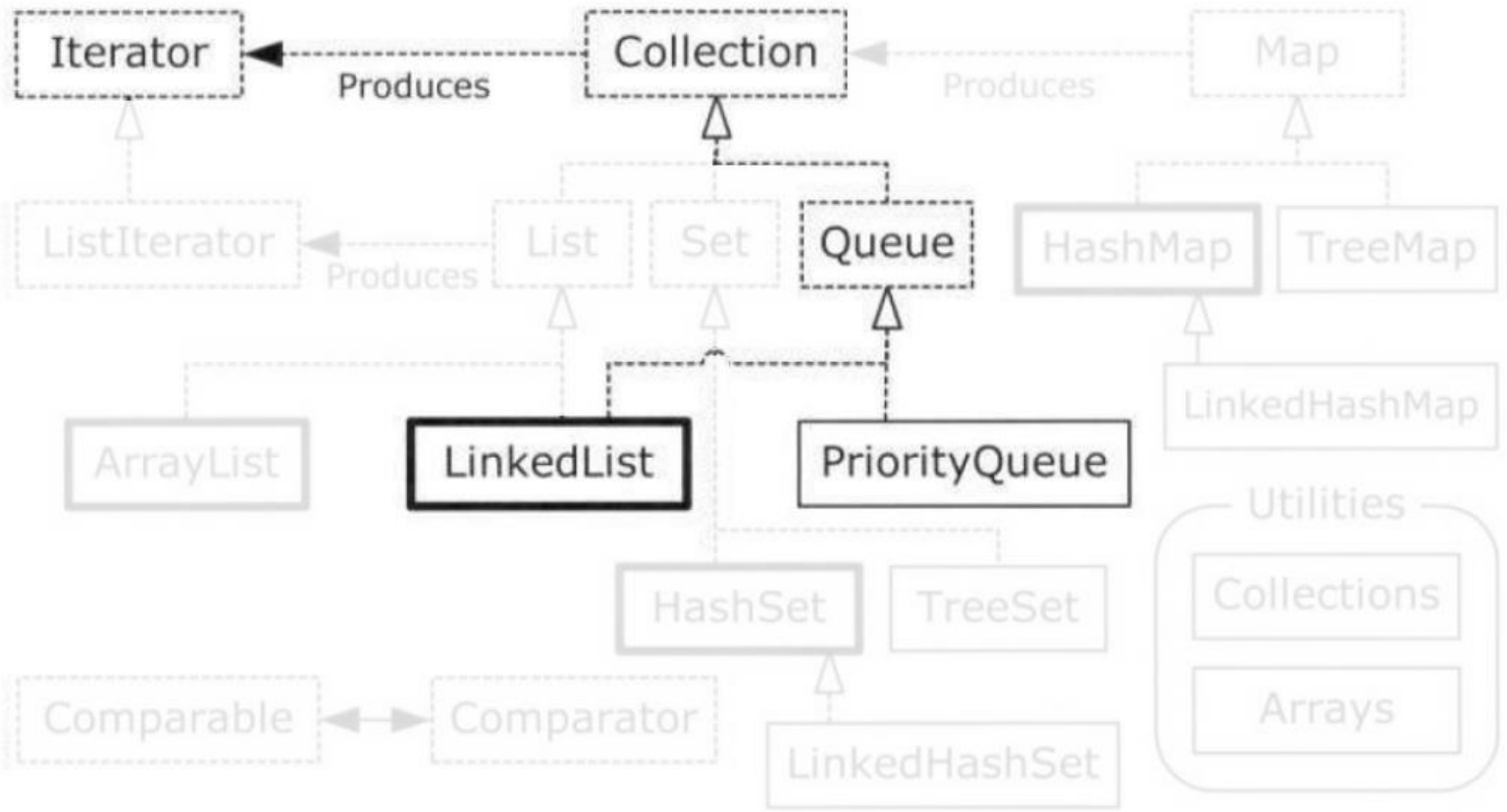


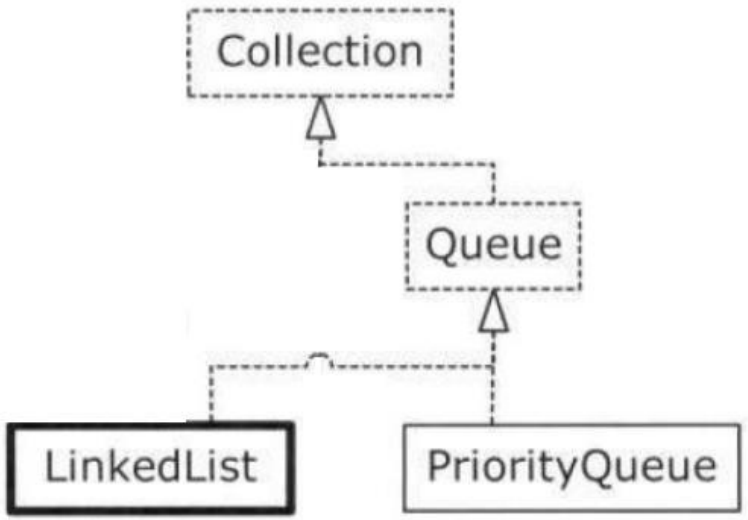



Image source: Thinking in Java (4th Edition), Bruce Eckel

## **java.util.Queue**(s) – Notes

- They are essentially **Lists** (thus, they can hold individual elements and allow duplicates), but are governed by **rules**.
- Have **characteristic behavior**: e.g. first-in-first-out (queues), last-in-first-out (stacks).
- In Java, `Queue` is an **interface** and `Stack` a legacy class; `LinkedList` can be used as their underlying **implementation**, for adequate or equival. behavior, for both.
- Although intended for multi-threaded applications, Java offers two implementations for single-threaded purposes: `LinkedList` and `PriorityQueue`.

# java.util.Queue(s)




**Queues** are available in **many** flavors. The most used are:

- `Queue` (FIFO)
- `PriorityQueue` (aka min-*heap*)
- `Deque` (aka Double-ended queue, via LinkedList behavior)

Legacy:

- `Stack` (LIFO)

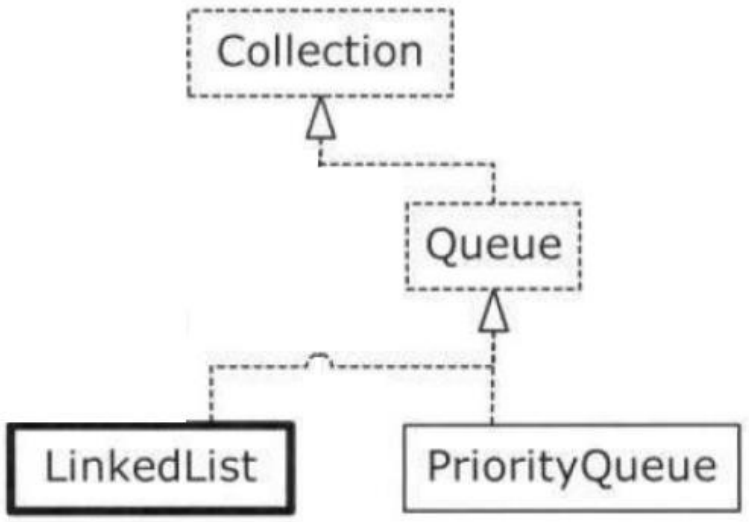
(discouraged; use `Deque` instead)

When and why would one use such data structures?



Image source: Thinking in Java (4th Edition), Bruce Eckel

# Queue behavior (via java.util.LinkedList)




In general, Queues are useful in **concurrent programming**: they safely **transfer** objects from one **thread** to another.

`LinkedList` has methods to support queue behavior, which we'll see a bit later.



Image source: Thinking in Java (4th Edition), Bruce Eckel

# **java.util.Queue** – Quick example

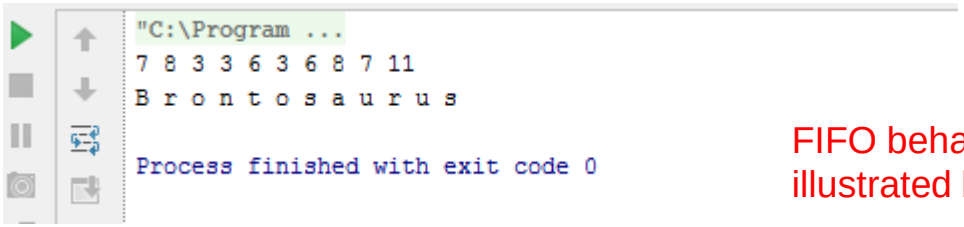
```
public static void printQueue(Queue queue) {
    // There are elements available ?
    while (queue.peek() != null)
        // Retrieve and print element
        System.out.print(queue.remove() + " ");
    System.out.println();
}

public static void main(String[] args) {
    // Upcasting to a Queue from a LinkedList.
    Queue<Integer> intQueue = new LinkedList<Integer>();
    Random rand = new Random(23);
    for(int i = 0; i < 10; i++)
        intQueue.offer(rand.nextInt(i + 10)); // Offer elements for insertion
    printQueue(intQueue);
    // Upcasting to a Queue from a LinkedList.
    Queue<Character> charQueue = new LinkedList<~>();
    for (char c : "Brontosaurus".toCharArray())
        charQueue.offer(c); // Offer elements for insertion
    printQueue(charQueue);
}
```

Check if queue has elements to give

Retrieve (removes) element and appends a ‘ ’ to it

declaration with proper bounds

Breaks a string into chars[]

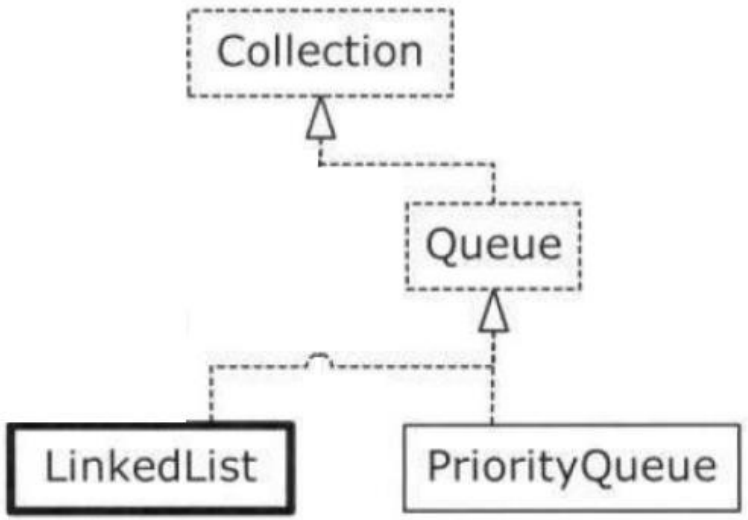



FIFO behavior is illustrated by output order



Code source: Thinking in Java (4th Edition), Bruce Eckel

# java.util.PriorityQueue




First-In-First-Out is an example of the most utilized *queuing discipline*.

A **queuing discipline** for a queue decides, given the group of elements in it, which one is removed from it next (i.e. it is pulled out of the queue).

`PriorityQueue` sorts elements (by default) using “least to greatest” element *queuing discipline* (i.e. in increasing order).



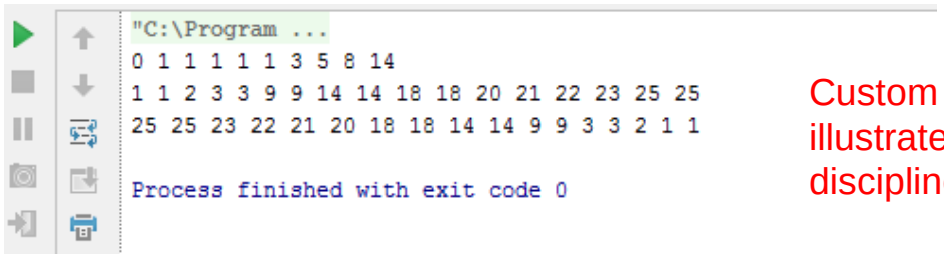
Image source: Thinking in Java (4th Edition), Bruce Eckel

# **java.util.PriorityQueue** – Quick example

```
public static void main(String[] args) {

  PriorityQueue<Integer> priorityQueue =
    new PriorityQueue<Integer>();
  Random rand = new Random(47);
  for(int i = 0; i < 10; i++)
    priorityQueue.offer(rand.nextInt(i + 10));
  QueueDemo.printQueue(priorityQueue);

  List<Integer> ints = Arrays.asList(25, 22, 20,
    18, 14, 9, 3, 1, 1, 2, 3, 9, 14, 18, 21, 23, 25);
  priorityQueue = new PriorityQueue<Integer>(ints);
  QueueDemo.printQueue(priorityQueue);
  priorityQueue = new PriorityQueue<Integer>(
      ints.size(), Collections.reverseOrder());
  priorityQueue.addAll(ints);
  QueueDemo.printQueue(priorityQueue);
}
```

declaration with proper bounds

previous used method to print contents

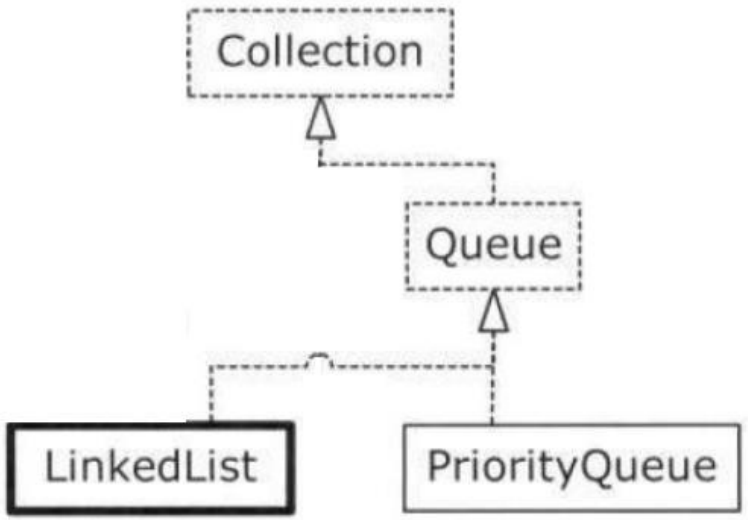



Custom output is illustrated by queuing discipline



Code source: Thinking in Java (4th Edition), Bruce Eckel

# Stack behavior (via java.util.Deque/LinkedList)




`Stacks` are used to **evaluate expressions** in programming languages.

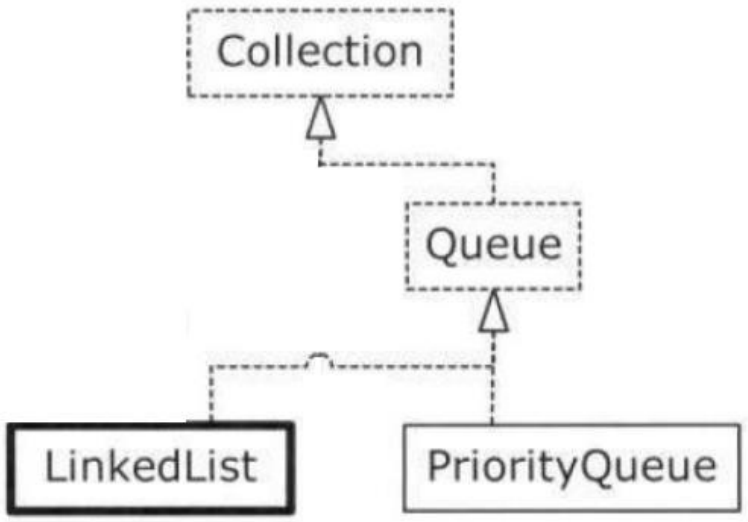
Controversy over `Stack` class in Java: original has a bad design, kept for backwards compatibility for existing code.

**Prefer** `Deque + LinkedList` for LIFO behavior, instead of this class!



Image source: Thinking in Java (4th Edition), Bruce Eckel

# Double-ended queue behavior (via java.util.LinkedList)




Not covered during course.

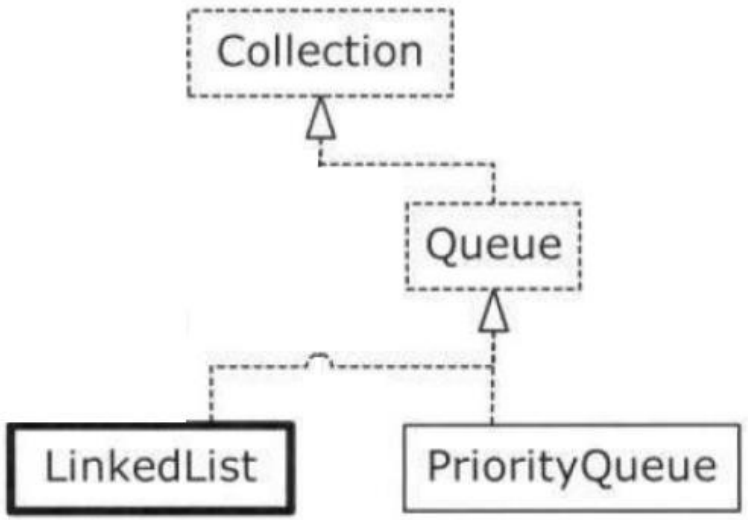
As self-study, find out what is it all about:

see `java.util.Deque`



Image source: Thinking in Java (4th Edition), Bruce Eckel

# java.util.Queue(s)




The most **common operations** you will do with/on a **Queue** are:

- `add(elem) / offer(elem)`
- `remove()/poll()`
- `element()/peek()`

For `Stack` class they are:

- `empty()`
- `push(elem)`
- `pop()`
- `peek()`



Image source: Thinking in Java (4th Edition), Bruce Eckel

## **java.util.Queue**(s) – Conclusions

- `Queues` are generally useful in **concurrent programming**.
- However, Java has some queue implementations intended for single-threaded applications.
- `Queue` (FIFO) behavior is offered by `LinkedList`.
- `Deque` should be used instead of `Stack` (LIFO), for current Java implementations.
- `PriorityQueue` offers heap-like behavior; it **orders elements** based on a **priority** rule.

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# Thank you!

Questions or comments on these topics and more, are welcome!

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We salute you! ☺