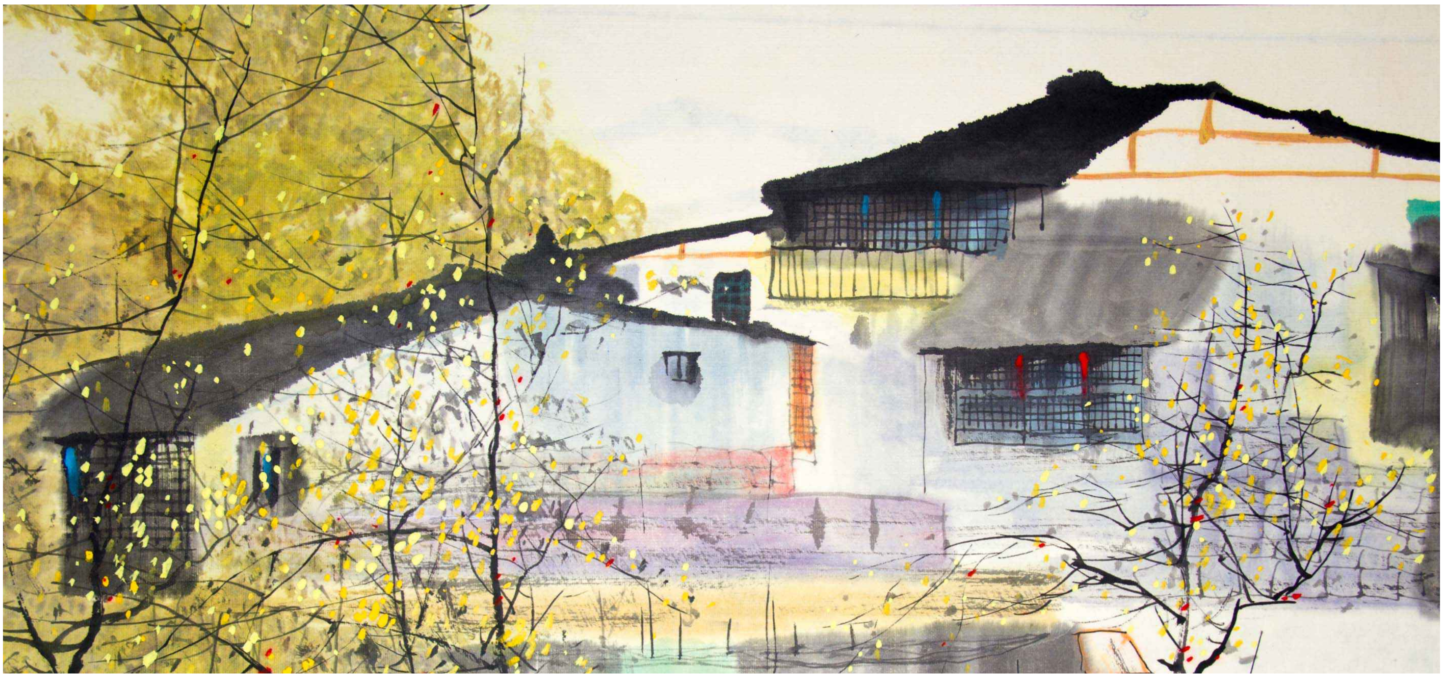

30-Java 8: Lambda Expressions

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Learning Objectives

> Understand how a lambda expression works

> List the built-in 戈 interfaces

> Write lambda expressions for each built-in functional interface

> Identify the correct built-in functional interface given the number of parameters, return type, and method name and vice versa

> List common methods which use lambdas as arguments

> Use default methods to combine lambda expressions

> Use method references to shorten lambda expressions

What is a Lambda Expression?

- ***Lambda expressions*** was first introduced in **Java 8 (1.8).**

What we learned before:

```
interface Age {
    int x = 21; // implicit public static
    void getAge();
    //default or/and static method ... which include implementation
}

// The old way to implement the methods of Age Interface
class WhatWeLearnedBefore implements Age {

    @Override
    public void getAge() {
        // printing the age
        System.out.print("Age is " + x); // implementation
    }
}

class Week4 {
    public static void main(String[] args) {
        // Myclass is implementation class of Age interface
        WhatWeLearnedBefore obj = new WhatWeLearnedBefore();
        // calling getage() method implemented at Myclass
        obj.getAge();
    }
}
```

- An example to give you a quick idea of what Labdma is.

```
interface FunctionalInterface {
    // only one abstract method
    void getAge(int a);

    // A non-abstract (or default) function
    default void sayHello() {
        System.out.println("Hello");
    }
}

//
class Dog implements FunctionalInterface {
    String name;

```

```java
    @Override
    public void getAge(int x) {
        System.out.println(2 * x);
    }
}

class Test {
    public static void main(String args[]) {
        // lambda expression to implement above
        // functional interface.
        // Also, we can write x -> System.out.println(2 * x);
        FunctionalInterface fobj = (int x) -> System.out.println(2 * x);

        // This calls above lambda expression and prints 10.
        fobj.getAge(5); // 10
        fobj.sayHello(); // default method
    }
}
```

- A *lambda expression* is a function which can be created without belonging to any class. It is thus an alternative to writing full-blown functions.

```java
interface FunctionalInterface {
    // a method that accepts two integers and calculates the sum
    int sum(int a, int b);
}
class Test {
    public static void main(String args[]) {
        // lambda expression with 2 parameters
        FunctionalInterface fobj = (a, b) -> {
            int c = a + b;
            // if more than 1 line of code inside the codeblock,
            // we need to have keyword "return"
            return c / 2;
        };

        FunctionalInterface fobj2 = (a, b) -> a + b / 2; // skip "return" keyword
    }
}
```

- A *lambda expression* can be passed around as if it was an object and executed on demand. It allows functionality to be passed into methods as an argument.

```
List<String> names = Arrays.asList("Peter", "Paul", "Mary");

// print names in a for loop
for (String n : names) {
    System.out.println("Hello " + n);
}

// an equivalent one-liner by passing a lambda expression into forEach()
names.forEach(
// Lambda Expression, represent the implementation of Consumer.accept()
n -> {
        System.out.println("Hello " + n);
        System.out.println("Hello2 " + n);
}
);

/*
Hello Peter
Hello Paul
Hello Mary
Hello Peter
Hello2 Peter
Hello Paul
Hello2 Paul
Hello Mary
Hello2 Mary
*/
```

Syntax Variations

- A *lambda expression* has the following characteristics:
    - **Optional type declaration**
    - **Optional parentheses around a single parameter**
    - **Optional curly braces for one-liner**
    - **Optional return keyword for one-liner**
- A lambda expression can be written in various ways:

```
// No parameter, return int or String
() -> 12
() -> "abc"
```

```java

// One parameter, return its square
// Optional parentheses around a single parameter
// Optional curly braces for one-liner
// Optional return keyword for one-liner
x -> x * x
// (x) -> x * x
// (int x) -> x * x

// Two parameters, return their difference
(x, y) -> x - y

// One parameter with explicit type, print its value with no return value
// (String s) -> System.out.println("Hello " + s)
s -> System.out.println("Hello " + s)

// Two parameters with explicit type, return their sum
(int x, int y) -> x + y

// One parameter with explicit type, a method body enclosed in curly braces
// and an explicit return statement
public interface interfaceName {
    String print(int x);
}
// main
n -> {
    StringBuilder sb = new StringBuilder();
    sb.append("[");
    for (int i = 0; i < n; i++) {
        sb.append(i);
        if (i < n - 1) {
            sb.append(", ");
        }
    }
    sb.append("]");
    return sb.toString();
};
```

Example

- ***Lambda expressions*** are used primarily to **represent the instance of a functional interface** (i.e. an interface with a single abstract method).

- ***Lambda expression*** **eliminates the need to create anonymous classes** in order to implement a functional interface.

```java
@FunctionInterface
interface MathOperation {
    int compute(int a, int b);

    default static String method() {
        return "abc";
    }
}

@FunctionalInterface
interface ChatBox {
    void speak(String message);
}

public class MathOperationTester {
    // op.compute(a, b), polymorphism.
    // How to implement calculate method if we don't use MathOperation as parameter
    private static int calculate(int a, int b, MathOperation op) {
        return op.compute(a, b);
    }

    public static void main(String[] args) {
       // Anonymous class to implement the MathOperation interface
       MathOperation subtractionWithoutLambda = new MathOperation() {
            @Override
            public int compute(int a, int b) {
                return a - b;
            }
        };
        // Explicit types & No return keyword, still fine
        MathOperation subtraction = (int a, int b) -> a - b;

        // Implicit lambda expression, No parameter type
        // No return keyword, most common syntax
        MathOperation addition = (a, b) -> a + b;

        MathOperation average = (a, b) -> (a + b) / 2;
        MathOperation max = (a, b) -> a > b ? a : b;

        // Explicit types & With return keyword, still fine
        MathOperation multiplication = (int a, int b) -> { return a * b; };

        // Lambda expression passed in as a method argument
        System.out.println("12 + 4 = " + calculate(12, 4, addition));
        System.out.println("12 - 4 = " + calculate(12, 4, subtraction));
        System.out.println("12 * 4 = " + calculate(12, 4, multiplication));

        // Lambda expression without a reference variable
        System.out.println("12 / 4 = " + calculate(12, 4, (a, b) -> a / b));

        // No parentheses for single param, most common syntax
        ChatBox chatBox1 = message -> System.out.println("Hello " + message);
        // With parentheses
        ChatBox chatBox2 = (message) -> System.out.println("Goodbye " + message);
        chatBox1.speak("Peter");
        chatBox1.speak("Mary");
    }
}

/*
12 + 4 = 16
12 - 4 = 8
12 * 4 = 48
12 / 4 = 3
Hello Peter
Hello Mary
*/
```

Functional Interfaces

- A *functional interface* is an interface that contains **ONLY one abstract method**.
- A *functional interface* can have **any number of default and static methods**.
- It's **recommended** to add the `@FunctionalInterface` annotation to declare a *functional interface.* This clearly communicates the purpose of the interface, and also **allows a compiler to generate an error if the annotated interface does not satisfy the conditions**.
- Let's start with **built-in functional interfaces** supported in Java.

Function and *BiFunction*

- The most simple and general use case of a *lambda*. A *Function* receives one value and returns one value. It is defined as:

```java
@FunctionalInterface
public interface Function<T, R> {
    R apply(T t);
}
```

- A ***BiFunction*** receives two values and returns one value. It is defined as:

```java
@FunctionalInterface
public interface BiFunction<T, U, R> {
    R apply(T t, U u);
}
```

Example of *Function*

- One of the usages of the *Function* type in the standard library is the ***`Map.computeIfAbsent()`*** method. This method **returns a value from a map by key, but calculates the value if the key is not already present in the map**. To calculate the value, the method uses the *Function* implementation passed in from the method argument:

```java
Map<String, Integer> nameLengthMap = new HashMap<>();

// "String::length" equivalent to "s -> s.length()"
// Function<String, Integer>, Integer is return type, while String is input type
Function<String, Integer> computeLength = t -> t.length(); // String::length;
// Why computeLength will calculate length of "Peter"? Pls check source of Map.computeIfAbsent
// computeLength is a contract for map.computeIfAbsent to execute the behavior according to your logic
// So, means you can control part of the behavior of the method map.computeIfAbsent
Integer computedValue = nameLengthMap.computeIfAbsent("Peter", computeLength);

System.out.println(computedValue);  // prints 5
```

- *HashMap* is empty, the key "Peter" does not exist inside the map initially. We calculate the value by applying the *function* to the key (i.e. "Peter"), put the computed value into the map, then return from the method call.

- For the *function* implementation, when **the parameter type and the number of parameters are matched between the input and output parameters**, we may **replace the *lambda expression* with a *method reference expressed in*** `::` **.**

```
// 源碼 of computeIfAbsent
default V computeIfAbsent(K key,
      Function<? super K, ? extends V> mappingFunction) {
    // 判断这个映射函数是否为空，为空抛出NullPointerException
    Objects.requireNonNull(mappingFunction);
    V v;
    // 判断指定的额key对应的val是否为空
    if ((v = get(key)) == null) {
      V newValue;
      // 判断映射函数计算出来的newValue是否为空
      if ((newValue = mappingFunction.apply(key)) != null) {
        // 不为空将这个key和计算出来的val存到集合
        put(key, newValue);
        // 并返回这个计算出来的val
        return newValue;
      }
    }
    // 判断指定的额key对应的val不为空直接返回val
    return v;
}
```

Example of *BiFunction*

- The ***`Map.merge()`*** method **returns a value from a map by key, but merges the existing value with the new value if the key already exists in the map**. To merge the value, the method uses the *BiFunction* implementation passed in from the method argument:

```
Map<String, Integer> nameFrequencyMap = new HashMap<>();
nameFrequencyMap.put("Peter", 2);

// equivalent to (oldValue, newValue) -> oldValue + newValue
BiFunction<Integer, Integer, Integer> mergeFrequencyByName = (x, y) -> x * y;
//Integer::sum;
Integer mergedValue = nameFrequencyMap.merge("Peter", 3, mergeFrequencyByName);

System.out.println(mergedValue); // 6
```

- Again, the *BiFunction* implementation can be replaced with a method reference because **the parameter type and the number of parameters are matched between the input and output parameters.**

```
// 源碼 of Map.merge()
default V merge(K key, V value, BiFunction<? super V, ? super V, ? extends V> remappingFunction) {
     Objects.requireNonNull(remappingFunction);
     Objects.requireNonNull(value);

     V oldValue = get(key);
     V newValue = (oldValue == null) ? value :
             remappingFunction.apply(oldValue, value);

     if(newValue == null) {
        remove(key);
     } else {
        put(key, newValue);
     }
     return newValue;
}
```

UnaryOperator and *BinaryOperator*

- `UnaryOperator` and `BinaryOperator` are a special case of *Function and BiFunction.*
- They **require all parameters to be the same type**, thus:
    - A *UnaryOperator* transforms its value into one of the same type
    - A *BinaryOperator* merges two values into one of the same type

```
@FunctionalInterface
public interface UnaryOperator<T> extends Function<T, T> {}

@FunctionalInterface
public interface BinaryOperator<T> extends BiFunction<T, T, T> {}

// This means their method signatures are the same as that of Function and BiFunction
T apply(T t);

T apply(T t1, T t2);
```

Example

```java
// same as x -> x.toUpperCase()
UnaryOperator<String> strUpperCase = String::toUpperCase;
System.out.println(strUpperCase.apply("rawr"));  // prints "RAWR"

// same as (x, toAdd) -> x.concat(toAdd)
BinaryOperator<String> strConcat = String::concat;
System.out.println(strConcat.apply("hello ", "world"));  // prints "hello world"
```

Supplier

- A `Supplier` is used when you want to generate or supply values without taking any input, which is defined as:

```java
@FunctionalInterface
public interface Supplier<T> {
     T get();
}
```

Example

```java
Supplier<Integer> randomInteger = () -> new Random().nextInt(10) + 1;
System.out.println(randomInteger.get());  // returns any number between 1 and 10

// equivalent to Supplier<LocalDate> dateOfToday = () -> LocalDate.now();
Supplier<LocalDate> dateOfToday = () -> LocalDate.now();
System.out.println(dateOfToday.get());  // returns the date of today
```

Consumer and BiConsumer

- You use a `Consumer` when you want to do something with one **parameter but not return anything** (also known as a *side effect*). `BiConsumer` does the same thing except that it takes **two parameters**.

```java
@FunctionalInterface
public interface Consumer<T> {
    void accept(T, t);
}

@FunctionalInterface
public interface BiConsumer<T, U> {
    void accept(T t, U u);
}
```

Example

- The `Collection.forEach()` method performs some action for each element in a collection in an iteration. The action is specified by the *lambda* that is passed to the method which implements the *Consumer* interface.
- Note that `ConcurrentModificationException` will still be thrown if any structural changes are made to the collection during the iteration (e.g. adding or removing elements).

```java
List<String> names = Arrays.asList("Peter", "Paul", "Mary");

// lambda passed in as *Consumer*
Consumer<String> printName = name -> System.out.println("Hello " + name);
printName.accept("World"); // Hello World
names.forEach(printName); // list.forEach(lambda expression)

Map<String, Integer> ages = new HashMap<>();
ages.put("Peter", 18);
ages.put("Paul", 19);
ages.put("Mary", 20);

// lambda passed in as BiConsumer
BiConsumer<String, Integer> printNameAndAge = (name, age) ->
                System.out.println(name + " is " + age + " years old");
ages.forEach(printNameAndAge);

/*
Hello Peter
Hello Paul
Hello Mary
Peter is 18 years old
Paul is 19 years old
Mary is 20 years old
*/
```

Predicate

- A ***Predicate*** is a function that receives a value and returns a boolean value.
- It is often used with filtering or matching, e.g. *Collection.removeIf().* Something like conditional statement.
- *A* BiPredicate does the same thing except it takes two parameters.

```
@FunctionalInterface
public interface Predicate<T> {
        boolean test(T t);
}

@FunctionalInterface
public interface BiPredicate<T, U> {
        boolean test(T t, U u);
}
```

Example - *Predicate*

```
// Naming Conversion: names (end with "s") for List. Just a norm.
// Technically you can use nameList also
List<String> names = Arrays.asList("Alex", "Amy", "Ben", "Charlotte", "Dicky");

//
Predicate<String> startsWithA = name -> name.startsWith("A");
Predicate<String> lengthLongerThan10 = name -> name.length > 10;
Predicate<String> elementIsAlex = name -> "Alex".equals(name);

if (startsWithA.test("Alex")) {
    System.out.println("Yes");
}

// lambda passed in to filter() as Predicate
List<String> filteredNames = names.stream()
                                .filter(s -> s.length > 5 && s.startsWith("A"))
                                .collect(Collectors.toList());

/*
Hello Alex
Hello Amy
*/
```

Example - *BiPredicate*

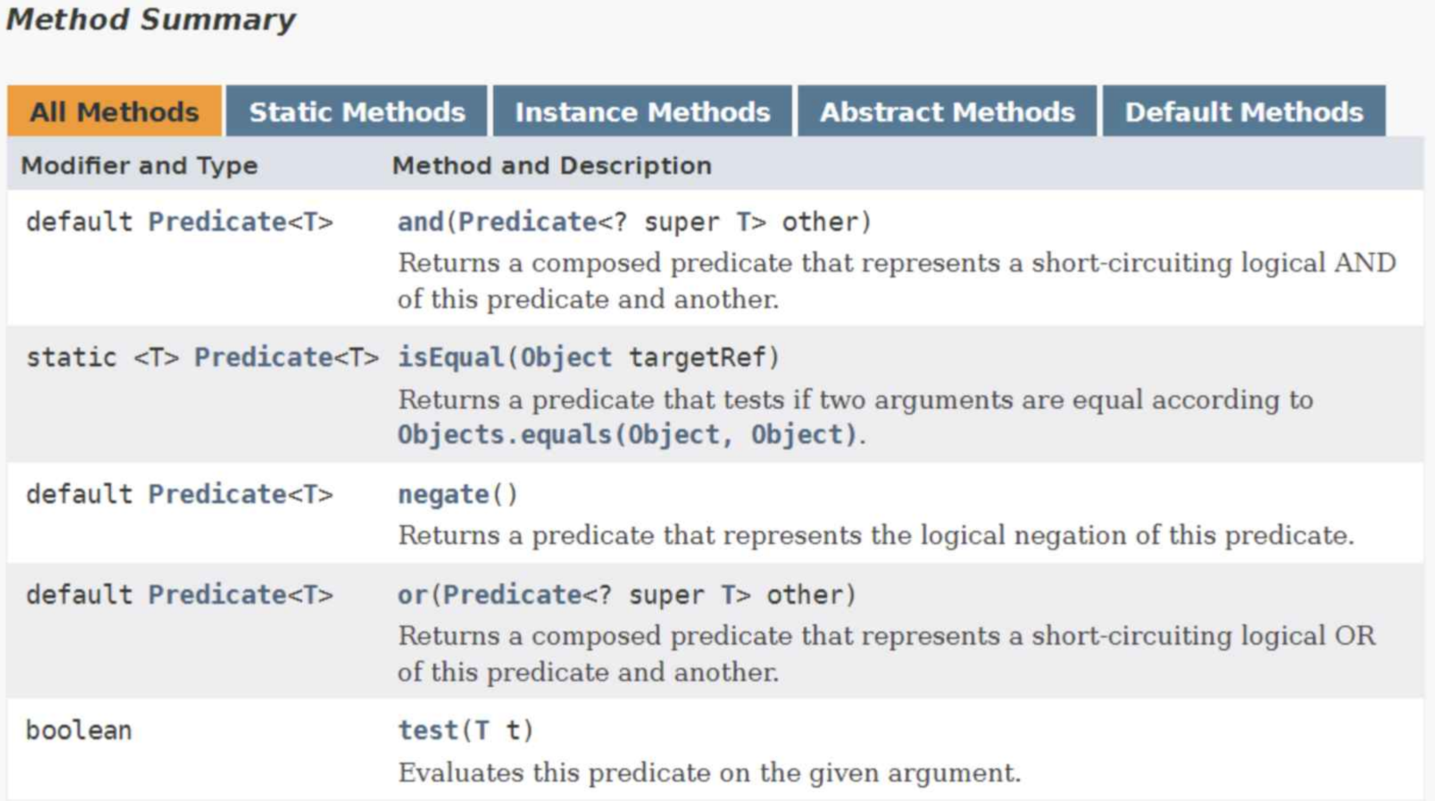
- Useful for writing test cases. We will cover it in the later section.

```
// equivalent to String::startsWith
BiPredicate<String, String> startsWithPrefix
                            = (s, prefix) -> s.startsWith(prefix);

System.out.println(startsWithPrefix.test("World", "Hello")); // prints false
System.out.println(startsWithPrefix.test("Hello", "Hello")); // prints true
System.out.println(startsWithPrefix.test("HelloWorld", "Hello")); // prints true
System.out.println(startsWithPrefix.test("", "Hello")); // prints false
System.out.println(startsWithPrefix.test(null, "Hello")); // NullPointerException
```

Combining Predicates

- The ***`Predicate`*** interface provides *default* and *static helper* methods for us to combine multiple predicates by chaining.



Method Summary

Modifier and Type	Method and Description
`default Predicate<T>`	`and(Predicate<? super T> other)` Returns a composed predicate that represents a short-circuiting logical AND of this predicate and another.
`static <T> Predicate<T>`	`isEqual(Object targetRef)` Returns a predicate that tests if two arguments are equal according to `Objects.equals(Object, Object)`.
`default Predicate<T>`	`negate()` Returns a predicate that represents the logical negation of this predicate.
`default Predicate<T>`	`or(Predicate<? super T> other)` Returns a composed predicate that represents a short-circuiting logical OR of this predicate and another.
`boolean`	`test(T t)` Evaluates this predicate on the given argument.

- The ***`and()`*** method allows us to create a new *Predicate* by combining two existing *Predicates*:

```
Predicate<String> startsWithV = a -> a.startsWith("V");
Predicate<String> endsWithT = x -> x.endsWith("T");

```

```java
Predicate<String> combined = startsWithV.and(endsWithT);
Predicate<String> combined2 = startsWithV.or(endsWithT);

System.out.println(combined.test("VINCENT")); // prints true
System.out.println(combined2.test("OINCENM")); // prints false
```

Combining Comparators

- We can even combine *Comparators* by using *Comparator's default* method *thenComparing()*.
- Recall the *Customer* class we have from an earlier session:

```java
public class Customer {
    private int id;
    private String name;
    private LocalDate joinDate;
    // constructors + getters ...
}

Comparator<Customer> sortByName = (c1, c2) ->
              c1.getName().compareTo(c2.getName());

Comparator<Customer> sortByJoinDate = (c1, c2) ->
        c1.getJoinDate().compareTo(c2.getJoinDate());

Comparator<Customer> sortByNameAndJoinDate = sortByName.thenComparing(sortByJoinDate);
```

Method References

- *Method References* provide a more concise way to express a *lambda expression.*
- Method references can be used for the following types of methods:
  - **Static methods**
  - **Instance methods**

Example

```java
public class MethodReferenceExample {
    public static void main(String[] args) {
        List<String> namesList = new ArrayList<>();
        namesList.add("Alex");
        namesList.add("Benny");
        namesList.add("Carl");

        // method reference as static method
        List<String> helloNamesList = namesList.stream()
                .map(MethodReferenceExample::process)
                // .map(e -> MethodReferenceExample.process(e))
                .collect(Collectors.toList());

        System.out.println(helloNameList); // ["hello Alex", "hello Benny", "hello Carl"]
        // method reference as instance method
        List<String> uppercaseNamesList = namesList.stream()
                .map(String::toUpperCase)
                // .map(e -> e.toUpperCase)
                .collect(Collectors.toList());

        System.out.println(uppercaseNamesList); // ["ALEX", "BENNY", "CARL"]
    }

    private static String process(String s) {
        return "hello " + s;
    }
}
```

Constructor References

- `Constructor Reference` is used to refer to a constructor **without instantiating the named class**.

```java
@FunctionalInterface
interface EmployeeEmpty {
    Employee get();
}

@FunctionalInterface
interface EmployeeWithName {
    Employee get(String name);
}

class Employee {
    private String name;

    Employee() {
        System.out.println("Empty Constructor");
    }

    Employee(String name) {
        System.out.println("Create constructor with name");
        this.name = name;
    }

    public String toString() {
        return "name: " + name;
    }
}

// main
EmployeeEmpty empEmpty = Employee::new; // it actually doesn't call constructor
// EmployeeEmpty empEmpty = () -> new Employee();
System.out.println("Constructor isn't called yet");
System.out.println(empEmpty.get()); // instead, call constructor here

EmployeeWithName empWithName = Employee::new; // it actually doesn't call constructor
// EmployeeEmpty empEmpty = () -> new Employee(String s);
System.out.println("Constructor isn't called yet");
System.out.println(empWithName.get("VenturenixLAB").toString()); // instead, call constructor here

// Output
// Constructor isn't called yet
// Empty Constructor
// Constructor isn't called yet
// Create constructor with name
// name: VenturenixLAB
```

Questions

- Express a lambda expression in various syntax variations.
- What are the **built-in functional interfaces** supported in Java? Give an example of each interface.

- Write lambda expressions to work with common methods such as:
  - *Map.merge()*
  - *Map.computeIfAbsent()*
  - *Collections.sort()*
  - *Collections.forEach()*
  - *Collections.removeIf()*