

# Learning to Love the Lambda in the Stream

Introduction to Java 8 Lambda and Functional Interfaces

# Speaker Introduction

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# What is a Lambda Expression?

- ▶ In Java, it is an unnamed function that may be bound to an interface as an object.
- ▶ Similar to a closure: class members, *effectively final* arguments and local variables are available to it.
- ▶ Lambdas may only exist when assigned to a Functional Interface, including being passed in as a parameter or returned as a result.
- ▶ An *effectively final* local variable or argument is either declared final, or is not changed such that if the final declaration were added, the code remains valid.

# Lambda Examples

## ► Example 1a

```
Predicate<Integer> isFive = n -> n == 5;  
System.out.println(isFive.test(4)); // false
```

## ► Example 1b

```
Predicate<Integer> mkTestFunc(int value)  
    { return n -> n == value; }
```

```
Predicate<Integer> isFour = mkTestFunc(4);  
System.out.println(isFour.test(4)); // true
```

► Lambda expressions must be assigned to a functional interface

► `(n -> n == 5).test(4);` // Does not compile

# Lambda Syntax

- ▶ A lambda expression may take one of the following forms:
  - ▶ *[Argument List]* -> *statement*
  - ▶ *[Argument List]* -> { *statements*; **return**; }
- ▶ Argument List may take one of the following forms:
  - ▶ () -> ...
  - ▶ i -> ...
  - ▶ (i) -> ...
  - ▶ (Integer i) -> ...
  - ▶ (i,j...) -> ...
  - ▶ (Integer i, String j...) -> ...
- ▶ When using the { *statements*; **return**; } form, the return is optional for a void return value. When using a single *statement*, the result of the statement is implicitly returned.

# Functional Interface (FI) in Java 8

- ▶ “A functional interface is any interface that contains only one abstract method.” — [Oracle Java Tutorial](#)
- ▶ The sole abstract method referred to as the *functional method*
- ▶ Example 2- Valid Functional Interface

```
@FunctionalInterface // Optional
public interface Example2 {

    int myMethod(); // Functional Method

    boolean equals(Object other); // In Object
    int hashCode(); // In Object
    default int myMethod2() {return myMethod();}
    static int myMethod3() {return 0;}
}
```

# Binding Lambda to Example2 FI vs Anonymous Inner class

- ▶ Both of these implement myMethod defined in Example2.
- ▶ Since there is exactly one abstract functional method, method types and return values are inferred from the FI.

```
public class Example3 {  
    static public void main(String[] args) {  
        Example2 lambda = () -> 3; // 8 chars  
        Example2 innerClass = new Example2() {  
            @Override public int myMethod() {  
                return 3;  
            }  
        }; // 5 lines of code, 65 chars  
        System.out.println(lambda.myMethod()); // 3  
        System.out.println(innerClass.myMethod()); // 3  
    }  
}
```

The background features abstract, overlapping green geometric shapes, primarily triangles and polygons, in various shades of green, creating a modern and dynamic visual effect.

# Key Functional Interfaces

Used by Streams



# Functional Interface Conventions

- ▶ The abstract method is called the *functional method*
- ▶ The following conventions apply for type variables used by Java 8 FIs:
- ▶ T - First argument
- ▶ U - Second argument
- ▶ R - Return Value
- ▶ Any of the above are omitted if not used.
- ▶ If an FI lacks an argument, T is sometimes used for the return value instead of R.
- ▶ Many FIs that take one argument have a corresponding two argument version prefixed with “Bi”.

# Predicate<T>

- ▶ Accepts an argument, returns a `boolean`.
- ▶ Commonly used to select matching elements, or filter for matching elements.
- ▶ Functional method: `boolean test(T t)`
- ▶ 2 argument FI: `BiPredicate<T, U>`
- ▶ **Related Primitive FIs:** `DoublePredicate`, `IntPredicate`, `LongPredicate`

# Consumer<T>

- ▶ Accepts an argument. Returns no value (void).
- ▶ Commonly used to perform an operation, such as printing.
- ▶ Collections and Streams have this method to apply an action to each of their elements:

```
void forEach (Consumer<? super T> action)
```

- ▶ Useful for implementing a Visitor pattern via `forEach`
- ▶ Functional Method: `void accept (T t)`
- ▶ 2 Argument FI: `BiConsumer<T, U>`
- ▶ Related Primitive FIs: `DoubleConsumer`, `IntConsumer`, and `LongConsumer`

# Supplier<R>

- ▶ Accepts no arguments, returns a result
- ▶ Commonly used to provide an origin value to an algorithm.
- ▶ Useful for implementing the Factory pattern.
- ▶ Functional Method: `R get()`
- ▶ **Related Primitive FIs:** `DoubleSupplier`, `IntSupplier`, `LongSupplier`

# Function<T,R>

- ▶ Accepts an argument, returns a result.
- ▶ Commonly used to compute a result, or to map one value to another value.
- ▶ Functional Method: `R apply(T t)`
- ▶ 2 Argument FI: `BiFunction<T,U,R>`
- ▶ Related Primitive FIs: `[Double,Int,Long]Function`,  
`[Double,Int,Long]To [Double,Int,Long]Function`,  
`To [Double,Int,Long]Function`,  
`To[Double,Int,Long]BiFunction`

# UnaryOperator<T>

- ▶ Accepts an argument, returns the same type of result as its argument.
- ▶ Used to compute a result or map a value to the same type as the input.
- ▶ Functional Method: `T apply(T t)`
- ▶ 2 Argument FI: `BinaryOperator<T>`
- ▶ Related Primitive FIs:  
`[Double,Int,Long]UnaryOperator,`  
`[Double,Int,Long]BinaryOperator`
- ▶ `UnaryOperator<T>` **extends** `Function<T, T>`
- ▶ `BinaryOperator<T>` **extends** `BiFunction<T, T, T>`

# Comparator<T>

- ▶ Accepts two arguments, and returns an integer.
- ▶ Used to compare objects, and to impose a *total ordering* on a collection of objects.
- ▶ Functional Interface: `int compare(T o1, T o2)`
  - ▶ When  $o1 < o2$ , returns  $\leq -1$
  - ▶ When  $o1 = o2$ , returns 0
  - ▶ When  $o1 > o2$ , returns  $\geq 1$
- ▶ Even though Comparator has been around since the early days, it is a functional interface because it has a single abstract method.

# Optional<T>

- ▶ Not an interface, but a container class returned by various stream methods.
- ▶ Represents a value that may or may not exist. Used instead of returning a **null** value.
- ▶ `isPresent` determines if a value exists, `ifPresent` executes a `Supplier<T>` when a value exists, and `get()` obtains the value, throwing `NoSuchElementException` if it does not exist.
- ▶ 

```
Optional<Integer> found = Stream.of(1,2).max((a,b) -> a - b);  
System.out.print("Found: " + found.isPresent() + ", value = ");  
found.ifPresent(System.out::println); // Found: true, value = 2
```
- ▶ 

```
Optional<Object> notFound = Stream.of().max((a,b) -> 0);  
System.out.print("Found: " + notFound.isPresent());  
notFound.ifPresent(System.out::println); // Found: false
```



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# Method Reference

# Method Reference

- ▶ Shorthand for a Lambda that only calls a method
- ▶ Types of References
  - ▶ Static method, such as `String::valueOf`
  - ▶ Method on an instance, such as `System.out::println`
  - ▶ Constructor reference, such as `StringBuilder::new`
  - ▶ Instance method, such as `String::toUpperCase`
- ▶ Once familiarity with syntax is obtained, these can often be read and understood faster.
- ▶ A method reference may always be transformed into a lambda, but a lambda may not always be transformed into a method reference.

# Static Method Reference

## ► Example:

```
Function<char[],String> valueOf = String::valueOf;  
// valueOf = s -> String.valueOf(s);  
String value = valueOf.apply(new char[]  
{ 'H', 'e', 'l', 'l', 'o' });  
System.out.println(value); // Hello
```

## ► Arguments are bound in declaration order.

# Method Reference on an Instance

## ► Example:

```
Consumer<Object> printer = System.out::print;  
// printer = i -> System.out.print(i);  
Arrays.asList(1,2,3,4).forEach(printer); // 1234
```

- The same rules that apply for binding lambda variables also apply when binding to a method on an instance:
- class members, *effectively final* arguments and local variables may be used as a method reference on an instance.

# Constructor Method Reference

## ► Example:

```
Supplier<StringBuilder> supplier = StringBuilder::new;  
// supplier = () -> new StringBuilder();  
StringBuilder sb = supplier.get().append("Hi!");  
System.out.println(sb); // Hi!
```

- Creates a new instance of the class, and returns it as the result.
- Must be bound to a functional interface that has a non-void return type.

# Instance Method Reference

► Example:

```
UnaryOperator<String> toUpper = String::toUpperCase;  
// toUpper = s -> s.toUpperCase();  
System.out.println(toUpper.apply("abc")); // ABC
```

- The first argument of the lambda becomes the instance the method reference operates on.
- The remaining arguments are bound in the order they occur.

# Streams

Not to be confused with IO Streams

# What is a Java Stream?

- ▶ Abstraction for computation of elements.
- ▶ A computation structure, not a data structure.
- ▶ A stream consists of
  1. A data source, such as a collection, file, or computation. May be infinite, such as the set of numbers starting at 0. A data source is *lazy*.
  2. Zero or more intermediate operations.
    - ▶ Accepts a stream and returns a another stream with the operation appended to it.
    - ▶ *Lazy*: Only executed when a terminal operation processed the stream.
  3. A terminal operation
    - ▶ Returns a result, such as a number or a collection.
    - ▶ *Eager*: It requests the elements from the final stream, which has the effect of pulling elements from the data source and applying the intermediate operations to them. A stream is a passive description of a computation until a terminal operation is applied.
    - ▶ Closes the stream. Any further operations are invalid and result in an `IllegalStateException`.



# Add a collection of numbers

- ▶ Given `Collection<Integer> numbers` that has integers from 1 to 1000, add the collection.

- ▶ For Loop

```
int total = 0;
for(Integer number : numbers) {total += number;}
return total; // 500500
```

- ▶ Stream reduction

```
return numbers.stream().reduce(0, (i,sum) -> i+sum); // 500500
```

- ▶ Same Sum using an `IntStream`

```
return IntStream.rangeClosed(1, 1000).sum(); // 500500
```

# Breaking Down the Stream

```
stream(Collection<Integer> numbers) {  
    return numbers.stream() // Data Source  
        .reduce(0, (i,sum) -> i+sum); // Terminal Operation  
}
```

- ▶ All streams have a data source, zero or more intermediate operations, and a terminal operation.
- ▶ `numbers` collection is the data source.
- ▶ `reduce` is a terminal *reduction* on the stream.
- ▶ A reduction distills all of the values in a given stream to a single value.
- ▶ Integer reduction examples: sum, average, median, min, and max.
- ▶ The first argument to `reduce` is the identity property. For addition, it is 0. For a multiplication it is 1, for strings it is "" (empty string).
- ▶ The lambda is a `BinaryOperator<Integer>` that is given a running total and the current element. They are processed by adding them together.

# Primitive Streams

- ▶ `IntStream`, `LongStream`, and `DoubleStream`
- ▶ Offers a performance benefit over generic stream by avoiding boxing of primitive computations.
- ▶ Offers additional methods, such as `sum()`, `min()`, `max()`, `average()`, and `summaryStatistics()`.
- ▶ Can replace a traditional for loop

```
IntStream.range(0, 10).forEach(System.out::println); // Print 0-9
```

- ▶ Use `mapToInt`, `mapToLong`, `mapToDouble`, and `mapToObj` to convert an existing stream to an `IntStream`, `LongStream`, `DoubleStream`, and `Stream<T>` respectively.
- ▶ Use the `boxed()` method to convert a primitive stream to its equivalent object stream by boxing the primitive values as follows:
  - ▶ `IntStream` to `Stream<Integer>`
  - ▶ `LongStream` to `Stream<Long>`
  - ▶ `DoubleStream` to `Stream<Double>`

# Map

- ▶ Intermediate operation
- ▶ Apply a computation on stream elements.
- ▶ May be used to change the element type of a stream by returning values of a different type.

```
Stream<Character> s = IntStream.range(65, 75)
    .mapToObj(i -> (char)i); // Stream<Character>
s.forEach(System.out::print); // ABCDEFGHIJ
```

- ▶ Change values, but keep data type (int).

```
IntStream.range(0, 10).map(i -> i*10)
    .forEach(System.out::println); // 0, 10 ... 90
```

# Filter

The `filter` intermediate operation creates a new stream with the contents of the previous stream where the `Predicate<T>` or primitive predicate is `true`.

```
IntSummaryStatistics summaryStatistics =  
IntStream.range(0, 1000) // Data Source  
.filter(i -> i %4 == 0) // Intermediate Operation  
.summaryStatistics(); // Terminal Operation  
System.out.println(summaryStatistics);  
/* count=250, sum=124500, min=0,  
average=498.000000, max=996 */
```

# Limit and Skip

- ▶ Limit intermediate operation limits the values produced by a stream. An infinite stream becomes a finite stream.
- ▶ Skip intermediate operation skips the specified elements
- ▶ Order of these operations matters
  - ▶ Skip before limit - Skipped items not counted against limit
  - ▶ Skip after limit - Skipped items counted against limit
- ▶ `IntStream.iterate(0, i -> i+1).skip(4).limit(6).forEach(System.out::print); // 456789`
- ▶ `IntStream.iterate(0, i -> i+1).limit(6).skip(4).forEach(System.out::print); // 45`

## Terminal Operations that return `Optional<T>`: `findFirst`, `findAny`, `Min`, and `Max`

- ▶ These terminal operations return an `Optional<T>` because the value does not exist in an empty stream.
- ▶ `findFirst` produces the first element in a stream. Because this implies ordering of the elements, any parallel stream is transformed into a sequential stream to guarantee element encounter order
- ▶ `findAny` produces any element on the stream. It does not impose any overhead on parallel stream, but may produce differing values on invocation of the same stream.
- ▶ `Min` produces the minimal element, and `max` produces the maximum element.

# Collecting - The Stream.collect Method

- ▶ The `Stream.collect` method performs a *mutable reduction*.
- ▶ This is a terminal operation that creates a new object that has each element of the stream applied to it. Example: convert a Stream to a Collection.

```
▶ List<Integer> ints = IntStream.of(1,2,2,3,4,5).boxed()  
.collect(Collectors.toList()); System.out.println(ints);  
// [1, 2, 2, 3, 4, 5]
```

```
▶ Set<Integer> intSet = IntStream.of(1,2,2,3,4,5).boxed()  
.collect(Collectors.toSet()); System.out.println(intSet);  
// [1, 2, 3, 4, 5]
```

```
▶ // Custom collection type with a sort applied to it.
```

```
LinkedHashSet<Integer> sortedSet = IntStream.of(1,2,2,3,4,5)  
.boxed().sorted(Comparator.reverseOrder())  
.collect(Collectors.toCollection(LinkedHashSet::new));  
System.out.println(sortedSet);  
// [5, 4, 3, 2, 1]
```



# Partition

- ▶ The Partition collector uses a `Predicate<T>` to create a map with the keys `false` and `true`.
- ▶ Both the `false` and `true` key and value always exist in the map even if the corresponding value is not present. In such a case, the value will be an empty collection, an empty optional, or a sum or count of 0.
- ▶ Use the predicate in the previous example to create a map with elements divisible by 4 and not divisible by 4.

```
Map<Boolean,Integer> summap =  
IntStream.range(0, 1000).boxed()  
.collect(partitioningBy(i -> i%4==0, summingInt(i -> i)));  
System.out.println(summap); // {false=375000, true=124500}
```

The `summingInt` collector is an example of a *downstream collector*. In this case, it accepts the result of the partitioning by collector and produces a sum reduction of the values.

# Grouping By

- ▶ For the next example, consider the following stream producing function

```
static Stream<String> aboutJack() {  
    return Stream.of("All", "work", "and", "no", "play", "makes",  
        "jack", "a", "dull", "boy", "but", "all", "play", "and", "no",  
        "work", "makes", "jack", "a", "fool"); }
```

- ▶ Group each word by starting letter, in alphabetical order

```
aboutJack().sorted().collect(  
    Collectors.groupingBy(s -> s.charAt(0),  
        TreeMap::new, Collectors.toCollection(TreeSet::new)));  
/* A=[All], a=[a, all, and], b=[boy, but], d=[dull],  
f=[fool], j=[jack], m=[makes], n=[no], p=[play], w=[work] */
```

# Grouping By Concurrent

- Streams may be processed in parallel by using the `parallel` method using concurrent collectors and data structures.

```
aboutJack().parallel().collect( Collectors.groupingByConcurrent(  
s -> s.charAt(0), ConcurrentSkipListMap::new,  
Collectors.toCollection(ConcurrentSkipListSet::new)));  
  
/* A=[All], a=[a, all, and], b=[boy, but], d=[dull], f=[fool],  
j=[jack], m=[makes], n=[no], p=[play], w=[work] */
```

- Count the words

```
aboutJack().parallel().collect(Collectors.groupingByConcurrent(  
s -> s, ConcurrentSkipListMap::new, Collectors.counting()));  
  
/* All=1, a=2, all=1, and=2, boy=1, but=1, dull=1, fool=1, jack=2,  
makes=2, no=2, play=2, work=2 */
```

# Joining

- ▶ A process where a stream of CharSequence is concatenated together to form a string. Recall the aboutJack stream:

```
static Stream<String> aboutJack() { return Stream.of(  
    "All", "work", "and", "no", "play", "makes", "jack", "a", "dull",  
    "boy", "but", "all", "play", "and", "no", "work", "makes",  
    "jack", "a", "fool"); }
```

- ▶ Join this into words separated with a space:

```
aboutJack().collect(Collectors.joining(" "));  
  
/* All work and no play makes jack a dull boy but all play  
and no work makes jack a fool */
```

# Unit Testing a Stream

Unit Tests as Builders or Decorators for a Stream

# Example Lambda: Fibonacci Sequence

- ▶ Fibonacci sequence is defined as a sequence of numbers where each number is the sum of the previous two.
- ▶ The recurrence relation is:  $F_0 = 0$ ,  $F_1 = 1$ ,  $F_n = F_{n-1} + F_{n-2}$
- ▶ The sequence, starting a 0, looks like this:
- ▶ 0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, ...
- ▶ Example code will compute the  $n_{th}$  Fibonacci number and return its value.
- ▶ Example unit test will verify each Fibonacci number as it is computed.
- ▶ [https://en.wikipedia.org/wiki/Fibonacci\\_number](https://en.wikipedia.org/wiki/Fibonacci_number)

# Unit Test Using Builder

Passes through the builder or adds an intermediate operation for testing.

# Unit Test Using Decorator

Decorate the lambdas used in the stream with testing functionality



# Questions

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- ▶ Twitter: @Richard\_Roda
- ▶ This Project: <https://github.com/RichardRoda/2017-CodePaLOUsa-Lambda>
- ▶ These slides (pdf): <https://tinyurl.com/love-lambda>
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- ▶ Oracle's Lambda Quick Start Guide:  
<http://www.oracle.com/webfolder/technetwork/tutorials/obe/java/Lambda-QuickStart/index.html>