



Lambda Expressions in Java 8: Part 2 – More Details

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Topics in This Section

- The `@FunctionalInterface` annotation
- Method references
- Lambda scoping rules
- Effectively final local variables

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The `@FunctionalInterface` Annotation

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Review: @Override

- **What is benefit of @Override?**

```
public class MyCoolClass {  
    @Override  
    public String toString() { ... }  
}
```

- **Correct code will work with or without @Override, but @Override still useful**

- Catches errors at compile time
 - Real method is toString, not tostring
- Expresses design intent
 - Tells fellow developers this is a method that came from parent class, so API for Object will describe how it is used

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New: @FunctionalInterface

- **Catches errors at compile time**

- If developer later adds a second abstract method, interface will not compile

- **Expresses design intent**

- Tells fellow developers that this is interface that you expect lambdas to be used for

- **But, like @Override not technically required**

- You can use lambdas *anywhere* 1-abstract-method interfaces (aka functional interfaces, SAM interfaces) are expected, whether or not that interface used @FunctionalInterface

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Interface Used in Numerical Integration Example

- **Last section**

```
public interface Integrable {  
    double eval(double x);  
}
```

- **Updated**

@FunctionalInterface

```
public interface Integrable {  
    double eval(double x);  
}
```

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Interface Used in Timing Utilities Example

- **Last section**

```
public interface Op {  
    void runOp();  
}
```

- **Updated**

@FunctionalInterface

```
public interface Op {  
    void runOp();  
}
```

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Method References

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Basic Method References

- **Simplest type: static methods**

- Replace

- (args) -> `ClassName.staticMethodName(args)`

- with

- `ClassName::staticMethodName`

- E.g., `Math::cos`, `Arrays::sort`, `String::valueOf`

- Another way of saying this is that if the function you want to describe already has a name, you don't have to write a lambda for it, but can instead just use the method name

- The signature of the method you refer to must match signature of the method in functional (SAM) interface to which it is assigned

- **Other method references described later**

- `variable::instanceMethod` (e.g., `System.out::println`)

- `Class::instanceMethod` (e.g., `String::toUpperCase`)

- `ClassOrType::new` (e.g., `String[]::new`)

Example: Numerical Integration

- In earlier example, replace these

```
MathUtilities.integrationTest(x -> Math.sin(x), 0, Math.PI);  
MathUtilities.integrationTest(x -> Math.exp(x), 2, 20);
```

- With these

```
MathUtilities.integrationTest(Math::sin, 0, Math.PI);  
MathUtilities.integrationTest(Math::exp, 2, 20);
```

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The Type of Method References

- **Question: what is type of Math::sin?**
 - Double? Function? Math?
- **Answer: can determine from context only**
 - The right question to ask would have been “what is the type of Math::sin *in code below?*”
 - MathUtilities.integrationTest(Math::sin, 0, Math.PI);
 - We can answer this the same way we answer any question about the type of an argument to a method: by looking at the API.
 - Conclusion: type here is Integrable
 - But in another context, Math::sin could be something else!
- **This point applies to all lambdas, not just method references**
 - The type can be determined only from context

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The Type of Lambdas or Method References

- **Interfaces** (like Java 7)

- public interface Foo { double method1(double d); }
- public interface Bar { double method2(double d); }
- public interface Baz { double method3(double d); }

- **Methods that use the interfaces** (like Java 7)

- public void blah1(**Foo** f) { ... f.method1(...)... }
- public void blah2(**Bar** b) { ... b.method2(...)... }
- public void blah3(**Baz** b) { ... b.method3(...)... }

- **Calling the methods** (use λ s or method references)

- blah1(**Math::cos**) or blah1(d -> **Math.cos(d)**)
- blah2(**Math::cos**) or blah2(d -> **Math.cos(d)**)
- blah3(**Math::cos**) or blah3(d -> **Math.cos(d)**)
 - All the above could also use Math::sin, Math::log, Math::sqrt, Math::abs, etc.

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Importance of Using Method References

- **Low!**

- If you do not understand method references, you can always use explicit lambdas
- Replace foo(Math::cos) with foo(d -> Math.cos(d))
- Replace bar(System.out::println) with bar(s -> System.out.println(s))
- Replace baz(Class::twoArgMethod) with (a, b) -> Class.twoArgMethod(a, b)

- **But method references are popular**

- More succinct
- Familiar to developers from several other languages, where you can refer directly to existing functions. E.g., in JavaScript

```
function square(x) { return(x*x); }
var f = square;
f(10); → 100
```

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The Four Kinds of Method References

Method Ref Type	Example	Equivalent Lambda
SomeClass::staticMethod	Math::cos	x -> Math.cos(x)
someObject::instanceMethod	someString::toUpperCase	() -> someString.toUpperCase()
SomeClass::instanceMethod	String::toUpperCase	s -> s.toUpperCase()
SomeClass::new	Employee::new	() -> new Employee()

var::instanceMethod vs. Class::instanceMethod

- **someObject::instanceMethod**

- Produces a lambda that takes *exactly as many* arguments as the method expects.

```
String test = "PREFIX:";  
String result1 = transform(someString, test::concat);
```

- The concat method takes one arg
- This lambda takes one arg, passing s as argument to test.concat
- Equivalent lambda is s -> test.concat(s)

- **SomeClass::instanceMethod**

- Produces a lambda that takes *one more* argument than the method expects. The first argument is the object on which the method is called; the rest of the arguments are the parameters to the method.

```
String result2 = transform(someString, String::toUpperCase);
```

- The toUpperCase method takes zero args
- This lambda takes one arg, invoking toUpperCase on that argument
- Equivalent lambda is s -> s.toUpperCase()

Method Reference Examples: Helper Interface

```
@FunctionalInterface
public interface StringFunction {
    String applyFunction(String s);
}
```

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Method Reference Examples: Helper Class

```
public class Utils {
    public static String transform(String s, StringFunction f) {
        return(f.applyFunction(s));
    }

    public static String makeExciting(String s) {
        return(s + "!!");
    }

    private Utils() {}
}
```

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Method Reference Examples: Testing Code

```
public static void main(String[] args) {
    String s = "Test";

    // SomeClass::staticMethod
    String result1 = Utils.transform(s, Utils::makeExciting); Test!!
    System.out.println(result1);

    // someObject::instanceMethod
    String prefix = "Blah";
    String result2 = Utils.transform(s, prefix::concat); BlahTest
    System.out.println(result2);

    // SomeClass::instanceMethod
    String result3 = Utils.transform(s, String::toUpperCase); TEST
    System.out.println(result3);
}
```

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Preview: Constructor References

- **In Java 7, difficult to randomly choose which class to create**
 - Suppose you are populating an array of random shapes, and sometimes you want a Circle, sometimes a Square, and sometimes a Rectangle
 - It requires tedious code to do this, since constructors cannot be bound to variables
- **In Java 8, this is simple**
 - Make array of constructor references and choose one at random
 - { Circle::new, Square::new, Rectangle::new }
 - This will be more clear once we introduce the Supplier type, which can refer to a constructor reference

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Preview: Making Random Person

```
private final static Supplier[] peopleGenerators =
    { Person::new, Writer::new, Artist::new, Consultant::new,
      EmployeeSamples::randomEmployee,
      () -> { Writer w = new Writer();
              w.setFirstName("Ernest");
              w.setLastName("Hemingway");
              w.setBookType(Writer.BookType.FICTION);
              return(w); }
    };

public static Person randomPerson() {
    Supplier<Person> generator =
        RandomUtils.randomElement(peopleGenerators);
    return(generator.get());
}
```

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Preview: Array Constructor References

- **Will soon see how to turn Stream into array**
 - `Employee[] employees = employeeStream.toArray(Employee[]::new);`
- **This is a special case of a constructor ref**
 - It takes an int as an argument, so you are calling “new Employee[n]” behind the scenes. This builds an empty Employee array, and then toArray fills in the array with the elements of the Stream
- **Most general form**
 - toArray takes a lambda or method reference to anything that takes an int as an argument and produces an array of the right type and right length
 - That array will then be filled in by toArray

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Variable Scoping in Lambdas

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Main Points

- **Lambdas are lexically scoped**
 - They do not introduce a new level of scoping
- **Implications**
 - The “this” variable refers to the outer class, not to the anonymous inner class that the lambda is turned into
 - There is no “OuterClass.this” variable
 - Unless lambda is inside a normal inner class
 - Lambdas cannot introduce “new” variables with same name as variables in method that creates the lambda
 - However, lambdas can refer to (but not modify) local variables from the surrounding method
 - Lambdas can still refer to (and modify) instance variables from the surrounding class

Examples

- **Illegal: repeated variable name**

```
double x = 1.2;  
someMethod(x -> doSomethingWith(x));
```
- **Illegal: repeated variable name**

```
double x = 1.2;  
someMethod(y -> { double x = 3.4; ... });
```
- **Illegal: lambda modifying local var from the outside**

```
double x = 1.2;  
someMethod(y -> x = 3.4);
```
- **Legal: modifying instance variable**

```
private double x = 1.2;  
public void foo() { someMethod(y -> x = 3.4); }
```
- **Legal: local name matching instance variable name**

```
private double x = 1.2;  
public void bar() { someMethod(x -> x + this.x); }
```

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Effectively Final Local Variables

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Main Points

- **Lambdas can refer to local variables that are not declared final (but are never modified)**

- This is known as “effectively final” – variables where it *would have been* legal to declare them final
- You can still refer to mutable *instance* variables
 - “this” in a lambda refers to main class, not inner class that was created for the lambda
 - There is no OuterClass.this.

- **With explicit declaration (explicitly final)**

```
final String s = "...";
doSomething(someArg -> use(s));
```

- **Effectively final (without explicit declaration)**

```
String s = "...";
doSomething(someArg -> use(s));
```

- Note the rule where the use of “final” is optional also applies in Java 8 to anonymous inner classes

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Example: Button Listeners

```
public class SomeClass ... {
    private Container contentPane;

    private void someMethod() {
        button1.addActionListener(event -> contentPane.setBackground(Color.BLUE));
        Color b2Color = Color.GREEN;
        button2.addActionListener(event -> setBackground(b2Color));
        button3.addActionListener(event -> setBackground(Color.RED));
        ...
    }
    ...
}
```

Instance variable: same rules as with anonymous inner classes in older Java versions; they can be modified.

Local variable: need not be explicitly declared final, but cannot be modified; i.e., must be “effectively final”.

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Example: Concurrent Image Download

- **Idea**

- Use standard Java threading to download a series of images of internet cafes and display them in a horizontally scrolling window

- **Java 8 twists**

- Because `ExecutorService.execute` expects a `Runnable`, and because `Runnable` is a functional (SAM) interface, use lambdas to specify the body of the code that runs in background
- Have code access local variables (which are effectively final but not explicitly declared final)

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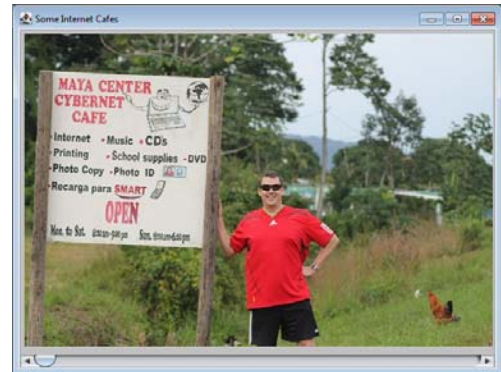
Main Code

```
...
ExecutorService taskList = Executors.newFixedThreadPool(poolSize);
for(int i=1; i<=numImages; i++) {
    JLabel label = new JLabel();
    URL location = new URL(String.format(imagePattern, i));
    taskList.execute(() -> {
        ImageIcon icon = new ImageIcon(location);
        label.setIcon(icon);
    });
    imagePanel.add(label);
}
...
```

Full code can be downloaded from
<http://www.coreservlets.com/java-8-tutorial/>

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Results



Multithreaded version takes less than half the time of the single-threaded version.
Speedup could be much larger if the images were taken from different servers.

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Wrap-Up

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Summary

- **@FunctionalInterface**
 - Use for all interfaces that will permanently have only a single abstract method
- **Method references**
 - `arg -> Class.method(arg)` → `Class::method`
- **Variable scoping rules**
 - Lambdas do not introduce a new scoping level
 - “this” always refers to main class
- **Effectively final local variables**
 - Lambdas can refer to, but not modify, local variables from the surrounding method
 - These variables need not be explicitly declared final as in Java 7
 - This rule (cannot modify the local variables but they do not need to be declared final) applies also to anonymous inner classes in Java 8

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