Java 8,11,15,16 Lambda Expressions and Streams

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НАЦІОНАЛЬНИЙ УНІВЕРСИТЕТ КОРАБЛЕБУДУВАННЯ ІМЕНІ АДМІРАЛА МАКАРОВА

Extracting employee names

```java
public List<String> empNames(List<Employee> employees) {
  List<String> e = new ArrayList<>();
  for (Employee emp : employees)
    e.add(emp.getName());
  return e;
}
```

Extracting employee ages

```java
public List<Integer> empAges(List<Employee> employees) {
  List<Integer> e = new ArrayList<>();
  for (Employee emp : employees)
    e.add(emp.getAge());
  return e;
}
```

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public List<String> empNames(List<Employee> employees) {
  List<String> e = new ArrayList<>();
  for (Employee emp : employees)
    e.add(emp.getName());
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  List<Integer> e = new ArrayList<>();
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  return e;
}
```

Variation   Duplication

Lets identify the control structure, and extract the behavior into an object

```java
public List<String> empNames(List<Employee> employees) {
  List<String> e = new ArrayList<>();
  for (Employee emp : employees)
    e.add(emp.getName());
  return $;
}
```

```java
public interface Mapper<U, T> {
  public T map(U u);
}
```
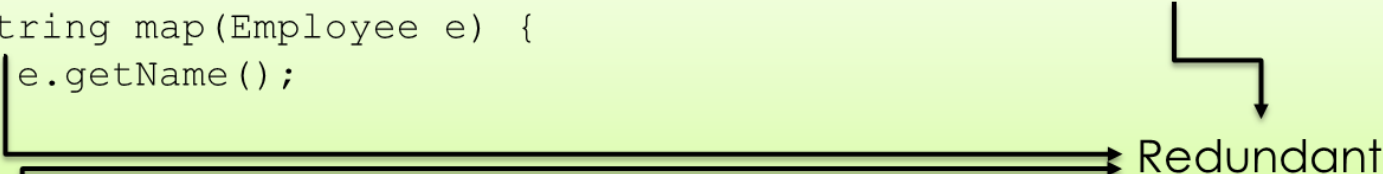
```java
public <U, T> List<T> map(
    List<U> list, Mapper<? super U, ? extends T> m) {
  List<T> e = new ArrayList<>();
  for (U u : list)
    e.add(m.map(u));
  return e;
}
```

Extracting employee names
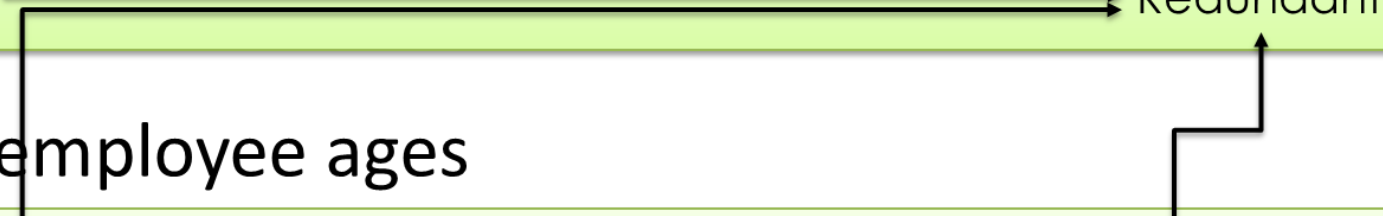
```java
List<String> empNames = map(employees, new Mapper<Employee,String>() {
    public String map(Employee e) {
        return e.getName();
    }
});
```

Redundant

Extracting employee ages

```java
List<Integer> empAges = map(employees, new Mapper<Employee,Integer>() {
    public Integer map(Employee e) {
        return e.getAge();
    }
});
```

We removed the code duplication, but this is still very verbose…

➡ Semantically, `map` is a **higher level function**

 ➡ This means that it accepts a function as an **argument** (or returns a function)

➡ Syntactically, functions do not exist as first class entities

 ➡ All verbs (functions) have be accompanied by a noun (class)

 ➡ http://steve-yegge.blogspot.co.il/**2006**/03/execution-in-kingdom-of-nouns.html

 ➡ translation: https://ru.hexlet.io/blog/posts/javaland

➡ Prior to Java 8, Java was the only programming language in popular use without anonymous functions / blocks / lambdas / function pointers

 ➡ This is **not** purely a **syntactic** issue; Java also lacked proper support for such function in its **collections** and **standard libraries**

 ➡ Some libraries, like Guava, attempted to fill the void

Enter Java 8!

- Extracting employee names:

```java
List<String> empNames = employees.stream()
    .map(x -> x.getName())
    .collect(Collectors.toList());
```

- Extracting employee ages:

```java
List<Integer> empAge = employees.stream()
    .map(Employee::getAge) // method reference instead of lambda
    .collect(Collectors.toList());
```

- Still very verbose compared to other languages (C#, Scala, Python)
  - "boiler-plate" ratio lessens when we compose actions (see later)

```
List<String> empNames = employees.stream()
    .map(x -> x.getName())
    .collect(Collectors.toList());
```

- `stream()` is a **default** method of `List`
- `map` is a higher level function of `Stream`
- `x -> x.getName()` is a **lambda expression**
- `collect` turns the `Stream` back to a normal `Collection` (in our case, a `List`)
- Let's go over each of these terms one by one

default Methods

```java
List<String> empNames = employees.stream()
    .map(x -> x.getName())
    .collect(Collectors.toList());
```

➡ **default** methods are (default) implementations for **interfaces**

   ➡ Can be **overridden** extending interfaces and implementing classes

```java
interface Foo {
  void a(); // regular abstract method
  default void b() { // can also be overriden
    System.out.println("I'm a default method!");
  }
}
```

➡ Adds **new** functionality to an existing interface without **breaking** all client code

   ➡ In our case, we added the **stream()** method to **Collection**

- So is this the same as **multiple inheritance**?
  - Nope; more similar to **Traits**
  - There is neither **conflict resolution** nor **constructors**, so the model is much **simpler**
- So are these **extension methods** (a la C#)?
  - No, because extension methods are actually **syntactic sugar** for **static decorators**
  - *You* can't add methods to library classes (e.g., in C# you can add extension methods to `String`).
- Solutions in other languages
  - Ruby – mixins
  - Python/Javascript – monkey patching
  - Scala – implicits / pimp my library
  - Haskell – type classes

Higher order functions

```
List<String> empNames = employees.stream()
  .map(x -> x.getName())
  .collect(Collectors.toList());
```

➡ `map` is a higher order function in `stream`

   ➡ A function that takes a function

➡ Other higher order functions in `Stream`

   ➡ `filter`, `map`, `flatMap`, `sorted`, `reduce`, ...

➡ Similar libraries in other languages

   ➡ `LINQ` in C#, `itertools` in Python, `Enumerable` in Ruby, etc.

Streams

- `Stream` is the **gateway** to the "functional collections" in Java 8
  - ➡ Provide a **uniform API** (why is this important?)
- We only iterate over a stream once, even if we have two or more higher level functions
- This is because streams are **lazily evaluated**
  - – Until we **collect** (or form some other **reduction**), no iteration takes place
  - ➡ **collect** is a form of **mutable reduction**
    - ➡ i.e., it reduces to a mutable container
    - ➡ Other reductions include `forEach` and, well, `reduce`
- Streams also give us "free" **parallelization** (why is it so easy?)

```
List<String> empNames = employees.stream()
    .parallel()
    .map(x -> x.getName())
    .collect(Collectors.toList());
```

Streams: Caveats

- Streams are "single serving" only!
  - This code will throw an exception:

```
Stream<Student> stream = students.stream();
Stream<String> names = stream.map(Student::getName);
Stream<Integer> ages = stream.map(Student::getAge);
```

  - This too:

```
Stream<String> names = students.stream.map(Student::getName);
stream.forEach(this::printStudent);
stream.forEach(this::addStudentToDatabase);
```

- Avoid returning `Stream` from a **public** function, or keeping one as a field,
  - An `Iterable` or `Collection` is usually more suitable
  - Although there are some (rare) cases where it's appropriate, there are usually better (monadic) types

```
List<String> empNames = employees.stream()
    .map x -> x.getName()
    .collect(Collectors.toList());
```

- ➤ The signature for `map` is:
  `map(Function<? super T,? extends R> mapper)`
- ➤ And here is the signature for `Function` (**default** methods retracted):

```
interface Function<T, R> { R apply(T t); }
```

- ➤ An **interface** which has **single abstract** (i.e., non-**default**) method (often abbreviated **SAM**) can be called a **functional interface**
- ➤ **Lambdas** are just **syntactic sugar** for implementing functional interfaces
  - ➤ Method reference (`::`) and lambdas are interchangeable, where applicable
  - ➤ References are considered "more elegant" (as we will see later)
- ➤ So is Java a **functional** language now?
  - ➤ Functions aren't first-class citizens; functions aren't even a proper part of the Java language, just a standard library **interface**
  - ➤ Although an alternative interpretation could argue that interfaces are the new functions

This design choice has a great pro: we can also use lambda with legacy API!

► Old code

```java
new Thread(new Runnable() {
  @Override
  public void run() {
    System.out.println("Kill me :[");
  }
}).start();
```

► New code

```java
new Thread(() -> System.out.println("PARTEH! :D|-< :D/-< :D\-<)).start();
```

► We can use the convenience `@FunctionalInterface` annotation to tell the compiler that the interface should be functional (a la `@Override`)

```java
@FunctionalInterface
interface Foo { void bar(); void bazz(); } // won't compile
```

➡ Assure we are not hiring anyone underage

```
assert employees.stream().noneMatch(x -> x.age < 18);
```

➡ Find the highest paid individual in the company

```
Optional<Employee> opt = employees.stream().maxBy((x, y) -> x.salary -
y.salary);
```

➡ What is returned if the list is **empty**?

➡ Instead of working with **null**, a new type **Optional<T>** is returned

  ➡ **Optional<T>** can be present (i.e. not **null**) or empty (i.e. **null**)

  ➡ Has a method **get()** that returns **T** or throws an exception

What is this?

- Assure we are not hiring anyone underage

```
assert employees.stream().noneMatch(x -> x.age < 18);
```

- Find the highest paid individual in the company

```
Optional<Employee> opt = employees.stream().maxBy((x, y) -> x.salary - y.salary);
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- What is returned if the list is **empty**?
- Instead of working with **null**, a new type **Optional<T>** is returned
  - **Optional<T>** can be present (i.e. not **null**) or empty (i.e. **null**)
  - Has a method **get()** that returns **T** or throws an exception

➥ [The billion dollar mistake](#)

➥ **`null`**s are incredibly dangerous!

  ➥ Often **unchecked** until **used**

   ➥ a "sleeper agent" that destroys the application, its origin is hard to trace

  ➥ By returning an `Optional`, we are **explicit** in our result type

   ➥ **Types are better than comments!**

➥ `Optional` also has **higher order functions**

```
Optional<Employee> richest = …
Optional<Integer> ageOfRichest =
richest.map(Employee::getAge);
```

➥ `filter` will **return** `empty` if the predicate returns **`false`**

```
richestEmployee.filter(x -> x.age >= 18);
```

➡️Optionals **compose** using `flatMap`

```java
// working with nulls
Student s = getStudent();
if (s == null)
    return null;
Course c = s.getCourse("Software Design");
if (c == null)
    return null;
Exam e = c.getMoedA();
if (e == null)
    return null;
return e.getGrade();
```

```java
// but if we returned Optionals…
getStudent()
    .flatMap(Student::getCourse)
    .flatMap(Course::getMoedA)
    .flatMap(Exam::getGrade)
```

- Get Ukrainian students with a top grade sorted by name in Java 7

```java
List<Student> topGrades = new ArrayList<>();
Collections.sort(students, new Comparator<Student>() {
  public int compare(Student student1, Student student2) {
    return student1.getName().compareTo(student2.getName());
  }
});
for (Student student: students)
  if ("Ukraine".equals(student.getCountry()))
    if (student.getGrade() >= 90)
      topGrades.add(student);
```

- Get Ukrainian students with a top grade sorted by name in Java 7

Sorts in place!
Why is this bad?

```java
List<Student> topGrades = new ArrayList<>();
Collections.sort(students, new Comparator<Student>() {
  public int compare(Student student1, Student student2) {
    return student1.getName().compareTo(student2.getName());
  }
});
for (Student student: students)
  if ("Ukraine".equals(student.getCountry()))
    if (student.getGrade() >= 90)
      topGrades.add(student);
```

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- Get Ukrainian students with a top grade sorted by name in Java 7

Sorts in place! Why is this bad?

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  public int compare(Student student1, Student student2) {
    return student1.getName().compareTo(student2.getName());
  }
});
for (Student student: students)
  if ("Ukraine".equals(student.getCountry()))
    if (student.getGrade() >= 90)
      topGrades.add(student);
```

Depth of 3!

A more complex example

- Get Ukrainian students with a top grade sorted by name in Java 7

Sorts in place! Why is this bad?

```java
List<Student> topGrades = new ArrayList<>();
Collections.sort(students, new Comparator<Student>() {
  public int compare(Student student1, Student student2) {
    return student1.getName().compareTo(student2.getName());
  }
});
for (Student student: students)
  if ("Ukraine".equals(student.getCountry()))
    if (student.getGrade() >= 90)
      topGrades.add(student);
```

Depth of 3!

- In Java 8 and later:

```java
List<Students> topStudents = students.stream()
  .filter(x -> "Ukraine".equals(x.getCountry()))
  .filter(x -> x.getGrade() >= 90)
  .sorted(Comparator.comparing(Student::getName))
  .collect(Collectors.toList());
```

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Other cool tricks

➡ Sum of all salaries in the company with "map-reduce"

```java
employees.stream()
  .mapToInt(Employee::getSalary)// note the mapToInt... why?
  .reduce(0, Integer::sum)
// could also be done with Lambdas, or simply .sum()
```

➡ Count the number of employees **by** rank

```java
Map<Rank, Long> countByRank =
employees.stream().collectors(
    Collectors.groupingBy(Employee::getRank,
                          Collectors.counting());
```

➡ Streams **compose** using `flatMap` too!

```java
List<Student> allIsraeliStudents = universities.stream()
  .flatMap(u -> u.getFaculties().stream())
  .flatMap(f -> f.getStudents().stream())
  .collect(Collectors.toList());
```

`Streams` **and** `Optionals` are an example of moving from **imperative** code to **declarative** code

➡️In imperative code we write the **exact**, **low level** steps:

  ➡️**Create** a new list object

  ➡️**Iterate** over the original list

    ➡️For every entry, **apply some function `f`** on it

    ➡️**Add** the result of `f` in the new list

  ➡️**Return** the new list

➡️In declarative programming,
we write a **higher level description:**

  ➡️**map** all elements in the list using some function `f`

  ➡️**collect** to a `List`

Declarative code is **shorter**, more **precise** and **explicit**, more **readable**, and less **error-prone**

- ➡ You can do pretty **anything** inside a `for` loop
- ➡ That means you have to **read** the **entire body** to know what's going on
- ➡ More room for **bugs**

Declarative code is written in a higher level of abstraction

- ➡ In our case, `maps` and `filters`, rather than object **creation** and **modification**
- ➡ **Higher order functions** instead of **control structures** and **primitive checks**
- ➡ Less **moving parts**, hide the **unnecessary details**

➼ Before Java 5, we had to iterate by **index**, or use the **iterator** directly

  ➼ Even more bugs: infinite loop, index modifications

➼ Using `list.add` is more declarative than managing the internal data structure on your own

  ➼ Using a library/function is usually more declarative than inlining its code

➼ Applies to **syntax**, not just **semantics**

  ➼ An array initializer (`new int[] {1, 2, 3}`) is more declarative than doing it manually

  ➼ A **lambda expression** is more declarative than an **anonymous functions**, but a **method reference** is more declarative than a lambda expression

  ➼ Rule of thumb: Less **tokens** ⇒ More declarative

- Avoid loops, use `Streams`
  - Almost any loop can be replaced with a Stream call
  - The new version of IntelliJ does this automagically
- Avoid **null**s, use `Optionals`
  - `Optionals` are clearer, safer, compose better, and support higher level functions
  - Only use **null**s when dealing with **legacy** APIs
- Prefer **declarative** to **imperative** code whenever possible

```java
package demo;

import ...

public class Demo {
    private static int withPrefix(List<Set<String>> nested, String prefix) {
        int count = 0;
        for (Set<String> element : nested) {
            if (element ≠ null) {
                for (String str : element) {
                    if (str.startsWith(prefix)) {
                        count += str.length();
                    }
                }
            }
        }
        return count;
    }
```

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