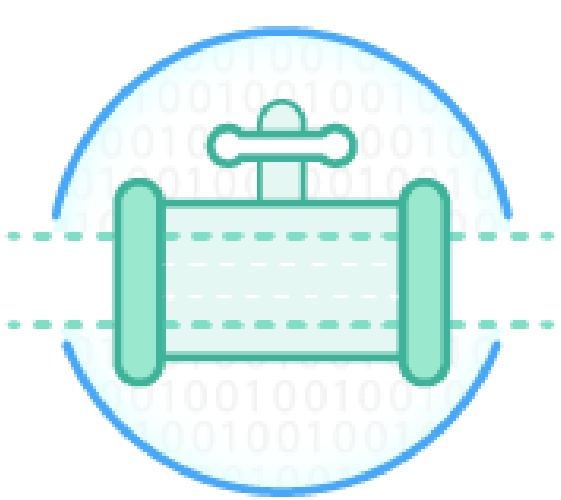
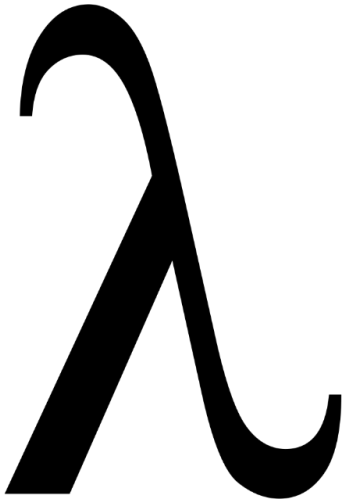
CMPS 251

Lambdas and Streams





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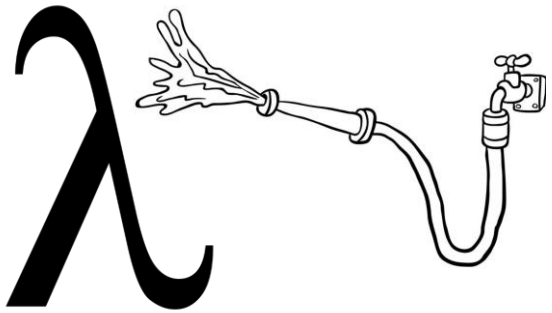
Content

1. Lambdas and Streams
2. Stream Operations
3. Read / Write JSON File

Lambdas and Streams



Back

The most important principle in Programming?

KEEP IT SHORT & SIMPLE

KISS

Declarative programming using Lambdas helps us to achieve KISS

Imperative vs. Declarative

Imperative Programming

- You tell the computer how to perform a task.

Declarative Programming

- You tell the computer **what you want**, and you let the computer (i.e. the compiler or runtime) figure out for itself the best way to do it.
- Also known as **Functional Programming**

What is a Lambda?

- Lambda is very similar to *a method*. It has:
  - Parameters
  - A body
  - A return type
- They **don't have a name** (anonymous method)
- They have no associated object
- They **can be passed as parameters** to other methods:
  - As *code* to be executed by the receiving method
- Concise syntax (introduced in Java 8):

Arrow token

```
Parameters -> Body
```

Lambda Expressions

- Lambda expression can be passed as a parameter to methods such as ***forEach***, ***filter*** and ***map*** methods :

```
List<Integer> numbers = List.of(1, 2, 3, 4, 5, 6, 7, 8, 9, 10);
numbers.forEach( e -> System.out.println(e) );
```

- Left side of `->` operator is a parameter variable.
- Right side is code to operate on the parameter and compute a result.
- When used a lambda is used with `Stream` or `List` the compiler can determine the parameter type.
- Multiple parameters are enclosed in parentheses. E.g., lambda passed to get longest word:

```
words.stream().max((v, w) -> v.length() - w.length())
```

Removal from a collection using a predicate lambda

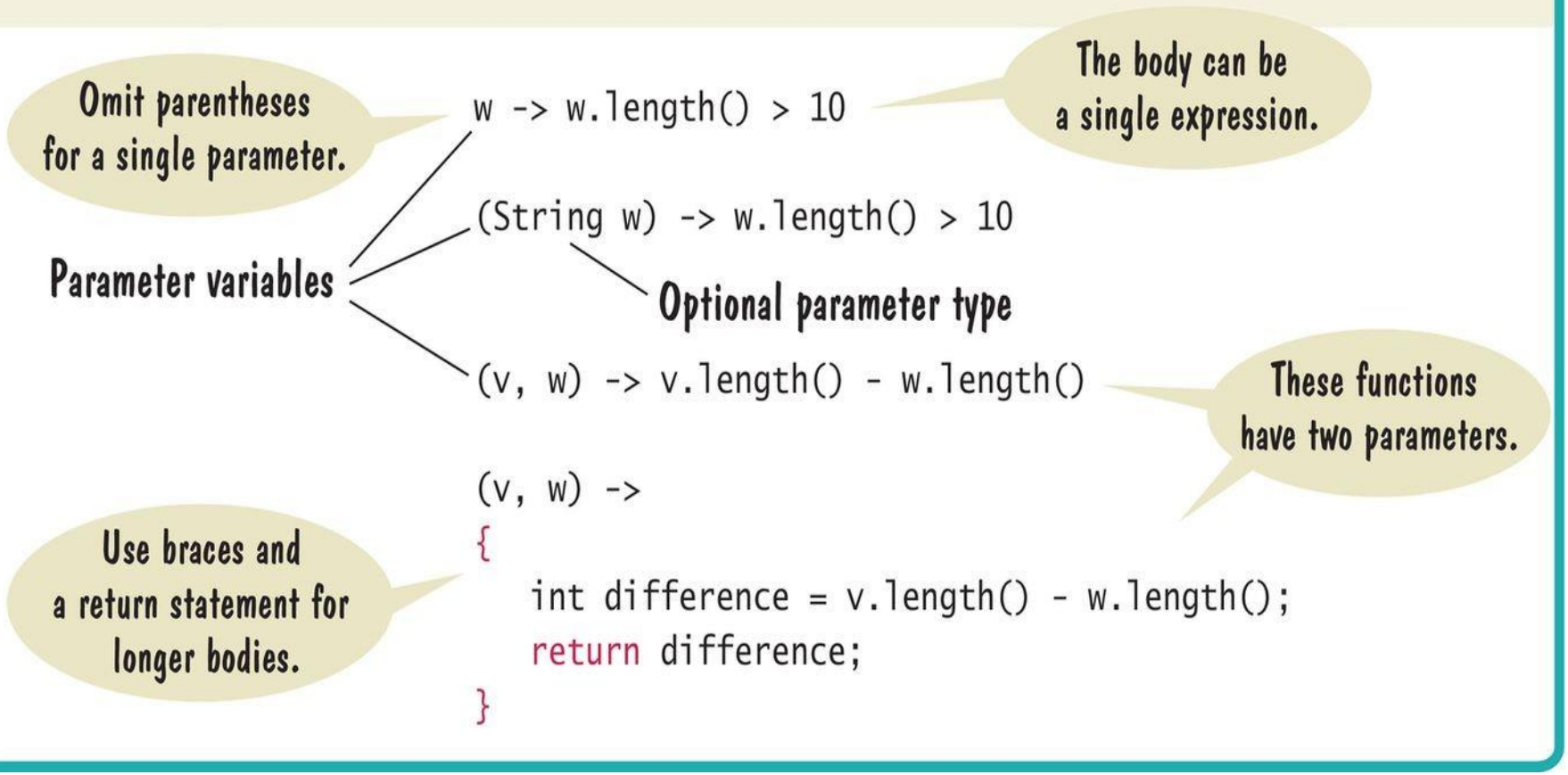
```
List<Integer> numbers = new ArrayList<>(
    List.of(1, 2, 3, 4, 5, 6, 7, 8, 9, 10) );

//Remove elements < 4
numbers.removeIf(n -> n < 4);
```

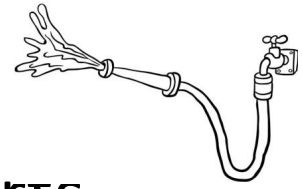
forEach and **removeIf** can be used directly on a list without a stream
forEach is used to loop over the list elements

Syntax Lambda Expressions

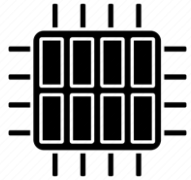
Syntax *Parameter variables -> body*



What is a Stream?



- A stream is a **sequence** of objects that supports convenient methods that can be ***pipelined*** to process a **list** of objects and produce the desired result
- They **don't store their own data.** They are just programmatic **wrappers** on existing data sources such as List, Array or File stream
- Support **Automatic parallelization**
  - Can split work **over multiple processors** using `stream().parallel()`



- **Lazy evaluation**: streams defer doing most operations until you actually request the results
- Streams were designed to **work well with lambdas**:

```
stream.filter( w  -> w.length() >  10 )
```

Producing Streams

- Any list can be turned into a stream:

```
List<String> wordList = new ArrayList<>();
Stream<String> words = wordList.stream();
```

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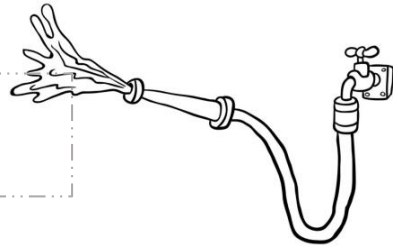
- Can create a Stream from a file

```
String filePath = "data/countries.txt";
Stream<String> countries = Files.lines(Paths.get(filePath));
```



- You can make infinite streams:

```
Stream<Integer> integers = Stream.iterate(0, n -> n + 1);
integers.forEach(System.out::println);
```

- You can turn any stream into a *parallel stream* using `stream().parallel()`
  - Operations such as `filter` and `count` run in parallel, each processor working on chunks of the data

The Stream Concept

- Algorithm for counting words longer than 10 characters:

```
List<String> words = . . .;
long count = 0;
for (var w : wordList) {
    if (w.length() > 10) { count++; }
}
```

- With Stream library:

```
List<String> words = . . .;
long count = words.stream().filter( w -> w.length() > 10 ).count();
```

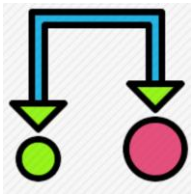
- You tell ***what*** you want to achieve (filter long strings then count them) => **Declarative programming**
- You don't program the ***how*** (loop through each element in turn, if it is long, increment a counter)
- "What, not how" makes code more concise + Operations can be executed in parallel

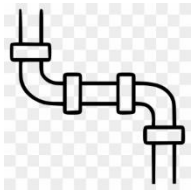
Producing Streams

Example	Result
`Stream.of(1, 2, 3)`	A stream containing the given elements. You can also pass an array.
`Collection<String> coll = . . .; coll.stream()`	A stream containing the elements of a collection.
`Files.lines(`*path*`)`	A stream of the lines in the file with the given path. Use a try-with-resources statement to ensure that the underlying file is closed.
`Stream<String> stream = . . .; stream.parallel()`	Turns a stream into a parallel stream.
`Stream.generate(() -> 1)`	An infinite stream of ones
`Stream.iterate(0, n -> n + 1)`	An infinite stream of `Integer` values
`IntStream.range(0, 100)`	An `IntStream` of `int` values between 0 (inclusive) and 100 (exclusive)
`Random generator = new Random(); generator.ints(0, 100)`	An infinite stream of random `int` values drawn from a random generator
`"Hello".codePoints()`	An `IntStream` of code points of a string

Stream Operations

Filter, Map, Reduce, and others



Filter

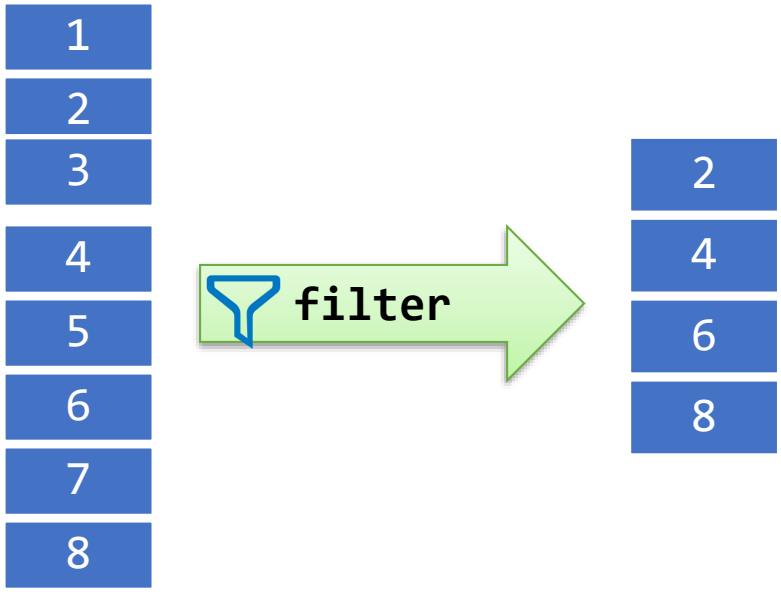
Keep elements that satisfy a condition

```
// Imperative
List<Integer> evens =
  new ArrayList<>();

for (var num : numbers) {
  if (num % 2 == 0) {
        evens.add(num);
  }
}
```

```
// Declarative
Stream<Integer> evens =
  numbers.stream()
        .filter (n -> n % 2 == 0);
        .forEach (System.out::println);
```

forEach - Calls a Lambda on Each Element of the Stream



findFirst

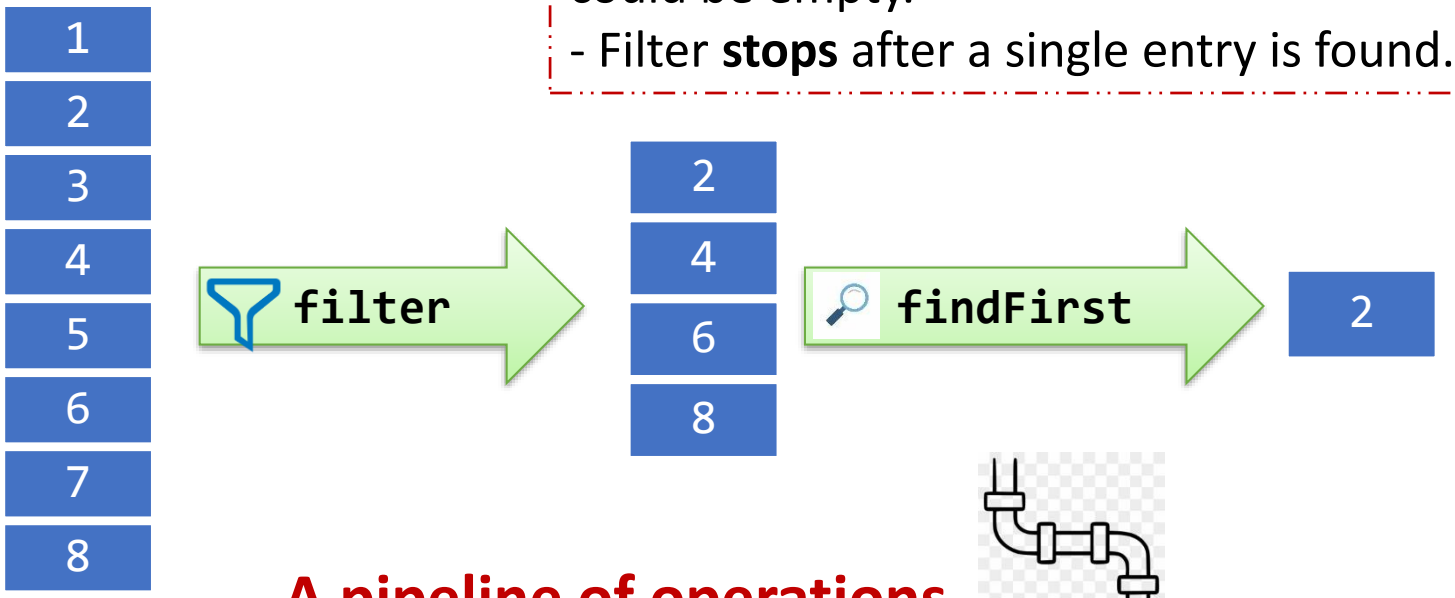
Return first element satisfying a condition

```
// Imperative
Integer firstEven;

for (var num : numbers) {
  if (num % 2 == 0) {
        firstEven = num;
        break;
  }
}
```

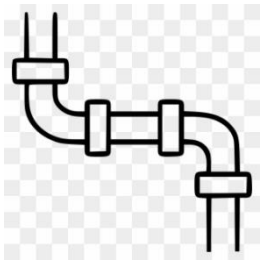
```
// Declarative
Optional<Integer> firstEven =
  numbers.stream()
         .filter (n -> n % 2 == 0);
         .findFirst();
```

- Returns an Optional<Integer> for the **first entry** in the Stream. There might none, so the Optional could be empty.
- Filter **stops** after a single entry is found.



A pipeline of operations

Stream Operations Pipeline



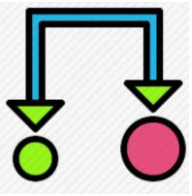
- Pipeline starts with a source stream
- Operations are either **Intermediate**, or **Terminal**
- **Intermediate operations** produce a new stream as output (e.g., map, filter, …)
  - These operations don't get processed until a terminal operation is called (lazy evaluation!)
- **Terminal operations** are the final operation in the pipeline (e.g., findFirst, reduce, collect, sum …)
  - One a terminal operation is invoked, the Stream is considered consumed and no more operations can be performed on it

Example of Lazy Evaluation

```
employees.stream()
    .filter(e -> e != null)
    .filter(e -> e.getSalary() > 500000)
    .findFirst()
    .orElse(null));
```

- **Apparent behavior**
  - Check all elements for null, call getSalary on all non-null (& compare to $500K) on all remaining, find first, return it or null
- **Actual behavior (lazy evaluation)**
  - Check first element, if not null call getSalary, if salary > $500K, return employee and exit. Otherwise repeat...
  - Return null if you get to the end and never found a match

Map

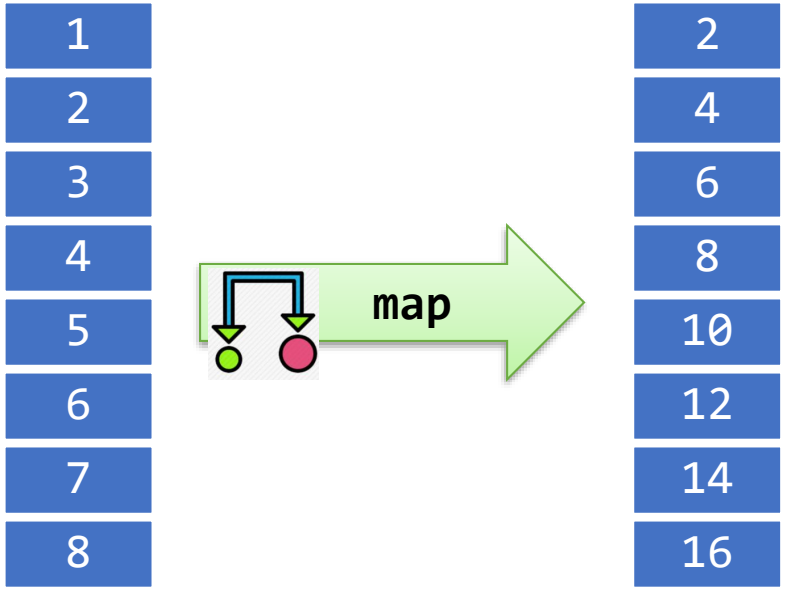


Transform elements by applying a Lambda to each element

```java
// Imperative
List<Integer> doubled =
  new ArrayList<>();

for (var num : numbers) {
    doubled.add(num * 2);
}
```

```java
// Declarative
Stream<Integer> doubled =
  numbers.stream()
         .map (n -> n * 2);
```



Reduce

Apply an accumulator function to each element of the list to reduce them to a single value.

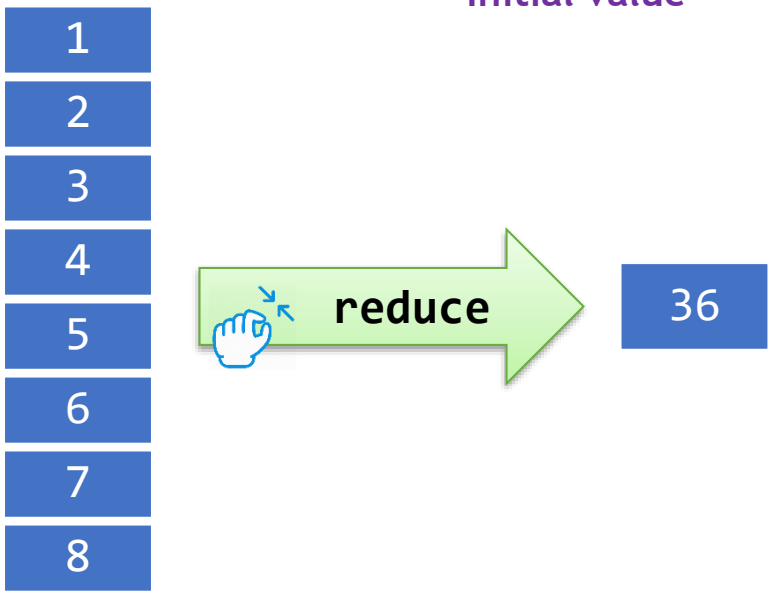
```
// Imperative
int total = 0;
for (var num : numbers) {
    total += num;
}
```

```
// Declarative
int total =
 numbers.stream()
        .reduce(0, (sum,n) -> sum + n);
```

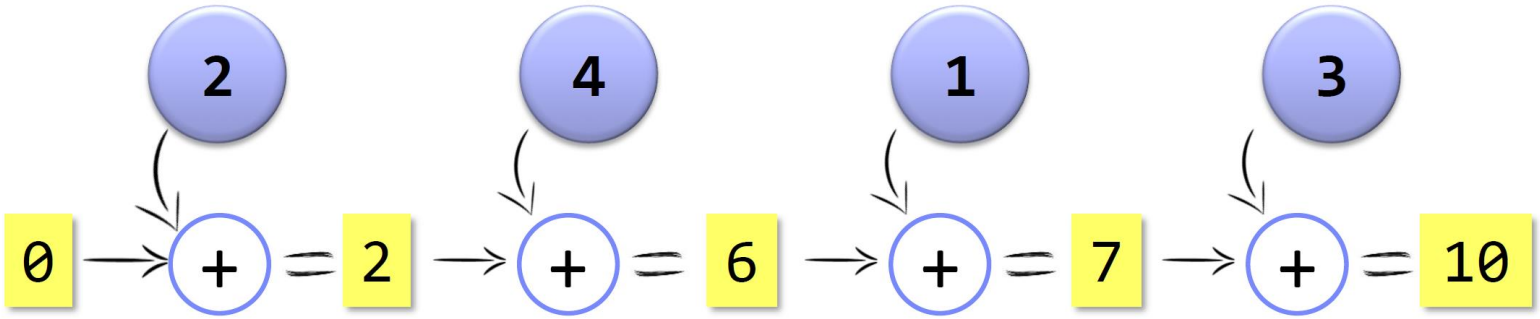
Initial value

Accumulation

Collapse the multiple elements of the input stream into a single element



Reduce




```
.reduce(0, (sum,n) -> sum + n);
```

Reduce is **terminal** operation that yields a single value

Convenience Reducers

Sum, Average, Count, Min, Max

```
List<Integer> nums = List.of(1, 2, 3, 4, 5, 6, 7, 8, 9, 10);

int sum = nums.stream().mapToInt(Integer::intValue).sum();

long count = nums.stream().mapToInt(Integer::intValue).count();

double average =
nums.stream().mapToInt(Integer::intValue).average().orElse(0);

int max = nums.stream().mapToInt(Integer::intValue).max().orElse(0);

int min = nums.stream().mapToInt(Integer::intValue).min().orElse(0);
```

- They work with **int**, **long** and **double** streams only
- They are **terminal** operations that yield a single value

Collecting Results

- After a stream operation (e.g. **`map`**, **`filter`**) you can **harvest** the results into a a `List` or `Set` using **`collect`**:

```
List<Integer> numbers = List.of(1, 2, 3, 4, 5, 1, 2, 3, 4, 5);
   List<Integer> evens =
         numbers.stream().filter(e -> e % 2 == 0)
                .collect(Collectors.toList());
```

- A stream of can be collected into a single string:

```
String evens = numbers.stream()
                      .filter(e -> e % 2 == 0)
                      .map(String::valueOf)
                      .collect(Collectors.joining(", "));
```

Flat Map

Do a map and flatten the results into 1 list

```
List<String> books =
     students.stream()
             .flatMap(s -> s.getBooks().stream())
             .distinct()
             .collect(Collectors.toList());
```

Each student has a list of books, the example above produces a list of **all** distinct books

flatMap - Each lambda application *produces a Stream*, then the Stream elements are ***combined*** *into a single Stream*.

Limiting Stream Size: limit and skip

- **`limit(n)`** returns a Stream of the first **`n`** elements
- **`skip(n)`** throws away the first **`n`** elements
- **Examples**
  - Return first 10 elements

```
someLongStream.limit(10)
```

  - Skip first 5 elements

```
someLongStream.skip(5)
```

Checking Matches: anyMatch, allMatch

- `anyMatch` and `allMatch` check if stream elements satisfy a boolean condition
  - **`anyMatch`** would immediately return true if it finds an element that satisfies the lambda condition
  - **`allMatch`** would immediately return false if it finds an element that fails the lambda condition
  - They stop processing once an answer can be determined
- **Examples**

```
boolean isSomeoneMegaRich = employees.stream()
                          .anyMatch(e -> e.getSalary() >= 100000);
boolean isEveryoneMegaRich = employees.stream()
                          .allMatch(e -> e.getSalary() >= 100000);
```

Sorting

Example: Sort strings by length (longest to shortest) and then alphabetically

```
List<String> words = Arrays.asList("The quick brown fox jumps over the lazy dog".split(" "));

// Sort words by word length then alphabetically
String sortedWords = words.stream()
  .sorted( Comparator.comparing(String::length)
                     .thenComparing(Comparator.naturalOrder())
         )
  .collect(Collectors.joining(" "));

System.out.println( sortedWords );
```

Comparator that compares strings by their length.

Can add a secondary comparison with **thenComparing.**
Compare first by length **then** alphabetically.

Stream Operators - Summary

Example	Comments
`stream.filter(`*condition*`)`	A stream with the elements matching the condition.
`stream.map(`*function*`)`	A stream with the results of applying the function to each element.

`stream.mapToInt(`*function*`)`
`stream.mapToDouble(`*function*`)`
`stream.mapToLong(`*function*`)`
	A primitive-type stream with the results of applying a function with a return value of a primitive type

`stream.limit(n)` `stream.skip(n)`	A stream consisting of the first `n`, or all but the first `n` elements.

`stream.distinct()`
`stream.sorted()`
`stream.sorted(`*comparator*`)`
	A stream of the distinct or sorted elements from the original stream.

Grouping Results

- Grouping is used to split results into groups
  - E.g., Group by Continent and get the Countries count

```
Map<String, Long> countryCountByContinent =
countries.stream()
        .collect(
          Collectors.groupingBy(c -> c.getContinent(),
                                Collectors.counting()
                               )
         );
```

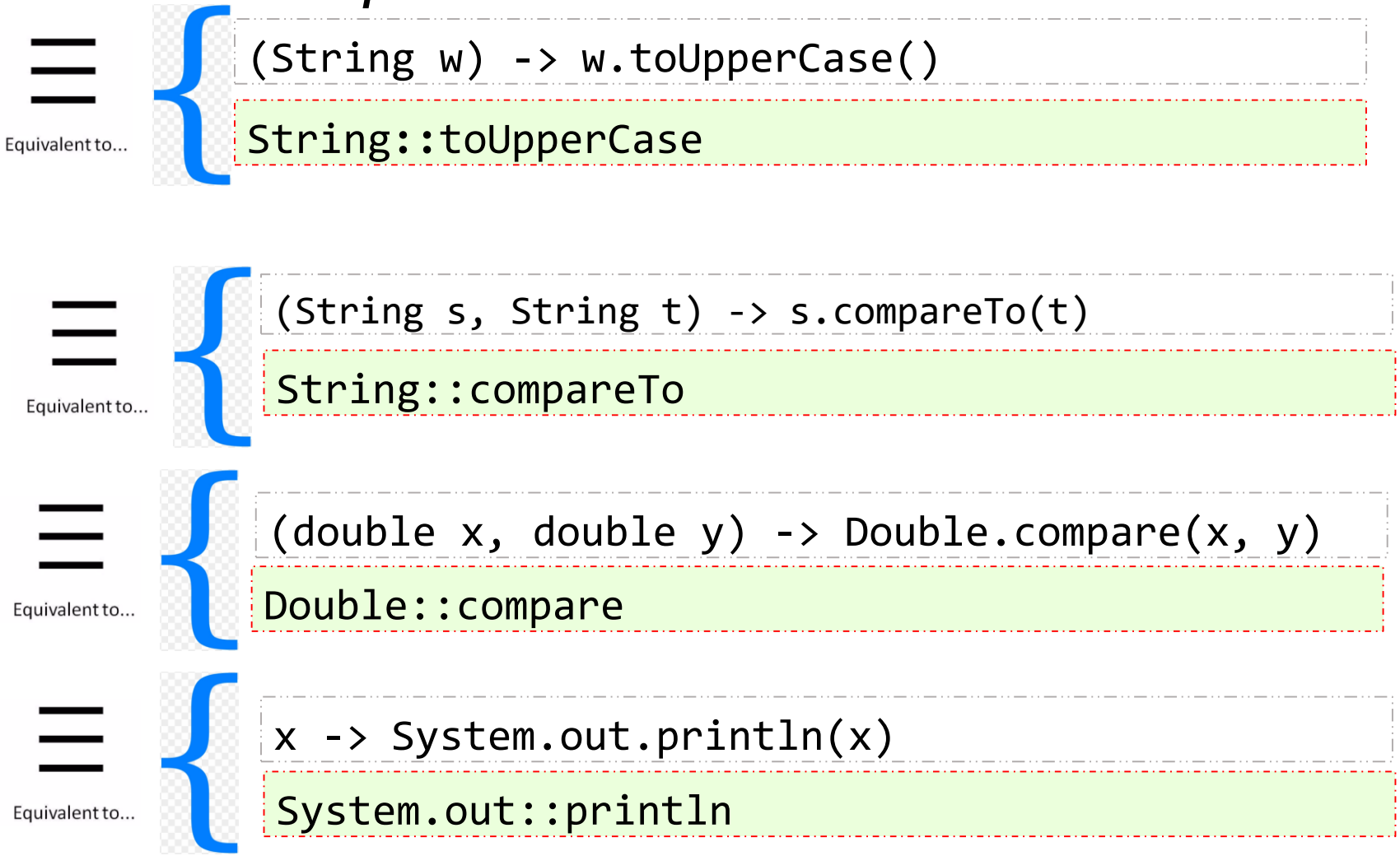
The **`Collectors.groupingBy`** produces a map:

- the **key** is the Continent
- the **value** if the Counties **count** computing using ***`Collectors.counting()`***

Other `Collectors` could be used such as `summingInt` and `averagingInt`

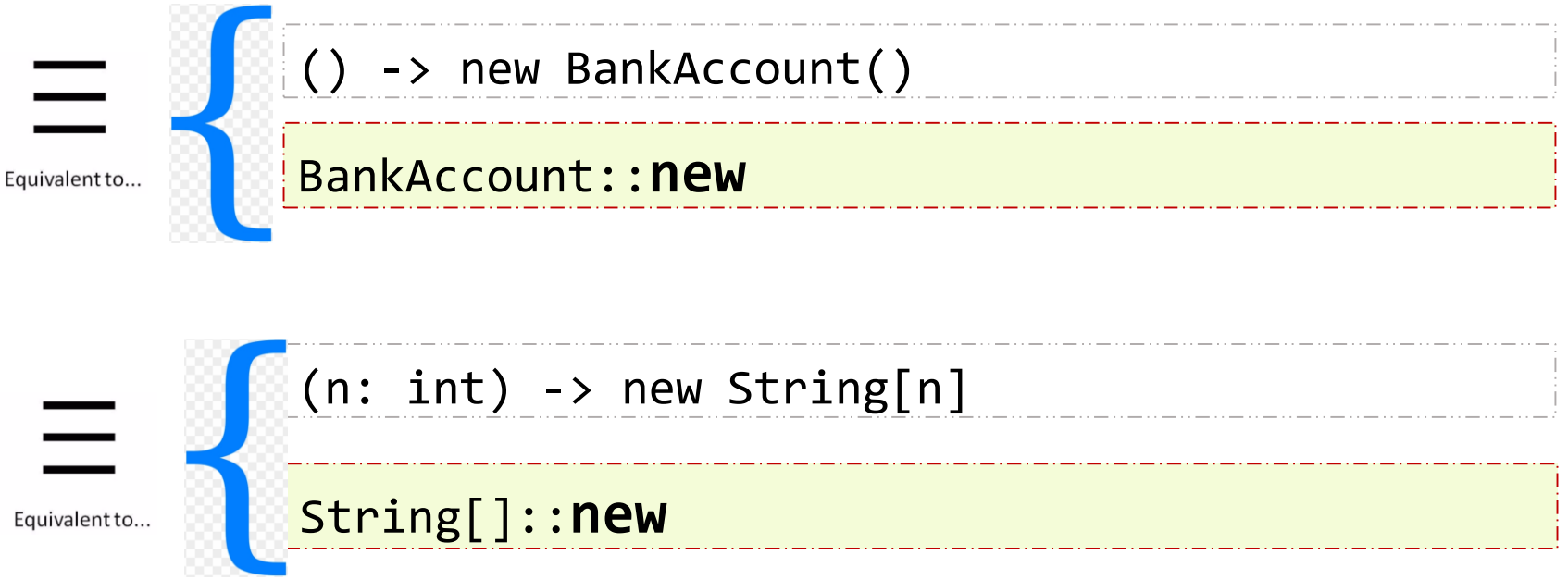
Method Expressions

- Common to have lambda expressions that just invoke a method
- Use ***method expression***: *`ClassName::methodName`*



Constructor Expressions

- Like method expression using special **new** method



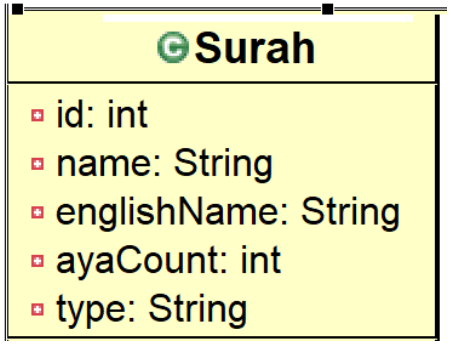

```
//Convert a stream of words to an array of Strings
String[] array = wordStream.toArray(String[]::new);
```

Read / Write JSON File

JSON Data Format

- **JSON** (JavaScript Object Notation) is a very popular lightweight data format to transform an object to a **text** form to ease storing and transporting data
- **Gson** library could be used to transform an object to json or transform a json string to an object

Transform an instance of Surah class to a JSON string:




```
Gson gson = new Gson();
Surah surah = new Surah(1, "الفاتحة" ,"Al-Fatiha", 7, "Meccan");
String surahJSON = gson.toJson(surah);
```

```
{
    "id": 1,
    "name": "الفاتحة",
    "englishName": "Al-Fatiha",
    "ayaCount": 7,
    "type": "Meccan"
}
```

Read / Write JSON file

- Read a JSON file and convert its content to objects

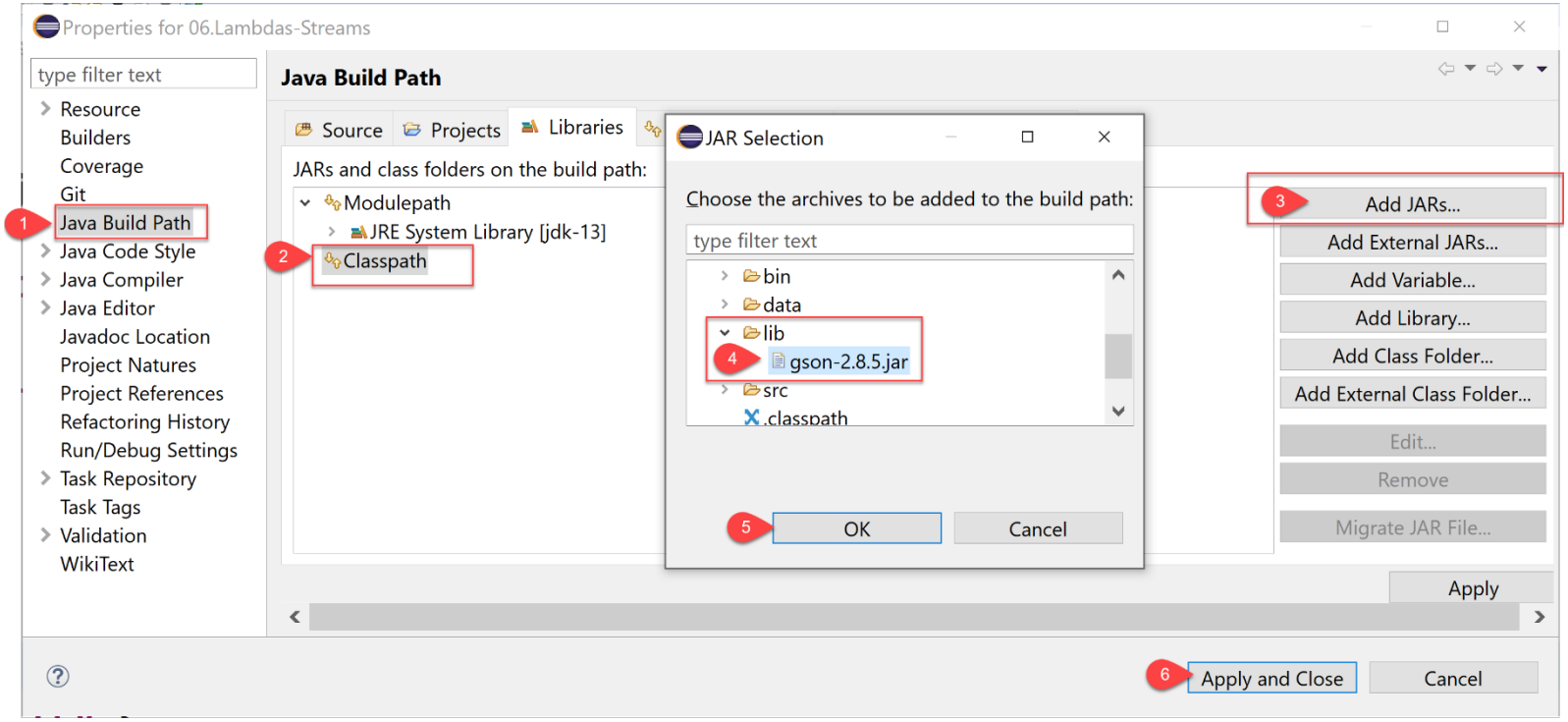
```
Gson gson = new Gson();
String filePath = "data/surah.json";
String fileContent = Files.readString(Paths.get(filePath));
Surah[] surahs = gson.fromJson(fileContent, Surah[].class);
```

- Write objects to a JSON file

```
String surahsJSON = gson.toJson(surahs);
Files.writeString(Paths.get(filePath), surahsJSON);
```

Steps to use Gson library

- Create a subfolder named **lib** under your project folder
- Download **Gson** library into **lib** subfolder
  https://repo1.maven.org/maven2/com/google/code/gson/gson/2.8.5/gson-2.8.5.jar
- Write-click your project and select **`Properties…`**
- Select ***`Java Build Path`***. Click ***`Classpath`*** then click ***`Add JARS…`*** select ***`gson-2.8.5.jar`*** from your project **lib** subfolder (see image below)



Summary

- To start thinking in the functional style ***avoid loops*** and instead use Streams and Lambdas
  - Widely used for list processing and GUI building to handle events
- A list can be converted to a stream for processing in a pipeline
  - Typical pipeline operations are filter, map and reduce
- Parallel processing of streams is possible
- JSON is a very popular lightweight data format to transform an object to a text form to ease storing and transporting data

Summary of Stream Operations

- **Make a Stream**
  - someList.stream(), Stream.of(objectArray), Stream.of(e1, e2…)
- **Collect output from a Stream**
  - stream.collect(Collectors.toList())
  - stream.toArray(ClassName[]::new)
- **forEach** [void output]
  - employeeStream.forEach(e -> e.setPay(e.getPay() * 1.1))
- **map** [outputs a Stream]
  - numStream.map(Math::sqrt)
- **filter** [outputs a Stream]
  - employeeStream.filter(e -> e.getSalary() > 50000)
- **findFirst** [outputs an Optional]
  - stream.findFirst().get(), stream.findFirst().orElse(other)