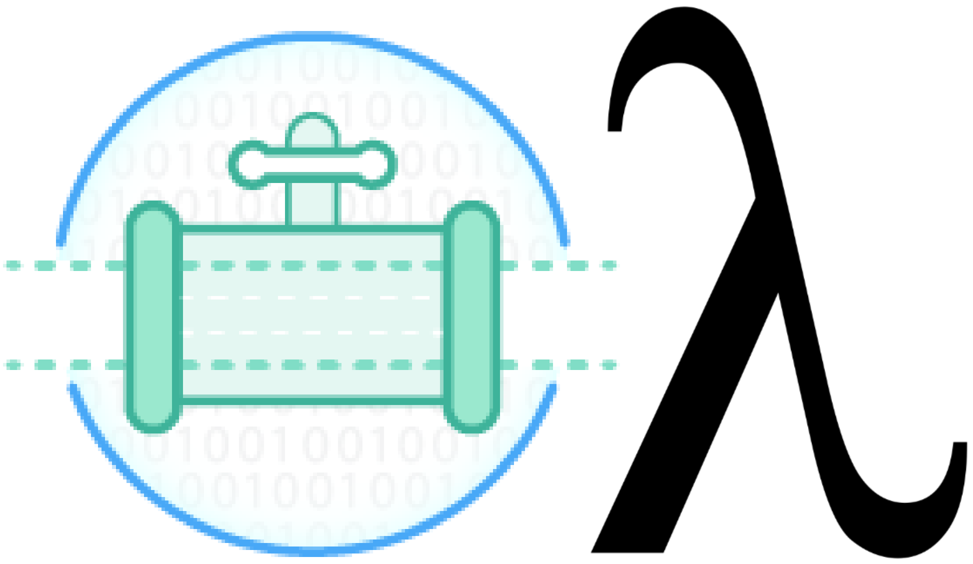
Lambdas and Streams



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The most important principle in Programming?

KEEP IT SHORT & SIMPLE

KISS

Declarative programming using Lambdas allows achieving 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 *simple methods.* It has:
  - A return type
  - Parameters
  - A body
- They don't have a name (anonymous method)
- They have no associated object
- They can be passed as parameters:
  - As *code* to be executed by the receiving method
- Syntax defined (introduced in Java 8) as:

Arrow token

```
Parameters -> Body
```

Lambda Expressions

- Lambda expressions can be used with `filter` and `map` methods :

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

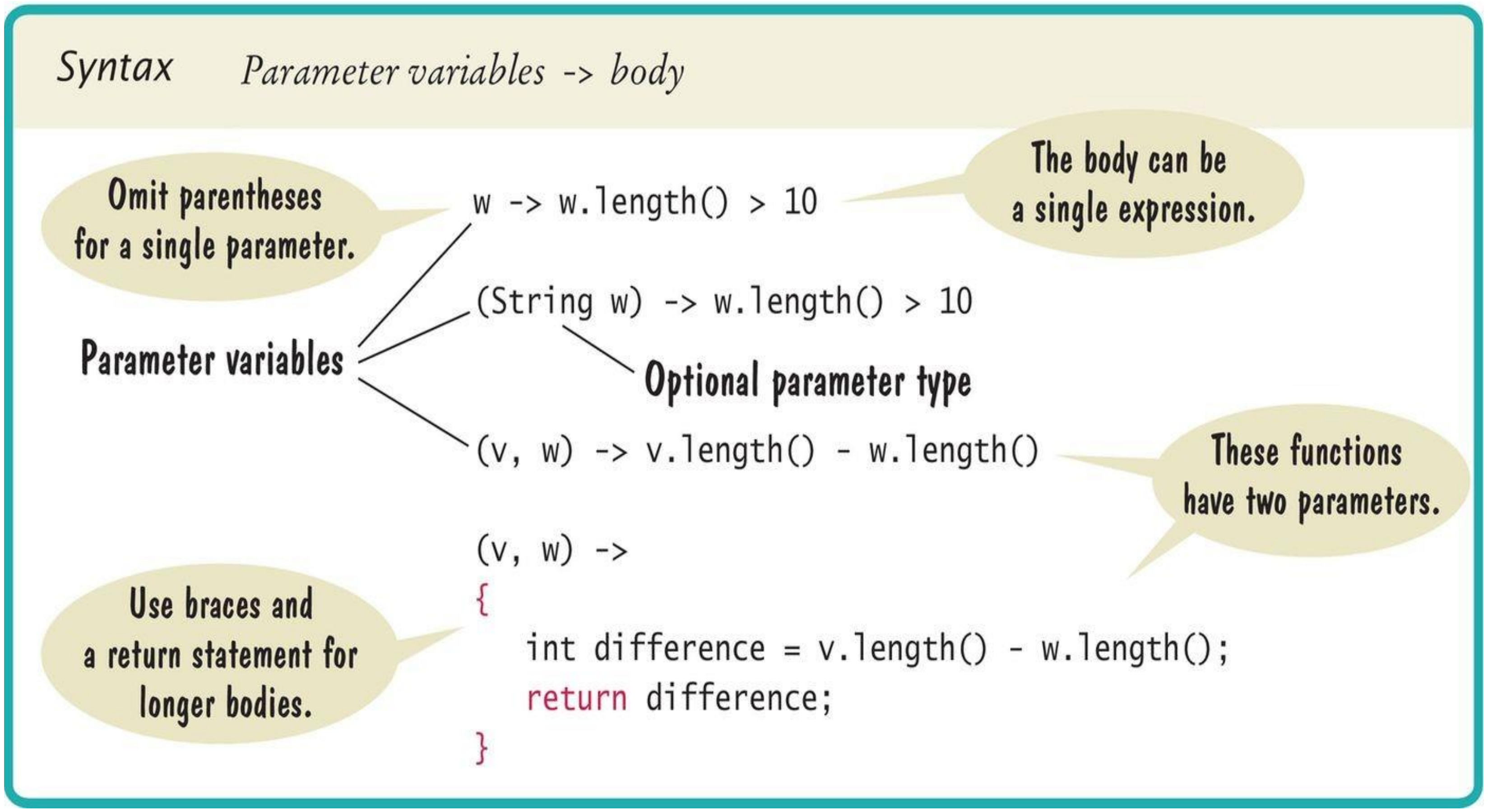
- Left side of `->` operator is a parameter variable.
- Right side is code to operate on the parameter and compute a result.
- When used with a type like `Stream<String>`, compiler can determine type.
- Multiple parameters are enclosed in parentheses:

```
(v, w) -> v.length() - w.length()
```

- This expression can be used with the `sorted` method in the `Stream` class to sort strings by length:

```
Stream<String> sortedWords = distinctWords.sorted( (v, w) -> v.length() - w.length());
   // "a", "how", "much", "wood", "could", "chuck"
```

Syntax Lambda Expressions


Syntax Parameter variables -> body
Omit parentheses for a single parameter.
The body can be a single expression.
Parameter variables
Optional parameter type
These functions have two parameters.
Use braces and a return statement for longer bodies.

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

(String w) -> w.length() > 10

(v, w) -> v.length() - w.length()

(v, w) ->
{
   int difference = v.length() - w.length();
   return difference;
}
```

What is a Stream?

- Stream API is used to process collections of objects.
- A stream is a **sequence** of objects that supports various methods which can be *pipelined* to produce the desired result.
- They don't store their own data
  - The data comes from elsewhere such as List, Arrays or I/O channels (disk or network)
- Can split work over multiple processors.
- Streams were designed to work well with lambda expressions:

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

- Any collection can be turned into a stream:

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

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The Stream Concept

- Algorithm for counting matches:

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

- With the Java 8 stream library:

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

- You tell *what* you want to achieve (Keep the long strings, count them).
- You don't program the *how* (visit each element in turn, if it is long, increment a variable).
- "What, not how" is powerful:
  - Operations can be executed in parallel.

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StreamDemo.java

```java
import java.io.File;
import java.io.IOException;
import java.util.ArrayList;
import java.util.List;
import java.util.Scanner;

public class StreamDemo
{
   public static void main(String[] args) throws IOException
   {
      Scanner in = new Scanner(new File("../countries.txt"));
      // This file contains one country name per line
      List wordList = new ArrayList<>();
      while (in.hasNextLine()) { wordList.add(in.nextLine()); }
      // Now wordList is a list of country names

      // Traditional loop for counting the long words
      long count = 0;
      for (String w : wordList)
      {
         if (w.length() > 10) { count++; }
      }

      System.out.println("Long words: " + count);

      // The same computation with streams
      count = wordList.stream()
         .filter(w -> w.length() > 10)
         .count();

      System.out.println("Long words: " + count);
   }
}
```

Producing Streams

- Several utility methods yield streams:

```
String filename = . . .;
try (Stream<String> lineStream = Files.lines(Paths.get(filename)))
{
   ...
} // File is closed here
```

- You can make infinite streams:

```
Stream<Integer> integers = Stream.iterate(0, n -> n + 1);
```

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

    ```
    Stream<String> parStream = lineStream.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

Back

Filter

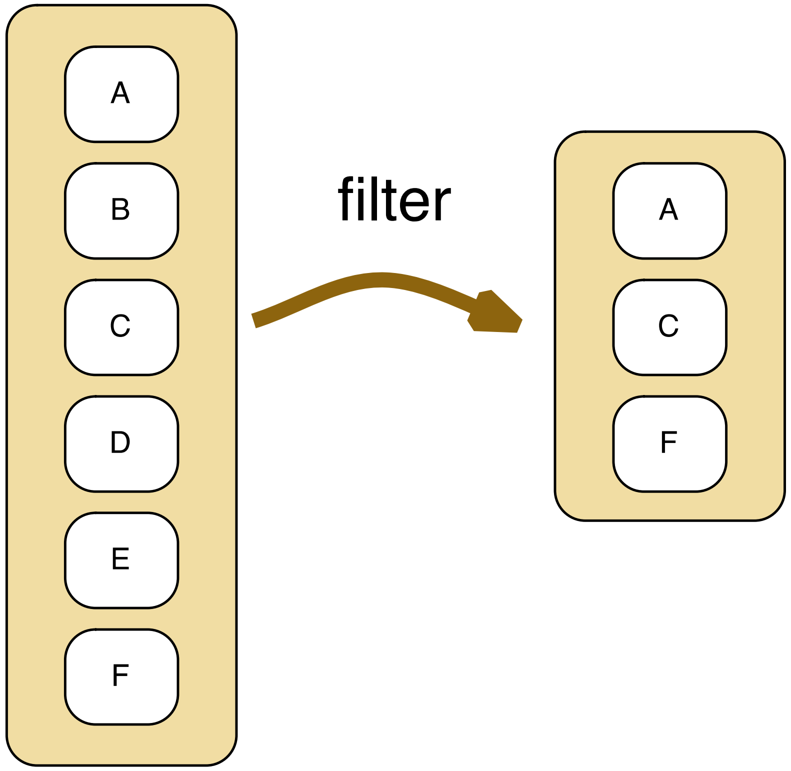
Keep elements that satisfy a condition

```
// Java 7
List<String> result =
  new ArrayList<String>();

for (String str : myList) {
  if (str.length() > 5) {
    result.add(str);
  }
}
```

```
// Java 8
Stream<String> filtered =
  myStream.filter
    (s -> s.length() > 5);
```

Filter



Find

Return one element satisfying a condition

```
// Java 7
String result = null;

for (String str : myList) {
  if (str.length() == 5) {
    result = str;
    break;
  }
}
```

```
// Java 8
Optional<String> result =
  myStream
  .filter
    (s -> s.length() == 5)
  .findAny();
```

Map

Transform elements by applying a Lambda to each element

```
// Java 7
List<Integer> lens =
  new ArrayList<Integer>();

for (String str : myList) {
  lens.add(str.length());
}
```

```
// Java 8
Stream<Integer> lens =
  myStream.map(s -> s.length());
```

Map Examples

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- `map` **transforms** stream by applying function to each element.
- Turn all words into lowercase:

```
Stream<String> words = Stream.of("A", "Tale", "of", "Two", "Cities");
Stream<String> lowerCaseWords = words.map(w -> w.toLowerCase());
// "a", "tale", "of", "two", "cities"
```

- Remove vowels from all words:

```
Stream<String> consonantsOnly = lowerCaseWords.map(  w ->
  w.replaceAll("[aeiou]", ""));
  // "", "tl", "f", "tw", "cts"
```

- Get the length of each element:

```
Stream<Integer> consonantCount = consonantsOnly.map(w -> w.length());
   // 0, 2, 1, 2, 3
```

StreamDemo.java

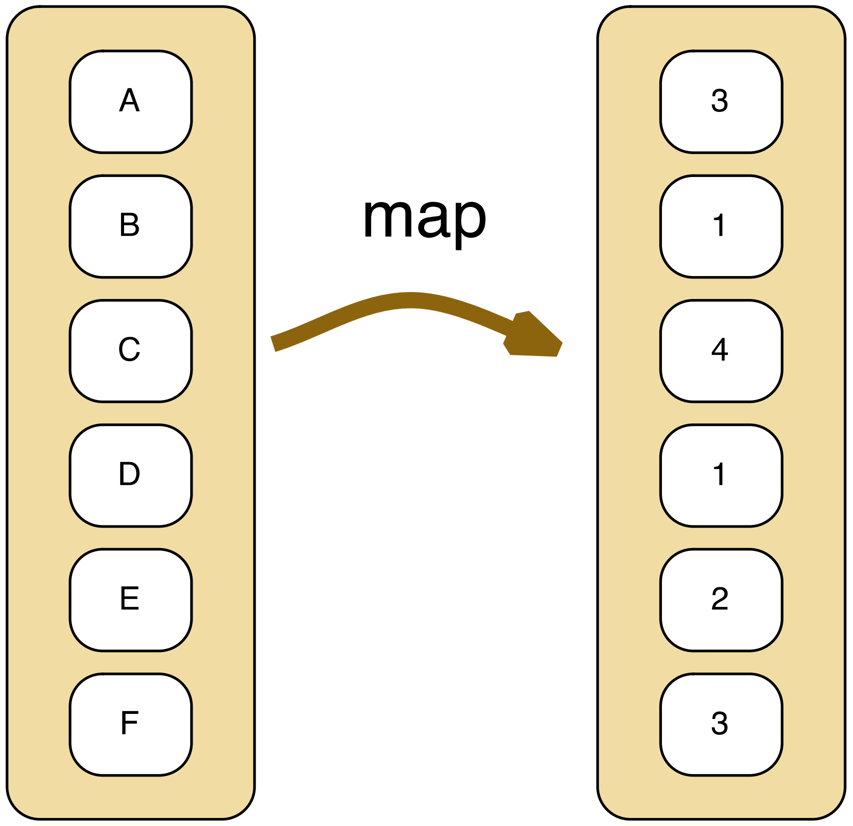
```java
import java.io.IOException;
import java.nio.file.Files;
import java.nio.file.Paths;
import java.util.List;
import java.util.stream.Collectors;
import java.util.stream.Stream;

public class StreamDemo
{
   public static void main(String[] args) throws IOException
   {
      try (Stream lines = Files.lines(Paths.get("../countries.txt")))
      { // Read the lines
         List result = lines
            .filter(w -> w.length() > 10) // Keep only long words
            .map(w -> w.substring(0, 7)) // Truncate to seven characters
            .map(w -> w + "...") // Add ellipses
            .distinct() // Remove duplicates
            .limit(20) // Keep only the first twenty
            .collect(Collectors.toList()); // Collect into a list
         System.out.println(result);
      }
   }
}
```

Program Run:

```
[Afghani..., America..., Antigua..., Bahamas..., Bosnia ...,
British..., Burkina..., Cayman ..., Central..., Christm...,
Cocos (..., Congo, ..., Cook Is..., Cote d'..., Czech R...,
Dominic..., El Salv..., Equator..., Falklan..., Faroe I...]
```

Map



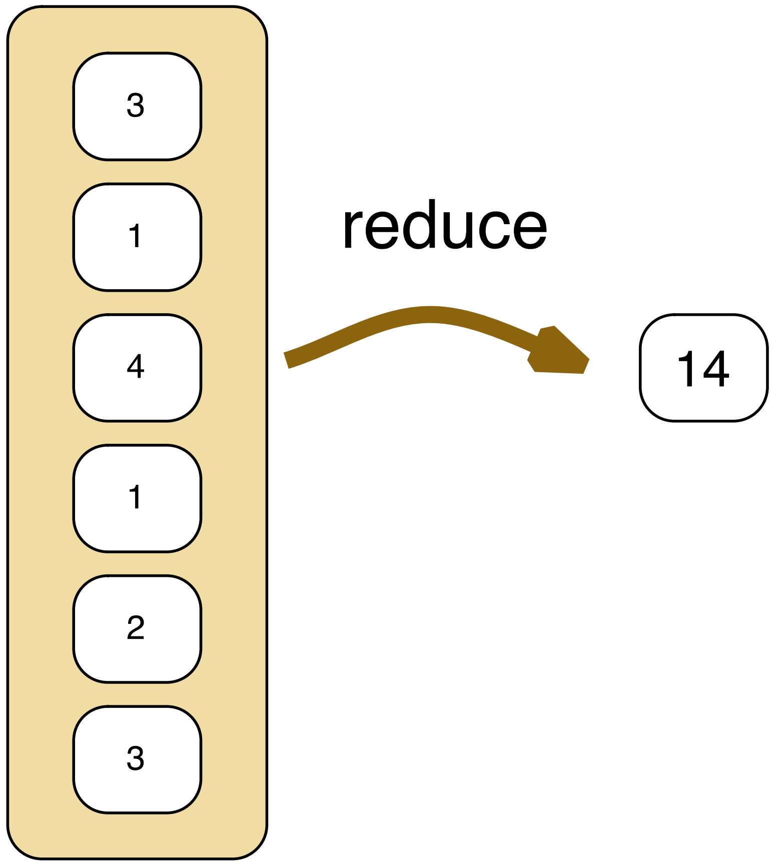
Reduce

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

```
// Java 7
int totalLen = 0;
for (String str : myList) {
  totalLen += str.length();
}
```

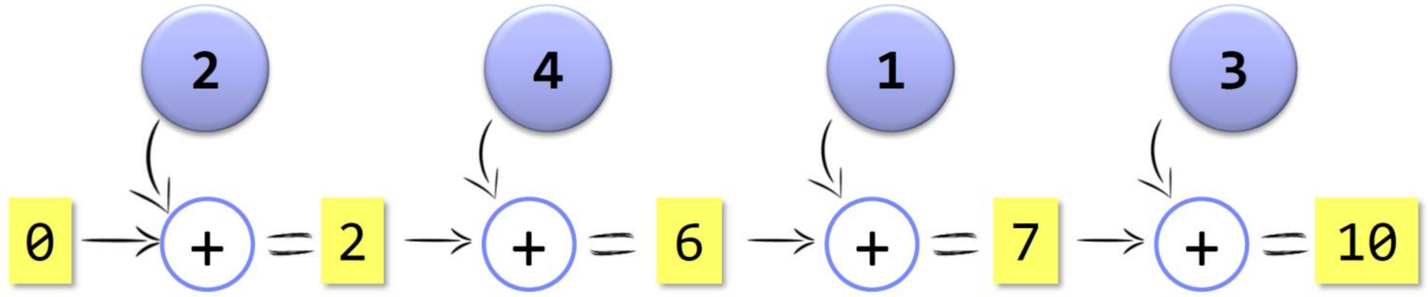
```
// Java 8
int totalLen =
  myStream
  .reduce(0,
   (sum,s) -> sum + s.length());
```

Reduce



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

Reduce



```
.reduce(0, +)
```

The reduce method – a comparative example

```
sightings.stream()
.filter(sighting -> animal.equals(sighting.getAnimal())
.map(sighting -> sighting.getCount())
.reduce(0, (total, count) -> total + count);
```

Initial value

```
int total = 0;
for(Sighting sighting : sightings) {
    if(animal.equals(sighting.getAnimal())) {
        int count = sighting.getCount();
        total = total + count;
    }
}
```

Accumulation

Removal from a collection using a predicate lambda

```
/**
 * Remove from the sightings list all of
 * those records with a count of zero.
 */
public void removeZeroCounts()
{
    sightings.removeIf(
         sighting -> sighting.getCount() == 0);
}
```

Convenience Reducers

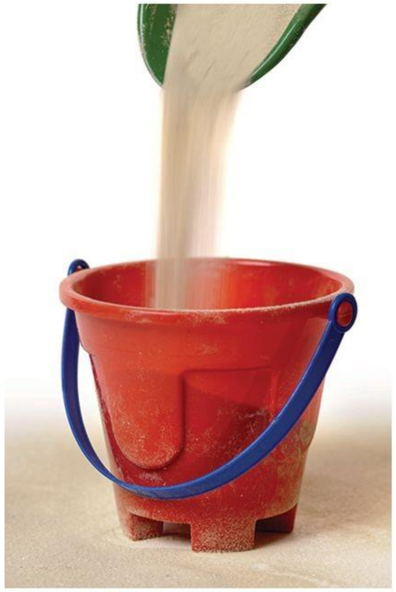
Min, Max, Sum, Average, Count, etc.

```
// Java 7
int totalLen = 0;
for (String str : myList) {
  totalLen += str.length();
}

double avgLen =
  ((double)totalLen)
    / myList.size();
```

```
// Java 8
OptionalDouble avgLen =
  myStream
  .mapToInt
    (s -> s.length())
  .average();
```

Collecting Results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- When you are done transforming a stream (e.g. with `filter`), want to harvest results.
- Some methods (e.g. `count`, `sum`) yield a single value.
- Other methods yield a collection.

- To collect into a `List` or `Set`, use `collect`:

```
List<String> result = stream.collect(Collectors.toList());
Set<String> result = stream.collect(Collectors.toSet());
```

The argument to `collect` is a `Collector` object.

We'll always use one of the static method of `Collectors` to get one.

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

```
String result = words.collect(Collectors.joining(", "));
  // Stream elements separated with commas
```

Flat Map

Do a map and flatten the result by one level

```
// Java 7
List<Character> chars =
  new ArrayList<Character>();

for (String str : myList) {
  for(char ch : str.toCharArray()){
    chars.add(ch);
  }
}
```

```
// Java 8
Stream<Character> chars =
  myStream
  .flatMapToInt
    (s -> s.chars())
  .mapToObj(i -> (char) i);
```

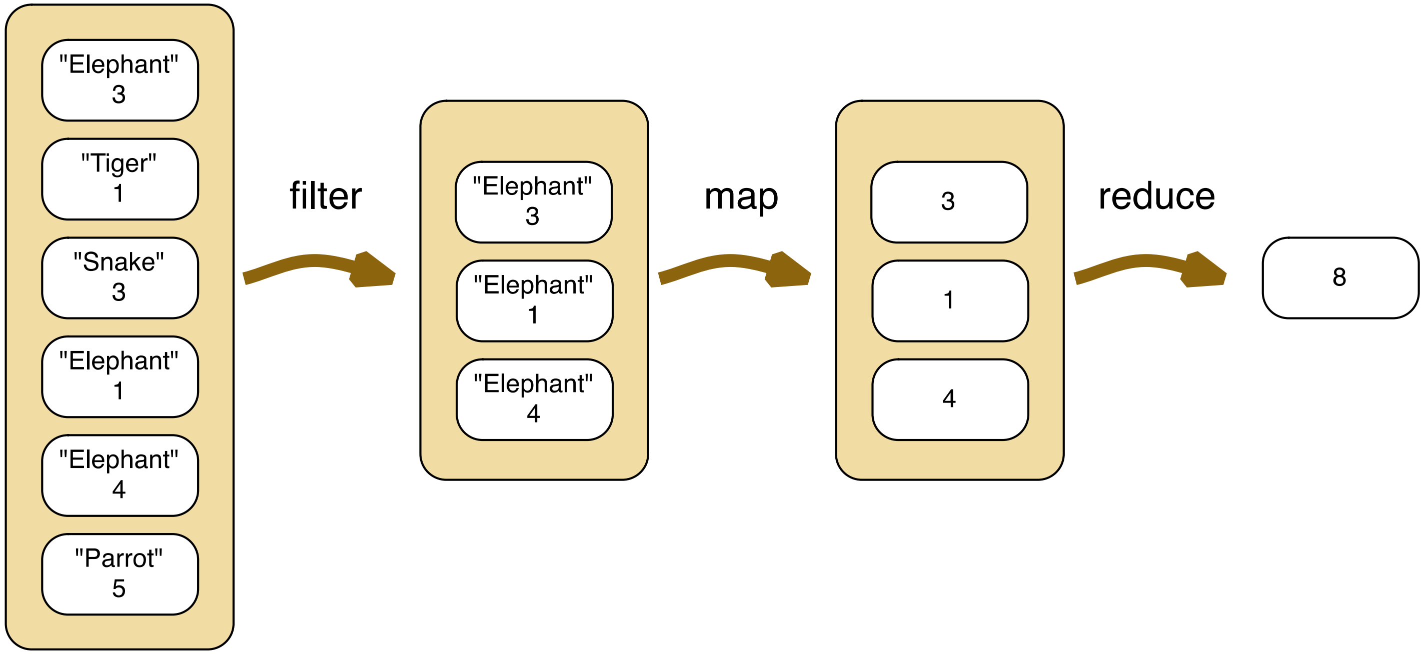
Sorting

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

Java 8

```
Stream<String> result =
  myStream
  .sorted(
     Comparator.comparing(String::length)
    .reversed()
    .thenComparing(
      Comparator.naturalOrder()
    )
  );
```

A pipeline of operations



```
filter(name is elephant).map(count).reduce(add up)
```

Pipelines

- Pipelines start with a source
- Operations are either:
  - Intermediate, or
  - Terminal
- **Intermediate operations** produce a new stream as output
- **Terminal operations** are the final operation in the pipeline

Tip: One Stream Operation Per Line

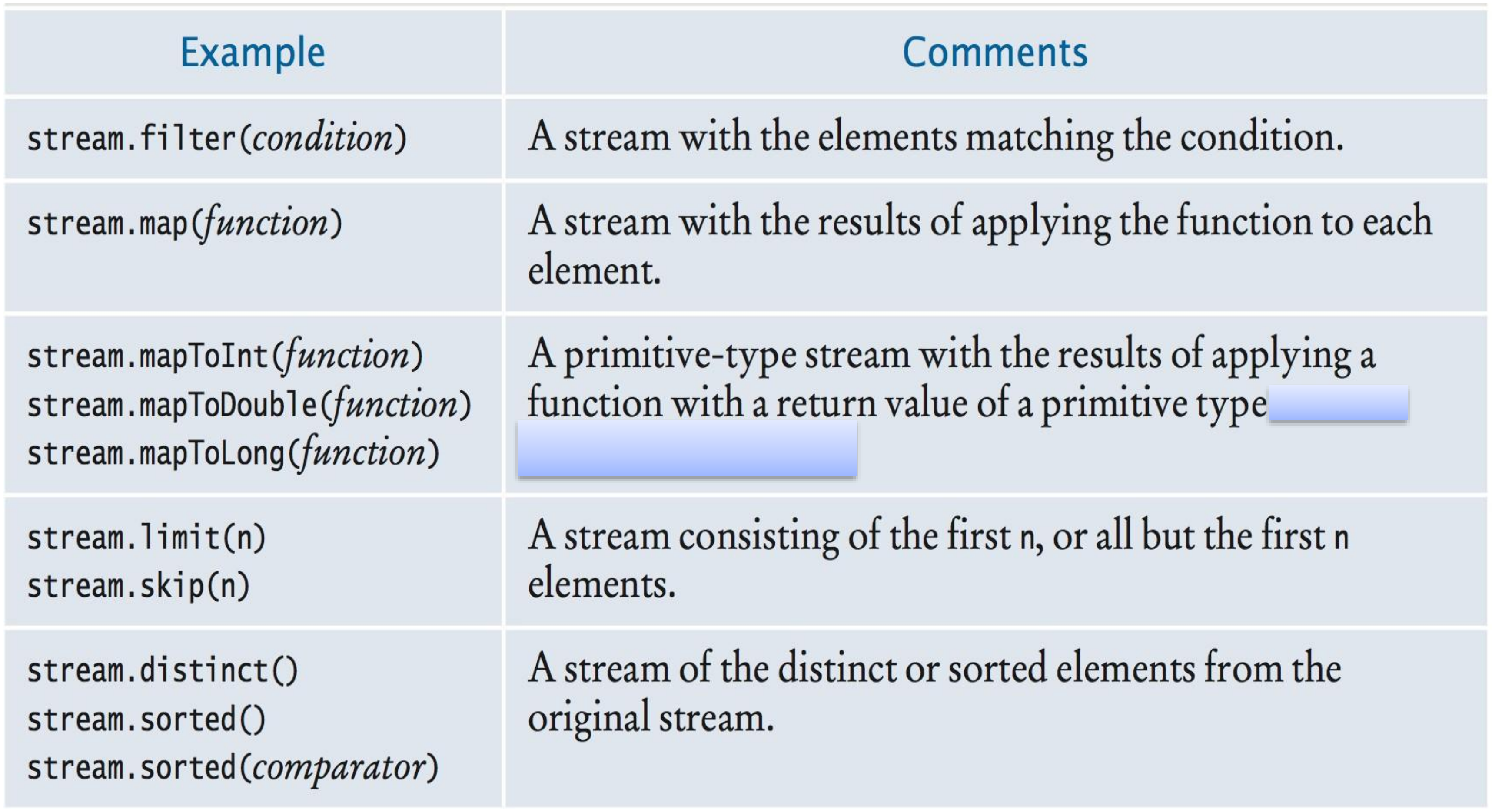
- It's best to put one stream operation per line:

```
List<String> result = list.stream() //Create the stream
  .filter(w -> w.length() > 10) // Keep long strings
  .limit(50) // Keep only the first fifty.
  .collect(Collectors.toList()); // Turn into a list
```

- If you cram as much as possible into one line, it is tedious to figure out the steps:

```
List<String> result = list.stream().filter(w -> w.length() > 10).limit(50)
.collect(Collectors.toList()); // Don’t use this formatting style
```

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 [redacted]

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.

More Stream Transformations

- Applying `map` yields a stream with the same number of elements.
- `filter` only retains matching elements:

```
Stream<String> aWords = words.filter(w -> w.substring(0, 1).equals("a"));
  // Only the words starting with "a"
```

- `limit` takes the first `n`:

```
Stream<String> first100aWords = aWords.limit(100);
```

- `skip` takes all but the first `n`:

```
Stream<String> allButFirst100aWords = aWords.skip(100);
```

- `distinct` yields a stream with duplicates removed:

```
Stream<String> words = Stream.of(
  "how much wood could a wood chuck chuck".split(" "));
Stream<String> distinctWords = words.distinct();
  // "how", "much", "wood", "could", "a", "chuck"
```

- `sorted` yields a new stream in which the elements are sorted

sorted:

```
            Stream<String> sortedWords =
              distinctWords.sorted();
  // "a", "chuck", "could", "how", "much", "wood"
```

Element type must be `Comparable`

Or supply a comparator: `distinctWords.sorted((s, t) -> s.length() - t.length())`

How to start thinking in the functional style

- Avoid “for” loops
  - If you find yourself using one, there’s probably a better way to do what you want.
- Use fewer variables
  - See if you can connect multiple steps together into an expressive “chain” of method calls.
- Avoid “side effects”
  - When you run a function, it shouldn’t inadvertently change the value of its input or some other variable.

Summary

- Streams and lambdas are an important and powerful Java feature
- A collection 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
- Widely used for collection processing and other areas particularly GUI building to handle events