



OSTBAYERISCHE
TECHNISCHE HOCHSCHULE
REGENSBURG

INFORMATIK UND
MATHEMATIK

Streams and Lambdas in Java 8

Working Environment

- Integrated Development Environment (IDE)
- JDK 8



Integrated Development Environments

NetBeans

NetBeans by Oracle

<https://netbeans.org/downloads/>

Any bundle will do
current version: 8.1

Eclipse

by Eclipse Foundation (formerly by IBM)

<http://www.eclipse.org/downloads/>

current version: Eclipse Mars (4.5); with Neon available
Choose bundle „...Java EE Developers“
or „...Java Developers“

IDEA

IntelliJ IDEA by JetBrains (commercial)

<https://www.jetbrains.com/idea/>

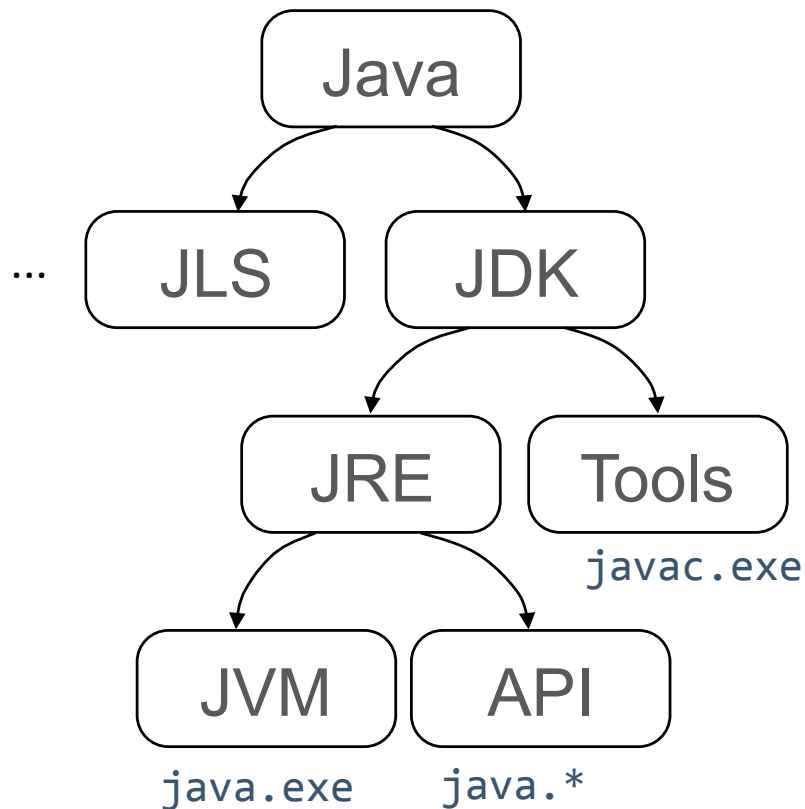
current version: 15

Students can get „Ultimate Edition“ for free

See <https://www.jetbrains.com/student/>



JDK 1.8 (JDK 8)



```
$ java -version
```

```
java version "1.8.0_65"
```

```
Java(TM) SE Runtime  
Environment (build 1.8.0_65-  
b17)
```

```
Java HotSpot(TM) 64-Bit  
Server VM (build 25.65-b01,  
mixed mode)
```



Dependency Management with Maven

Manage dependencies to 3rd party recursively and have your project build automatically

e.g. use Google Guava Libraries by simply adding one dependency.

The screenshot shows an IDE window with a Maven `pom.xml` file open. The left sidebar shows the project structure, including the `Dependencies` section where `guava-19.0.jar` is listed. The main editor displays the following XML code:

```
6 <version>0.1</version>
7 <packaging>jar</packaging>
8 <dependencies>
9   <dependency>
10     <groupId>com.google.guava</groupId>
11     <artifactId>guava</artifactId>
12     <version>19.0</version>
13   </dependency>
14 </dependencies>
15 <properties>
16   <project.build.sourceEncoding>UTF-8</project.build.sourceEncoding>
17   <maven.compiler.source>1.8</maven.compiler.source>
18   <maven.compiler.target>1.8</maven.compiler.target>
19 </properties>
20 </project>
```

The bottom panel shows the build output for a test run:

```
run:
Eve John Andrew default 8
60
static 1234
BUILD SUCCESSFUL (total time: 0 seconds)
```

Basics Revisited

- Interfaces
- Collections Framework
- Anonymous Inner Classes



Interfaces

“Ordinary” interfaces

Marker interfaces (e.g. `Serializable` or `Runnable`)

Functional interfaces (annotated with `@FunctionalInterface`)

`@interface` classes (Annotations)

New in Java 8:

static methods

default methods

Default methods¹

“A default method is a method that is declared in an interface with the `default` modifier; its body is always represented by a block. It provides a default implementation for any class that implements the interface without overriding the method. Default methods are distinct from concrete methods (§8.4.3.1), which are declared in classes.”

¹[Gosling 2015, p. 288]

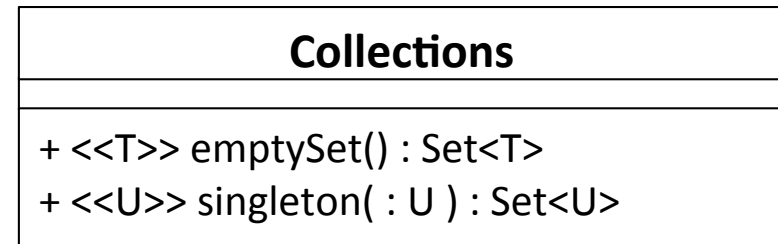
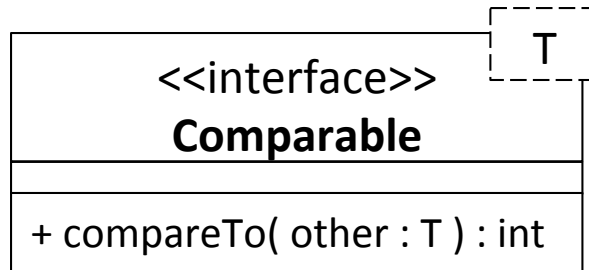


Generics with <>

Generic class:

Generic method:

Definition



```
public interface Comparable<T> {
    public int compareTo(T other);
}
```

```
public class Collections {
    public <T> Set<T> singleton(T obj)
    { ... }
}
```

Usage

```
class Student
implements Comparable<Person>
{
    public int compareTo(Person other)
    {
        // ...
    }
}
```

```
Set<String> name =
    Collections.singleton("Max");

Set<Person> persons =
    Collections.<Person>emptySet();
```




Collections Framework

Two things to remember:

1. There are Lists, Sets, and Maps:

```
List<T>:           ArrayList<T> or LinkedList<T>
Set<T>:           TreeSet<T> or HashSet<T>
Map<K, V>:        TreeMap<K, V> or HashMap<K, V>
```

2. Use “loosly coupled” references:

```
List<String> = new ArrayList<>();
```

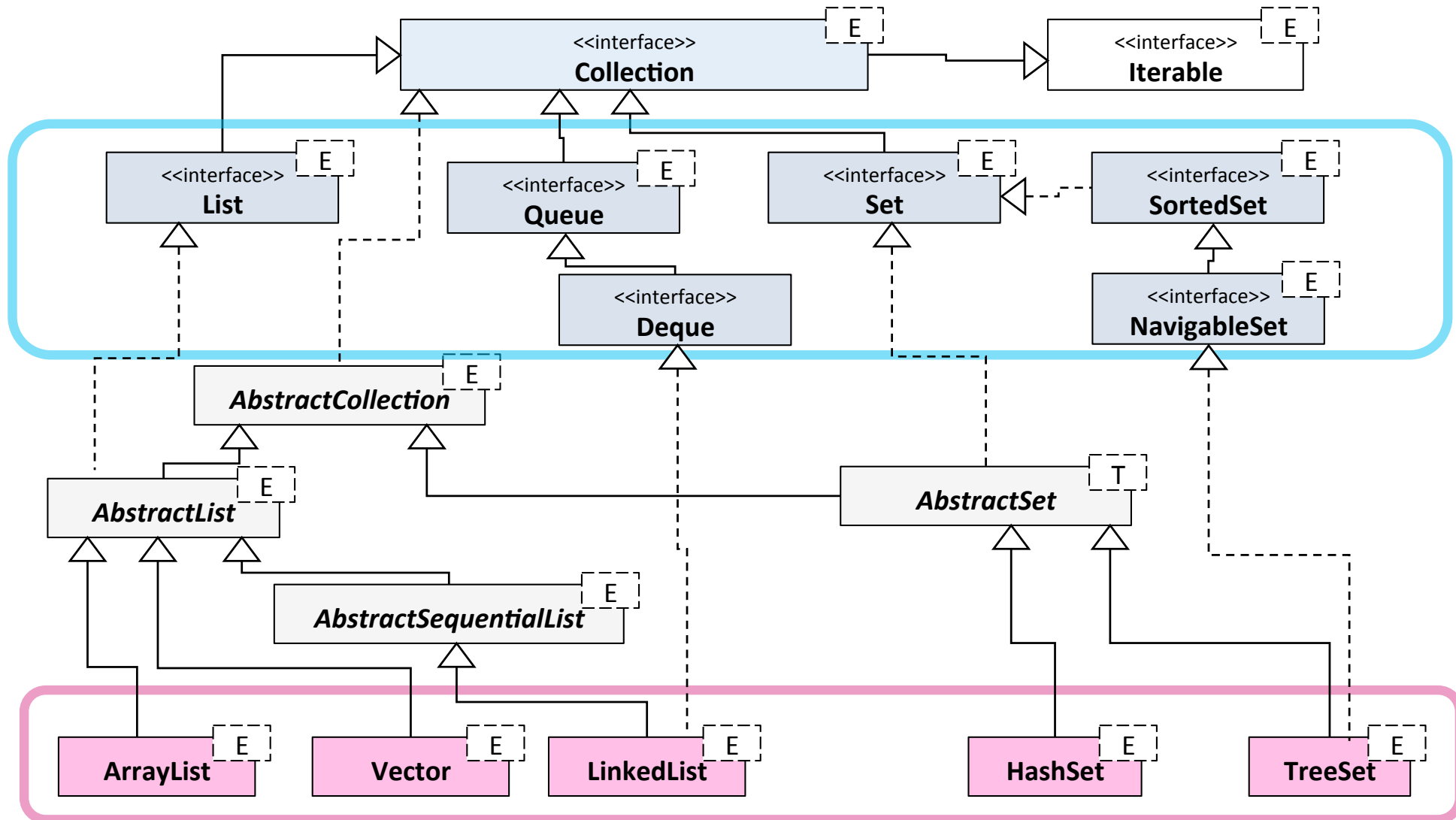
Collections Framework¹

“The collections framework is a unified architecture for representing and manipulating collections, enabling them to be manipulated independently of the details of their representation. It reduces programming effort while increasing performance. [...]”

¹[Oracle Corp. 2016]

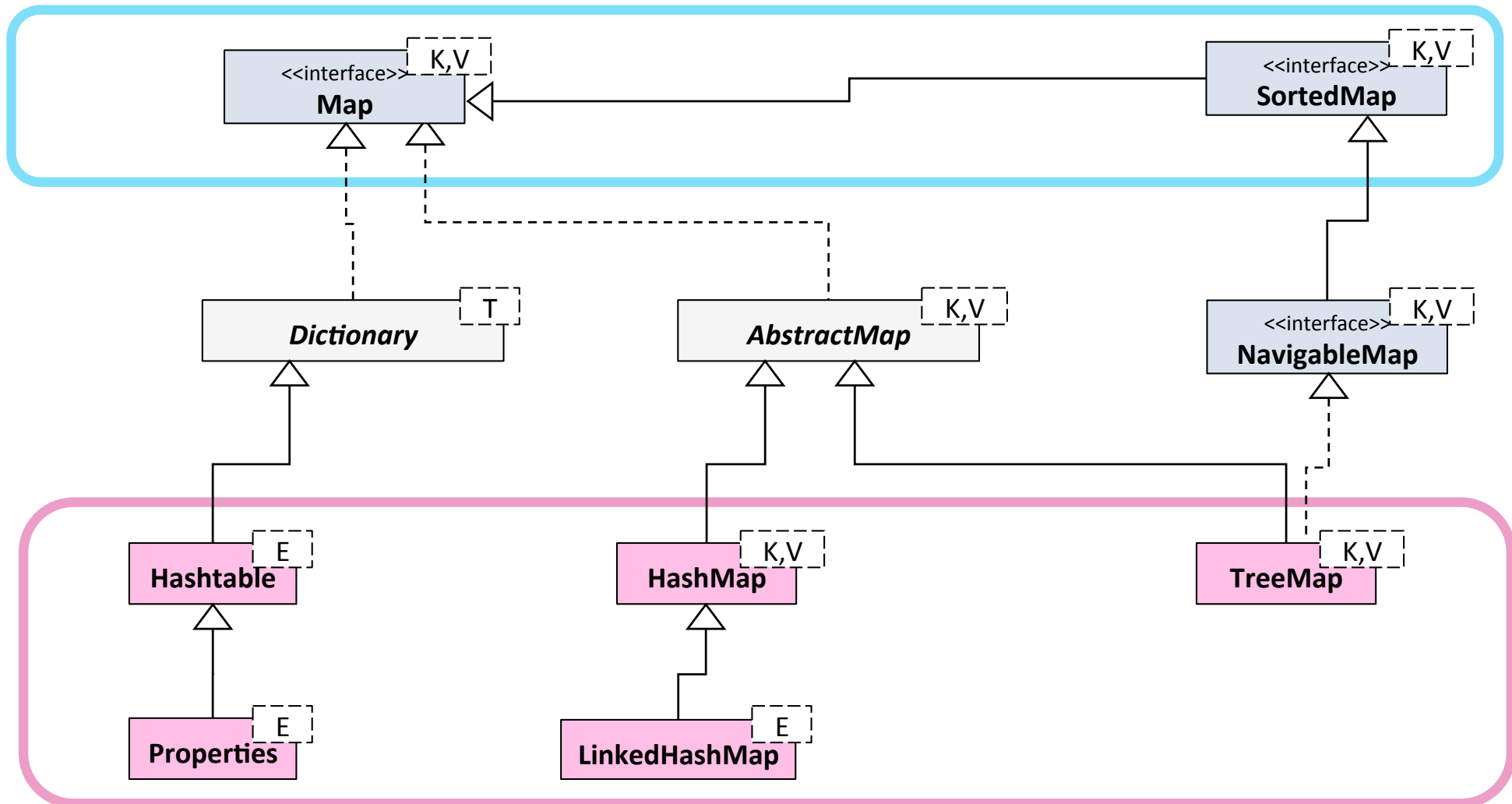


Collection interfaces (abridged)





Map interfaces (abridged)





Utilities in class Collections

```
public static void reverse(List<?> list)
public static <E> Collection<E> checkedCollection(Collection<E> c,
                                                    Class<E> type)
public static <T> List<T> nCopies(int n, T o)
public static int frequency(Collection<?> c, Object o)
public static void shuffle(List<?> list)
public static void rotate(List<?> list, int distance)
public static void reverse(List<?> list)
public static <T> boolean replaceAll(List<T> list, T oldVal, T newVal)
public static <T> T min(Collection<? extends T> coll,
                       Comparator<? super T> comp)

// others:
Arrays.asList(Object... o)
Arrays.stream(T[] array)
Stream.of(T[] array)
```



Anonymous Inner Classes

```
public interface Comparator<T> { int compare (T obj1, T obj2); }
```

```
public class Collections {  
    public static <T> void sort(List<T> l, Comparator<? super T> c)  
    {...}  
}
```

```
List<String> names = Arrays.asList("John", "Andrew", "Eve");
```

```
Collections.sort(names, new Comparator<String>() {  
    @Override public int compare(String s1, String s2) {  
        return Integer.compare(s1.length(), s2.length());  
    }  
});
```

```
for(String name : names) System.out.print(name + " ");  
// Eve John Andrew
```

Streams



Streams

A stream is “[...] a **sequence of elements** from a **source** that supports **aggregate operations**”:¹

- **“Sequence of elements:** A stream provides an interface to a sequenced set of values of a specific element type. However, streams don’t actually store elements; they are computed on demand.
- **Source:** Streams conamounte from a data–providing source such as collections, arrays, or I/O resources.
- **Aggregate operations:** Streams support SQL–like operations and common operations from functional proگرامing languages, such as filter, map, reduce, find, match, sorted, and so on.”

¹[Urma (2014a), section “Getting Started With Streams”]



Streams

- are not data structure
- do not contain storage for data
- are “pipelines” for streams of data (i.e. of objects)
- while in the pipeline data undergo transformation (without changing the data structure holding it)
- wrap collections (lists, set, maps)
- read data from it
- work on copies



How do data get into streams?

Streams are mainly generated based on collections:

```
List<String> names = Arrays.asList("John", "George", "Sue");  
  
Stream<String> stream1 = names.stream();  
  
Stream<String> stream2 = Stream.of("Tom", "Rita", "Mae");  
  
Stream<String> stream3;  
stream2 = Arrays.stream( new String[]{"Lisa", "Max", "Anna"} );
```

Or with builder pattern:

```
Stream<String> stream4 = Stream.<String>builder()  
    .add("Mike")  
    .add("Sandra").build();
```



How do data get out of streams?

- The Streaming API provides so called “finalizing” methods (i.e. methods that do not return stream objects)

```
forEach  
toArray  
collect  
reduce  
min  
max  
count  
anyMatch  
noneMatch  
findFirst  
findAny
```



Streaming example

“Take all names from the stream that start with the letter “J”, map the names into capital letters, skip one, and collect them into a new set”

```
List<String> names = Stream.of("John", "George", "Joe", "Sue", "James");  
  
Stream<String> stream1 = names.stream();  
  
_____ = stream1.filter( _____ )  
                .map( _____ )  
                .skip( _____ )  
                .collect( _____ );
```

Lambda Expressions and Functional Interfaces

- Lambdas
- Functional Interfaces



Lambdas or Closures

“Lambda” = “closure” = record storing a function (functionality, method) and its environment (but without a class or method name)

Roughly: anonymous method

Lambdas represent source code – not data and not object state!

Syntax:

```
( parameter list ) -> { expression(s) }
```

Examples:

```
(int x, int y) -> { return x + y; }
```

```
(long x) -> { return x * 2; }
```

```
() -> { String msg = "Lambda"; System.out.println(msg); }
```

For details on “functional programming” cf. [Huges 1984] or [Turner 2013]



Lambdas and functional interfaces

Functional interfaces are so called *SAM* types (single abstract method)

A functional interface has exactly one abstract method, e.g. `Runnable`, `Comparator<T>`, or `Comparable<T>`

Functional interfaces can define 0..* default methods and 0..* static methods

Using the `@FunctionalInterface` annotation on classes the compiler is required to generate an error message if it is no interface and it doesn't define exactly one SAM.

```
@FunctionalInterface
public interface Counter<T> {
    int count(T obj);
}
```

```
Counter<String> strCount = (String s) -> { return s.length(); };
```

[<https://docs.oracle.com/javase/8/docs/api/java/lang/FunctionalInterface.html>]



Your first lambda with Comparator<T>

```
@FunctionalInterface
public interface Comparator<T> { int compare(T obj1, T obj2); }
```

```
public class Collections {
    public static <T> void sort(List<T> l, Comparator<? super T> c)
    {...}
}
```

Your task:

Prepare your first lambda expression to compare two String objects by length

```
List<String> names = Arrays.asList("John", "Andrew", "Eve");
Collections.sort(names,      ???? );
for(String name : names) System.out.print(name + " ");
// Eve John Andrew
```



Functional interfaces in JDK

Selection of most used interfaces from package `java.util.function`:

```
// Computes a single input with no result
public interface Consumer<T> {
    void accept(T t);
    default Consumer<T> andThen(Consumer<? super T> after) {...}
}

// Represents a supplier of results.
interface Supplier<T> {
    T get();
}

// Computes a single output, produces output of different type
interface Function<T,R> {
    R apply(T t);
    default <V> Function<T,V> andThen(Function<? super R,? extends V> after) {...}
    default <V> Function<V,R> compose(Function<? super V,? extends T> before) {...}
}

// Represents a predicate (boolean-valued function) of one argument
interface Predicate<T> {
    boolean test(T t);
    default Predicate<T> and(Predicate<? super T> other) {...}
    default Predicate<T> negate() {...}
    // ...
}
```

BiConsumer<T,U>
BiFunction<T,U,R>
BinaryOperator<T>
BiPredicate<T,U>
BooleanSupplier
Consumer<T>
DoubleBinaryOperator
DoubleConsumer
DoubleFunction<R>
DoublePredicate
DoubleSupplier
DoubleToIntFunction
DoubleToLongFunction
DoubleUnaryOperator
Function<T,R>
IntBinaryOperator
IntConsumer
IntFunction<R>
IntPredicate
IntSupplier
IntToDoubleFunction
IntToLongFunction
IntUnaryOperator
LongBinaryOperator
LongConsumer
LongFunction<R>
LongPredicate
LongSupplier
LongToDoubleFunction
LongToIntFunction
LongUnaryOperator
ObjDoubleConsumer<T>
ObjIntConsumer<T>
ObjLongConsumer<T>
Predicate<T>
Supplier<T>
ToDoubleBiFunction<T,U>
ToDoubleFunction<T>
ToIntBiFunction<T,U>
ToIntFunction<T>
ToLongBiFunction<T,U>
ToLongFunction<T>
UnaryOperator<T>

[<https://docs.oracle.com/javase/8/docs/api/java/util/function/package-amountmary.html>]



Type inference

Lambda expressions allow for minimal syntax if compiler can deduct type information (so called *type inference*), e.g.:

```
@FunctionalInterface
public interface BiFunction<T, U, R> {
    R apply(T t, U u);
}
```

R = Integer could be inferred from return type of expression `t.Length() + u.Length()` → Integer (e.g. when used directly in typed method call)

```
BiFunction<String, Object, Integer> bf;
bf = (String txt, Object obj) -> { return t.length() + u.hashCode(); }
// can be even shorter:
bf = (txt, obj) -> t.length() + u.hashCode(); // se below
```

compiler can infer types from declaration of f

Further syntax shortening examples:

for single return statements keyword return together with {}-pair can be dropped

```
(int x, int y) -> { return x * y; } // shorter: (x, y) -> x * y
(long x) -> { return x * 2; } // shortest: x -> x * 2
```

()-pair can be dropped with only one parameter



Lambda as parameters and return types

Further examples for type inference using `Comparator<T>` as functional interface:

```
List<String> names = Arrays.asList("Ahab", "George", "Sue");
Collections.sort(names, (s1, s2) -> s1.length() - s2.length() );
```

T :: String can be deducted from names being a List<String>

Signature of Collections::sort method is:

```
public static <T> void sort(List<T> list, Comparator<? super T> c)
```

```
Collections.sort(names, createComparator() );
```

```
public Comparator<String> createComparator() {
    return (s1, s2) -> s1.length() - s2.length();
}
```

Statement returned here is of functional interface type Comparator<String>



Method references (“function pointers”)

Syntax: `Classname::methodName` `objectReferenceName::methodName`

Lambdas can be replaced by method references whenever there would not further actions within the the lambda

Examples:

Reference	Method reference...	...replacing Lambda
static method	<code>String::valueOf</code>	<code>obj -> String.valueOf(obj)</code>
instance method (via class)	<code>String::compareTo</code>	<code>(s1, s2) -> s1.comapreTo(s2)</code>
instance method (via object ref)	<code>person::getName</code>	<code>() -> person.getName()</code>
Constructor	<code>ArrayList::new</code>	<code>() -> new ArrayList<>()</code>

[Table taken from Inden 2015, p. 812]

Streaming API

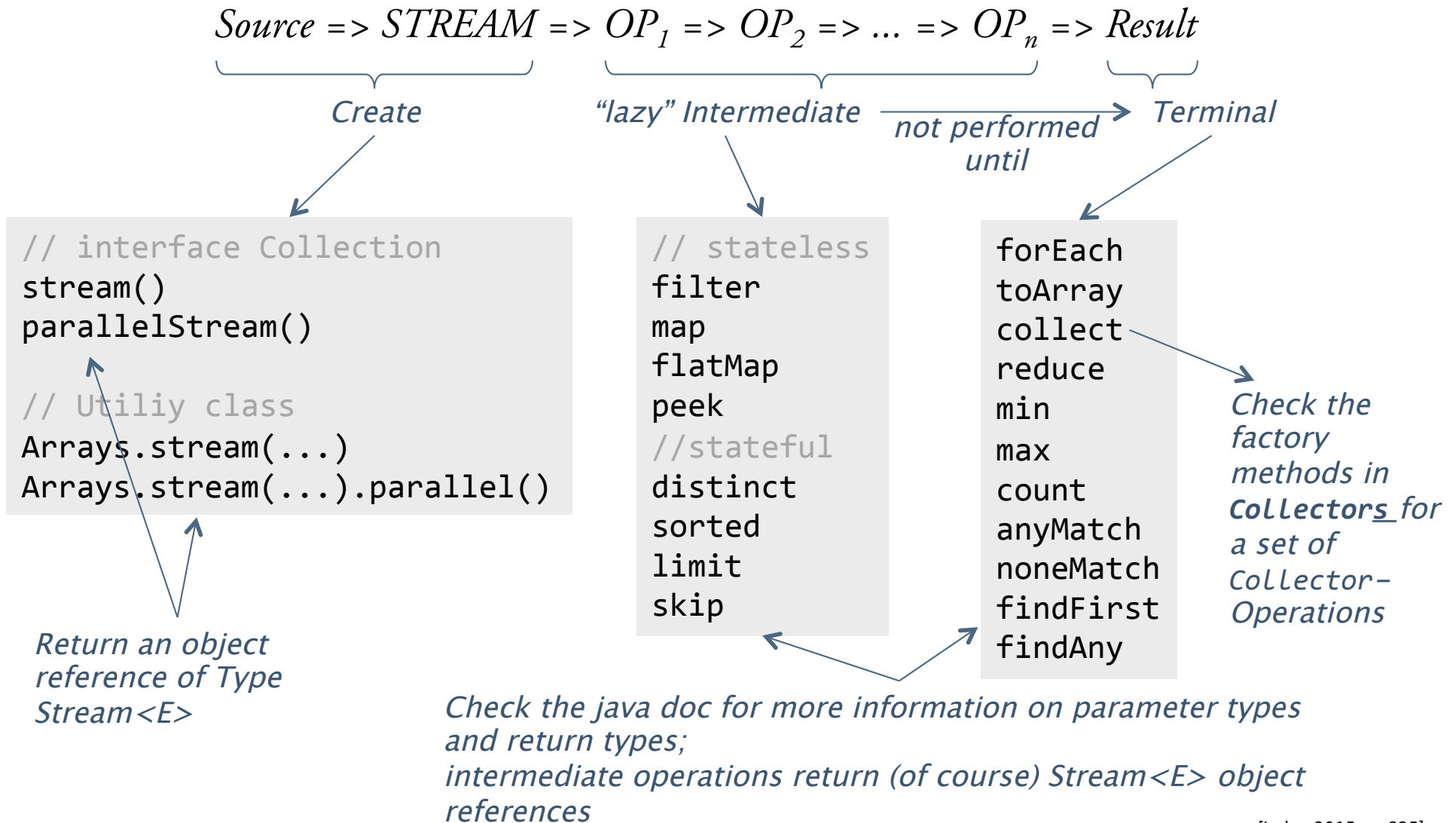
- Creating Streams
- Fluently working with streams
- Finalize Streams



Stream ops I use most



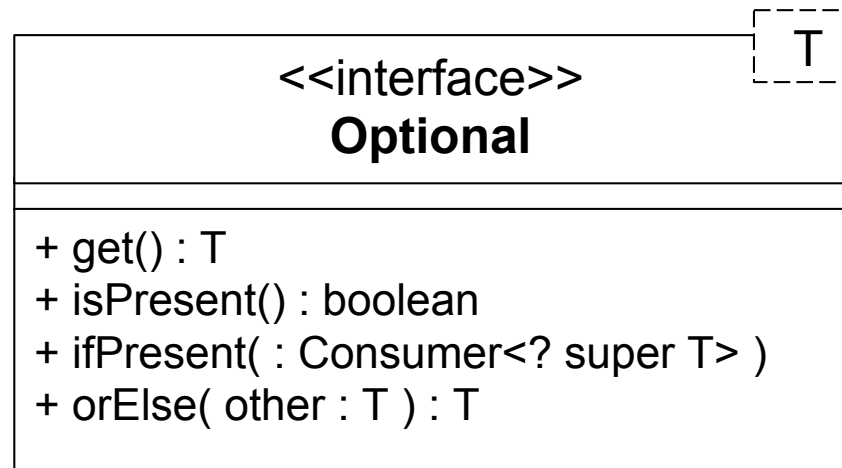
Stream operations





Class Optional<T>

The class `Optional<T>` is a container wrapped around an object and is useful if you do not know whether its content is `null` or not (e.g. when using in fluent programming style).





Example

“old fashioned”

```
List<Transaction> groceryTransactions = new ArrayList<>();
for(Transaction t : transactions){
    if(t.getType() == Transaction.GROCERY) {
        groceryTransactions.add(t);
    }
}
Collections.sort(groceryTransactions, new Comparator(){
    @Override
    public int compare(Transaction t1, Transaction t2){
        return t2.getValue().compareTo(t1.getValue());
    }
});
List<Integer> transactionIds = new ArrayList<>();
for(Transaction t : groceryTransactions) {
    transactionIds.add(t.getId());
}
```

Stream like

```
List<Integer> transactionIds =
    transactions.stream()
        .filter(t -> t.getType() == Transaction.GROCERY)
        .sorted(comparing(Transaction::getValue).reversed())
        .map(Transaction::getId)
        .collect(toList());
```

[taken from Urma (2014a)]

Bibliography



Gosling, J. et al. (2015): The Java® Language Specification – Java SE 8 Edition, March 2015, <http://docs.oracle.com/javase/specs/jls/se8/jls8.pdf>

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Turner, D. (2013): Some History of Functional Programming Languages. In: Loidl, H.–W. and Pena, R.: *Trends in Functional Programming: 13th International Symposium, TFP 2012, St. Andrews, UK, June 12–14, 2012, Revised Selected Papers*, p. 1–20. Springer: Berlin and Heidelberg

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