# Programming in Java – Streams

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# Agenda

Streams

Specialized streams

Optional

Advanced stream operations

Collectors

# Streams

*represent a sequence of elements from a source that supports data-processing operations*

*supports internal iteration*

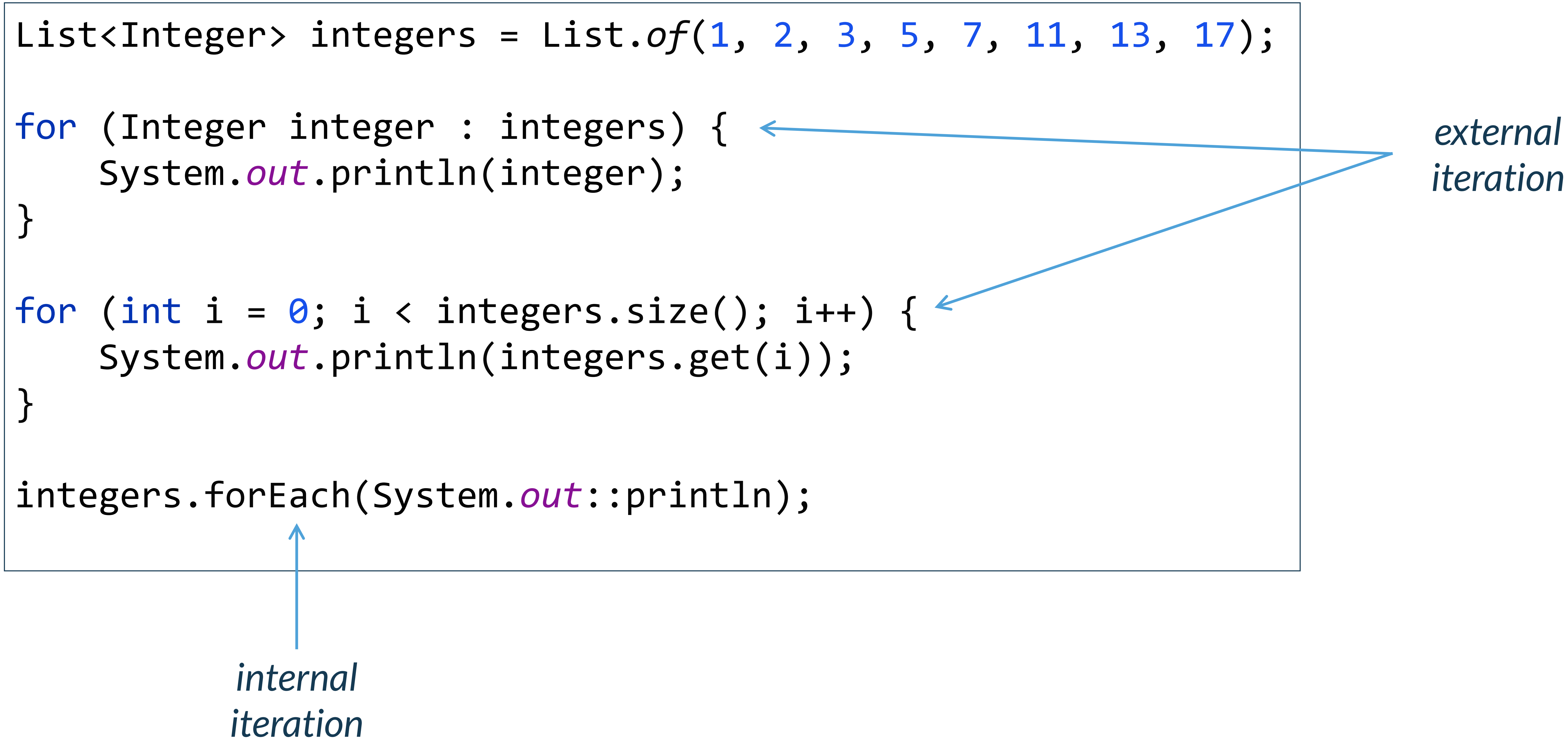
*streams*

*can be used to traverse collections*

*traversable only once*

*potentially unlimited in size*

# External/internal iteration



```
List<Integer> integers = List.of(1, 2, 3, 5, 7, 11, 13, 17);

for (Integer integer : integers) {
    System.out.println(integer);
}

for (int i = 0; i < integers.size(); i++) {
    System.out.println(integers.get(i));
}

integers.forEach(System.out::println);
```

*external iteration*

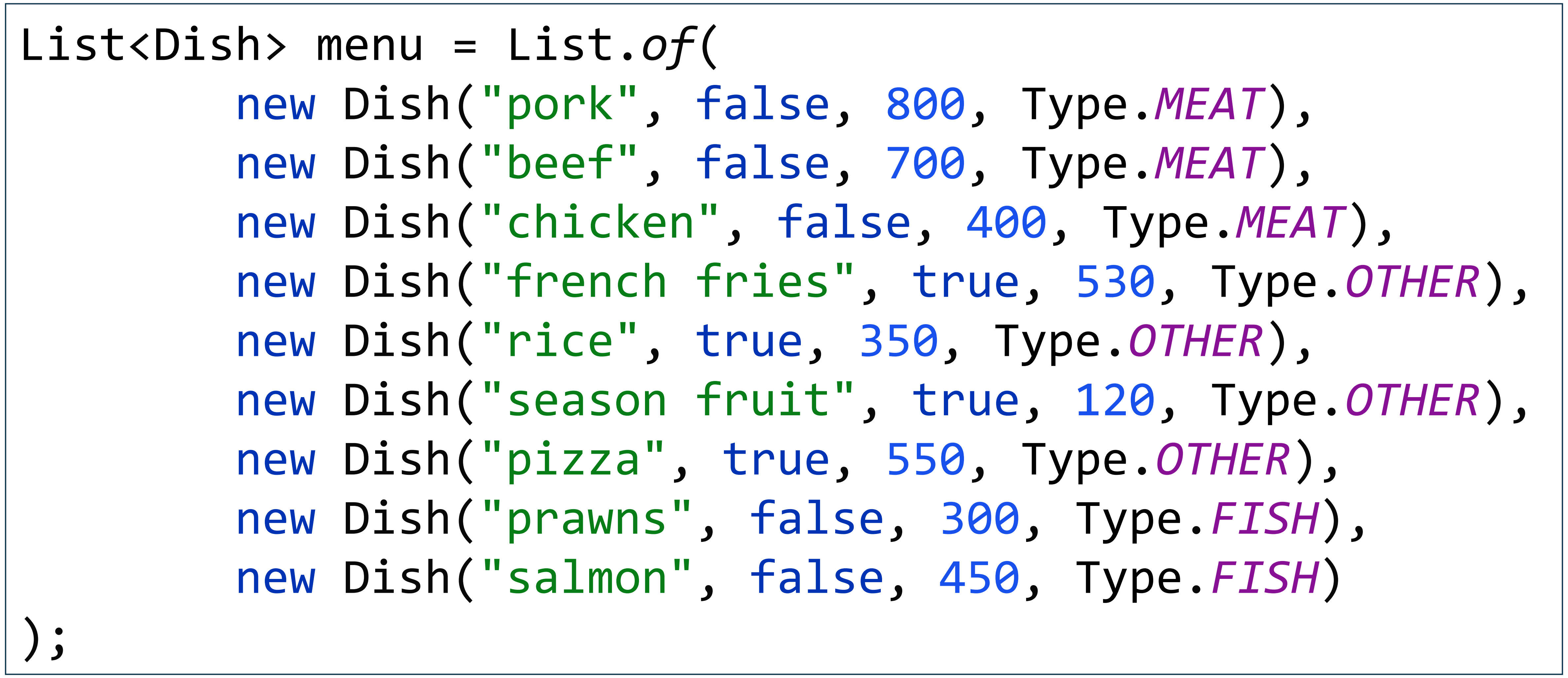
*internal iteration*

```java
public class Dish {

    public enum Type {MEAT, FISH, OTHER}

    private final String name;
    private final boolean vegetarian;
    private final int calories;
    private final Type type;

    public Dish(String name, boolean vegetarian, int calories, Type type) {
        this.name = name;
        this.vegetarian = vegetarian;
        this.calories = calories;
        this.type = type;
    }

    public String getName() {return name; }

    public boolean isVegetarian() {return vegetarian; }

    public int getCalories() {return calories; }

    public Type getType() { return type; }

    @Override
    public String toString() {
        return name;
    }
}
```

# Exercise

*Given a list of Dishes, create the list of dishes with less than 400 calories and sort them by the number of calories*

# The data



```
List<Dish> menu = List.of(
        new Dish("pork", false, 800, Type.MEAT),
        new Dish("beef", false, 700, Type.MEAT),
        new Dish("chicken", false, 400, Type.MEAT),
        new Dish("french fries", true, 530, Type.OTHER),
        new Dish("rice", true, 350, Type.OTHER),
        new Dish("season fruit", true, 120, Type.OTHER),
        new Dish("pizza", true, 550, Type.OTHER),
        new Dish("prawns", false, 300, Type.FISH),
        new Dish("salmon", false, 450, Type.FISH)
);
```

# The “imperative” solution

*Intermediate data*

```
List<Dish> lowCaloricDishes = new ArrayList<>();
for (Dish dish : menu) {
    if (dish.getCalories() < 400) {
        lowCaloricDishes.add(dish);
    }
}
Collections.sort(lowCaloricDishes, new Comparator<>() {
    public int compare(Dish dish1, Dish dish2) {
        return Integer.compare(dish1.getCalories(), dish2.getCalories());
    }
});
List<String> lowCaloricDishesName = new ArrayList<>();
for (Dish dish : lowCaloricDishes) {
    lowCaloricDishesName.add(dish.getName());
}
```

```
[season fruit, prawns, rice]
```

# The “declarative” solution

```
List<String> lowCaloricDishesName =
        menu.stream()
                .filter(d -> d.getCalories() < 400)
                .sorted(Comparator.comparing(Dish::getCalories))
                .map(Dish::getName)
                .collect(Collectors.toList());
```

```
[season fruit, prawns, rice]
```

*The last “operator” decides the return type of the method chain*

*When we use the Stream API, we make a continuous use of lambdas and method references, but lambdas and method references are not part of that API!*

# Traversable only once

*This is OK!*

```
Stream<Integer> s1 = Stream.of(12, 34, 55);
Stream s2 = s1.filter(x -> x > 30);
s2.forEach(System.out::println);
```

*This is not OK!!!!*

```
Stream<Integer> s1 = Stream.of(12, 34, 55);
s1.filter(x -> x > 30);
s1.forEach(System.out::println);
```

# Terminal and intermediate operators

```
Stream<String> s1 = Stream.of("Mariapia", "Enrico", "Stefano");

List<String> list1 = s1.filter(x -> x.startsWith("M"))
                                      .collect(Collectors.toList());

list1.forEach(System.out::println);
```

Intermediate
operator

Terminal operators

# Terminal and intermediate operators

```
Stream<String> s1 = Stream.of("Mariapia", "Enrico", "Stefano");
Stream<Integer> s2 = Stream.of(12, 34, 55);

System.out.println(s1.count());

List<Integer> list1 = s2.filter(x -> x > 30)
                        .filter(x -> x % 2 == 0)
                        .distinct()
                        .collect(Collectors.toList());

list1.forEach(System.out::println);
```

*Execution starts with the terminal operator*

# Other intermediate operators

```
Stream<String> s1 = Stream.of("Mariapia", "Enrico", "Stefano");

List<String> list1 = s1.filter(x -> x.length() > 2)
                       .limit(2)
                       .skip(1)
                       .collect(Collectors.toList());

list1.forEach(System.out::println);
```

# Some intermediate & terminal operators

| Operation | Type | Return type | Argument of the operation | Function descriptor |
|---|---|---|---|---|
| `filter` | *Intermediate* | `Stream<T>` | `Predicate<T>` | `T -> boolean` |
| `map` | *Intermediate* | `Stream<R>` | `Function<T, R>` | `T -> R` |
| `limit` | *Intermediate* | `Stream<T>` | `int` | |
| `skip` | *Intermediate* | `Stream<T>` | `int` | |
| `sorted` | *Intermediate* | `Stream<T>` | `Comparator<T>` | `(T, T) -> int` |
| `distinct` | *Intermediate* | `Stream<T>` | | |
| `forEach` | *Terminal* | `void` | `Consumer<T>` | `T -> void` |
| `count` | *Terminal* | `long` | | |
| `collect` | *Terminal* | *(generic)* | `Collector<T, A, R>` | *not a functional interface* |

# More slicing operators

```
Stream<Integer> s1 = Stream.of(12, 34, 55);
s1.takeWhile(x -> x < 50)
    .forEach(System.out::println);

Stream<Integer> s2 = Stream.of(12, 34, 55);
s2. dropWhile(x -> x < 50)
    .forEach(System.out::println);
```

*the stream should be ordered in the right way*

# Optional values

```
Stream<Integer> s2 = Stream.of(12, 34, 55);

Optional<Integer> value = s2.filter(x -> x > 30)
                            .filter(x -> x % 2 == 0)
                            .findFirst();

value.ifPresent(System.out::println);
```

*Please note that findFirst() returns an optional. Why?*

# Optional values

```
Stream<Integer> s2 = Stream.of(12, 34, 55);

Optional<Integer> value = s2.filter(x -> x > 30)
                            .filter(x -> x % 2 == 0)
                            .findAny();

value.ifPresent(System.out::println);
```

*findAny() is better for parallel execution. Why?*

# Other final operators

```
Stream<Integer> s1 = Stream.of(12, 34, 55);
boolean value1 = s1.allMatch(x -> x > 2);

Stream<Integer> s2 = Stream.of(12, 34, 55);
boolean value2 = s2.anyMatch(x -> x > 2);

Stream<Integer> s3 = Stream.of(12, 34, 55);
boolean value3 = s3.noneMatch(x -> x > 2);
```

*these operators implement short-circuit behavior*

# Mapping

```
List<String> dishNames = menu.stream()
        .map(Dish::getName)
        .collect(Collectors.toList());
```

*Map each dish to its name*

```
[pork, beef, chicken, french fries, rice, season fruit, pizza, prawns, salmon]
```

```
List<String> dishNames = menu.stream()
        .map(Dish::getName)
        .map(String::toUpperCase)
        .collect(Collectors.toList());
```

*Map each dish to its uppercase name*

```
[PORK, BEEF, CHICKEN, FRENCH FRIES, RICE, SEASON FRUIT, PIZZA, PRAWNS, SALMON]
```

```
List<Integer> dishNameLengths = menu.stream()
        .map(Dish::getName)
        .map(String::length)
        .collect(Collectors.toList());
```

*Map each dish to its name length*

```
[4, 4, 7, 12, 4, 12, 5, 6, 6]
```

# Creating a stream

*many possibilities*

```
List<String> list1 = Arrays.asList("Stefano", "Mariapia", "Enrico");
List<String> list2 = Arrays.asList(("Nina", "Jan", "Tinkara");

list1.stream().count();

HashSet<String> set1 = new HashSet<>();
set1.stream().count();

Stream s1 = Stream.empty();
Stream s2 = Stream.of(list1, list2);
```

# Numeric streams

*created with range() and rangeClosed()*

```
IntStream ints1 = IntStream.range(0, 10);
System.out.println(
      ints1.filter(x -> x % 2 == 0).count()
);

IntStream ints2 = IntStream.rangeClosed(0, 10);
System.out.println(
      ints2.filter(x -> x % 2 == 0).count()
);
```

# Numeric streams

*created by mapping from other streams*

```
Stream<Integer> s1 = Stream.of(12, 34, 34, 55, 102);
System.out.println(
        s1.mapToInt(x -> x + 1).sum()
);

Stream<Integer> s2 = Stream.of(12, 34, 34, 55, 102);
System.out.println(
        s2.mapToInt(x -> x + 1).max()
);
```

*however…*

# Numeric streams

*be careful with max() and min() !*

```
Stream<Integer> s2 = Stream.of(12, 34, 34, 55, 102);

OptionalInt value = s2.mapToInt(x -> x + 1).min();
value.ifPresent(System.out::println);
```

*Note the specialized Optional definition*

# Other stream creation options

```
int [] a = {1, 2, 3};
System.out.println(Arrays.stream(a).sum());

LongStream st1 = LongStream.iterate(2, x -> x * x);
long []b = st1.limit(5).toArray();

Arrays.stream(b).forEach(System.out::println);

Stream.generate(Math::random)
      .limit(5)
      .forEach(System.out::println);
```

*What about the length of these streams?*

# The flatMap operator

```
int[] c = IntStream.rangeClosed(0, 2)
                   .flatMap(x -> IntStream.rangeClosed(0, 2)
                                           .map(y -> x + y))
                   .toArray();

List<Integer> m2 = Stream.of(Arrays.asList(1,2,3), Arrays.asList(4,5,6))
                            .flatMap(x -> x.stream())
                            .collect(Collectors.toList());
```

# peek()

*Stream<T>* **peek**(*Consumer<? super T> action*)

*produces a stream after applying the operation*

*only for debugging!*

```
OptionalInt value = IntStream.of(1, 2, 3, 4)
        .peek(x -> System.out.println("processing: " + x))
        .filter(n -> n % 2 == 0)
        .peek(y -> System.out.println("accepted " + y))
        .findFirst();
```

# Other map flavors

*produces a stream of primitive types*

```
DoubleStream mapToDouble(ToDoubleFunction<? super T> mapper)
IntStream mapToInt(ToIntFunction<? super T> mapper)
LongStream mapToLong(ToLongFunction<? super T> mapper)
```

```
List<String> list6 = Arrays.asList("Mariapia", "Teresa");

int sum = list6.stream()
                    .mapToInt(String::length)
                    .sum()
```

# Other map flavors

*can change the type of a stream of primitive types*

*IntStream* **map***(IntUnaryOperator mapper)*
*DoubleStream* **mapToDouble***(IntToDoubleFunction mapper)*
*LongStream* **mapToLong***(IntToLongFunction mapper)*
*Stream<T>* **mapToObj***(IntFunction<? extends T> mapper)*

```
List<Integer> list7 = IntStream.rangeClosed(1, 10)
        .mapToObj(x -> x * 2)
        .collect(Collectors.toList());
```

# boxed()

*converts a specialized stream into a Stream with boxed values*

```
List<Integer> list8 = IntStream
      .rangeClosed(1, 10)
      .boxed()
      .collect(Collectors.toList());
```

# unordered(), parallel() and sequential()

*unordered() transforms the stream from sequential to unordered*

*parallel() determines a parallel mode for execution of the stream*

*sequential() determines a sequential mode for execution of the stream*

# unordered(), parallel() and sequential()

*parallel processing example*

```
List<Integer> list8 = IntStream.rangeClosed(1, 10)
      .boxed()
      .collect(Collectors.toList());

List<Integer> list9 = list8.stream()
      .unordered()
      .parallel()
      .peek(x -> System.out.println(Thread.currentThread()
                                              .getName()))
      .map(x -> x + 1)
      .collect(Collectors.toList());
```

# unordered(), parallel() and sequential()

*what happens here?*

```
List<Integer> list8 = IntStream.rangeClosed(1, 10)
        .boxed()
        .collect(Collectors.toList());

List<Integer> list9 = list8.stream()
        .unordered()
        .parallel()
        .peek(x -> System.out.println(Thread.currentThread()
                                                    .getName()))
        .sequential()
        .map(x -> x + 1)
        .collect(Collectors.toList());
```

# unordered(), parallel() and sequential()

*the stream has a single execution mode!*

# forEachOrdered()

*processes the elements in the order specified by the stream, independently if the stream is executed serial or parallel*

```
IntStream.rangeClosed(1, 100)
    .parallel()
    .map(x -> x + 1)
    .forEachOrdered(System.out::println);
```

# FlatMap

*The flatMap method replaces each value of a stream with another stream and then concatenates all the generated streams into a single stream.*

```
String result = menu.stream()
        .map(Dish::getName)
        .map(name -> name.split(""))
        .flatMap(Arrays::stream)
        .distinct()
        .collect(Collectors.joining(", "));

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

```
p, o, r, k, b, e, f, c, h, i, n,  , s, a, u, t, z, w, l, m
```

# A bit more about flatMap()

*these two examples are equivalent*

```
List<String> list13 = Arrays.asList("Mariapia", "Teresa");

list13.stream()
      .map(x -> x.length())
      .forEachOrdered(System.out::println);

list13.stream()
      .flatMap(x -> Stream.of(x.length()))
      .forEachOrdered(System.out::println);
```

# A bit more about flatMap()

*get, for each number x in the input stream, the pair (x, 2*x)*

```
List<Integer> list8 = IntStream.rangeClosed(1, 10)
        .boxed()
        .collect(Collectors.toList());

list8.stream()
        .map(x -> new int[]{x, 2 * x})
        .forEach(x -> System.out.println(x[0] + ", " + x[1]));
```

# A bit more about flatMap()

*it can also be implemented as*

```
list8.stream()
      .flatMap(x -> Stream.of(x, 2 * x))
      .forEach(System.out::println);
```

*or even better*

```
IntStream.rangeClosed(1, 10)
      .flatMap(x -> IntStream.of(x, 2 * x))
      .forEach(System.out::println);
```

# A bit more about flatMap()

*create a single stream from two lists*

```
Stream.of(list11, list12)
        .flatMap(x -> x.stream())
       .forEachOrdered(System.out::println);
```

# A bit more about flatMap()

*combining values from two streams*

```
list11.stream()
    .flatMap(x -> list12.stream()
        .flatMap(y -> Stream.of(x, y)))
    .forEachOrdered(x -> System.out.print(x + " "));
```

# reduce()

*combine the elements of a stream repeatedly to produce a single value*

*summation*

```
int tot = list15.stream()
                        .reduce(0, (x, y) -> x + y);
```

*product*

```
int tot = list15.stream()
                        .reduce(1, (x, y) -> x * y);
```

# reduce()

*it can be also written as*

```
int tot3 = list15.stream()
                   .reduce(0, Integer::sum);
```

*note that the initial value can be omitted*

```
Optional<Integer> tot4 = list15.stream()
                                 .reduce((x,y) -> x + y);
```

# reduce()

*calculate the minimum*

```
Optional<Integer> tot5 = list15.stream()
                                        .reduce((x, y) -> x < y ? x : y);
```

*other possibility*

```
Optional<Integer> tot6 = list15.stream()
                                        .reduce(Integer::min);
```

# reduce()

*what about concatenation of strings?*

```
List<String> list16 = Arrays.asList("Stefano", "Mariapia", "Enrico");
String str = list16.stream().reduce("", (x,y) -> x + y);
```

*other possibility:*

```
String str2 = books
    .stream()
    .collect(Collectors
        .reducing("titles: ", Book::getTitle, (x, y) -> x + y));
```

# reduce

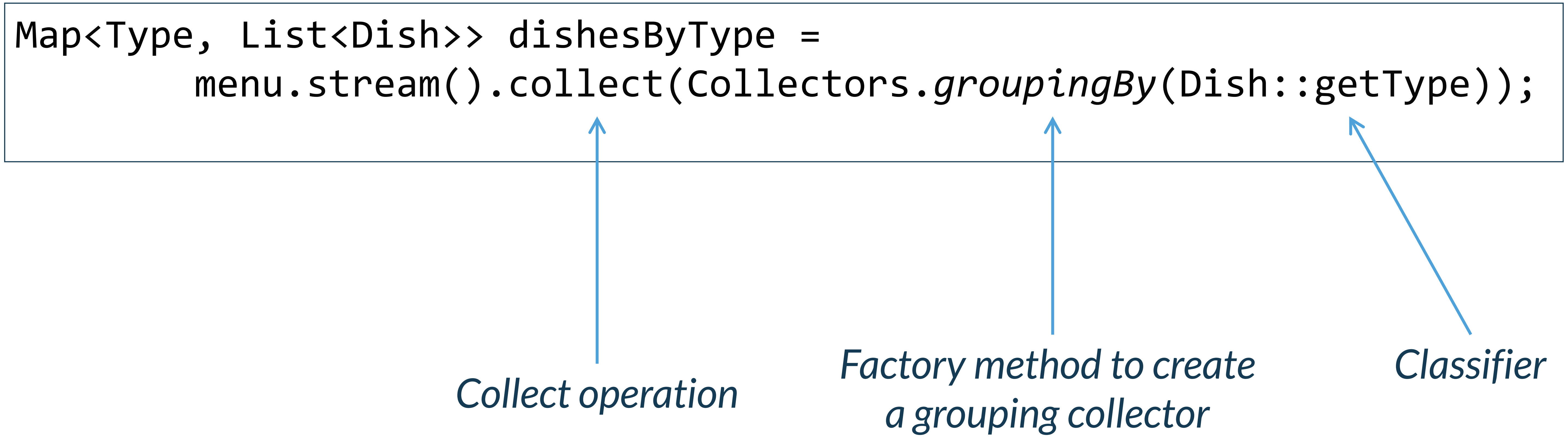
*other examples*

```
int count = books
      .stream()
      .map(x -> 1)
      .reduce(0, (x,y) -> x + y);
```

```
int totalPages = books
      .stream()
      .collect(Collectors
            .reducing(0, Book::getNumberOfPages, (x,y) -> x + y));
```

# Grouping

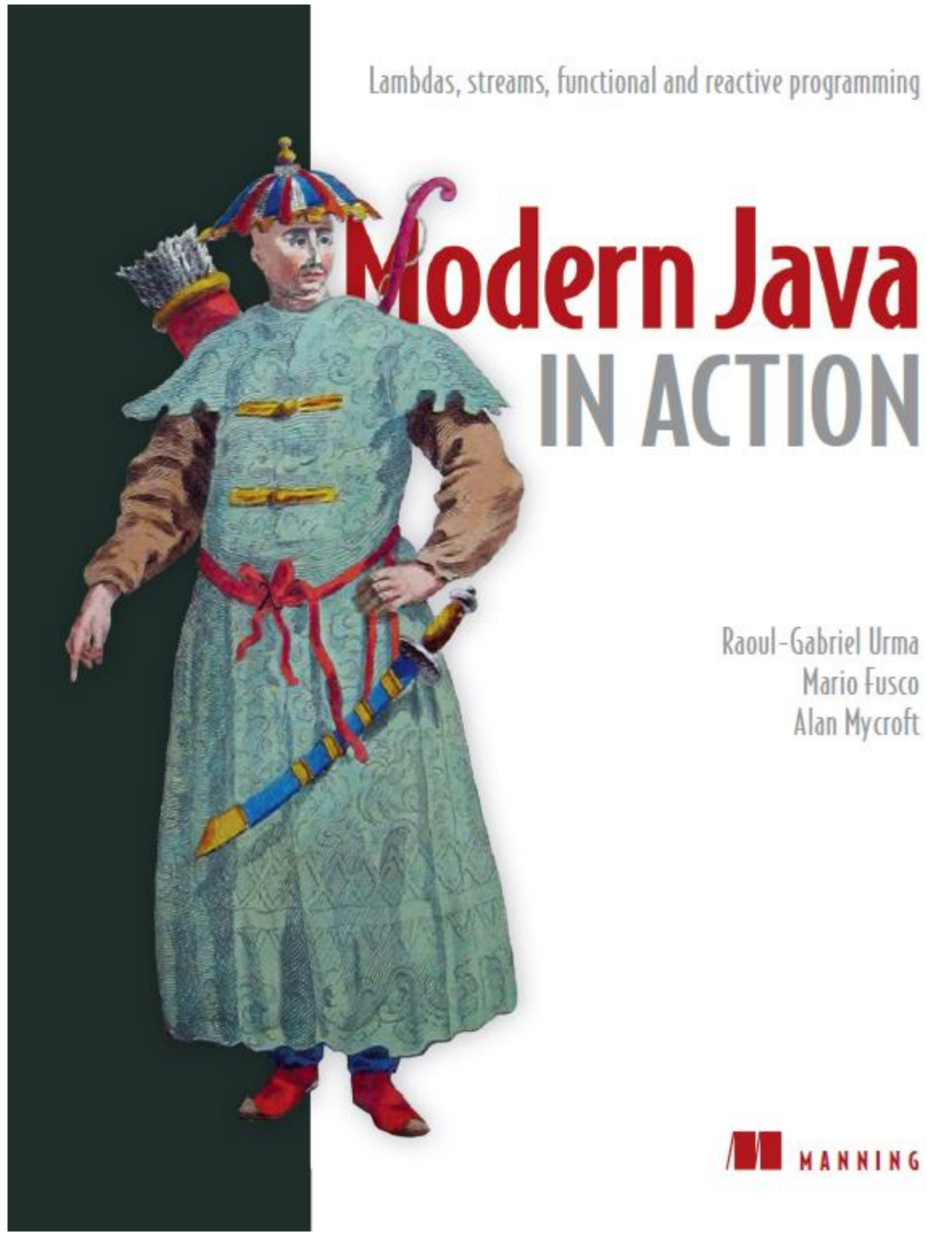
*In the collect() operation we can specify a grouping operation to classify the element of the stream in different groups*



```
Map<Type, List<Dish>> dishesByType =
        menu.stream().collect(Collectors.groupingBy(Dish::getType));
```

```
{FISH=[prawns, salmon], OTHER=[french fries, rice, season fruit,
pizza], MEAT=[pork, beef, chicken]}
```

# To know more



*Raoul-Gabriel Urma, Mario Fusco, Alan Mycroft*

*Modern Java in Action*

# Thank you!

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