Streams & Lambdas

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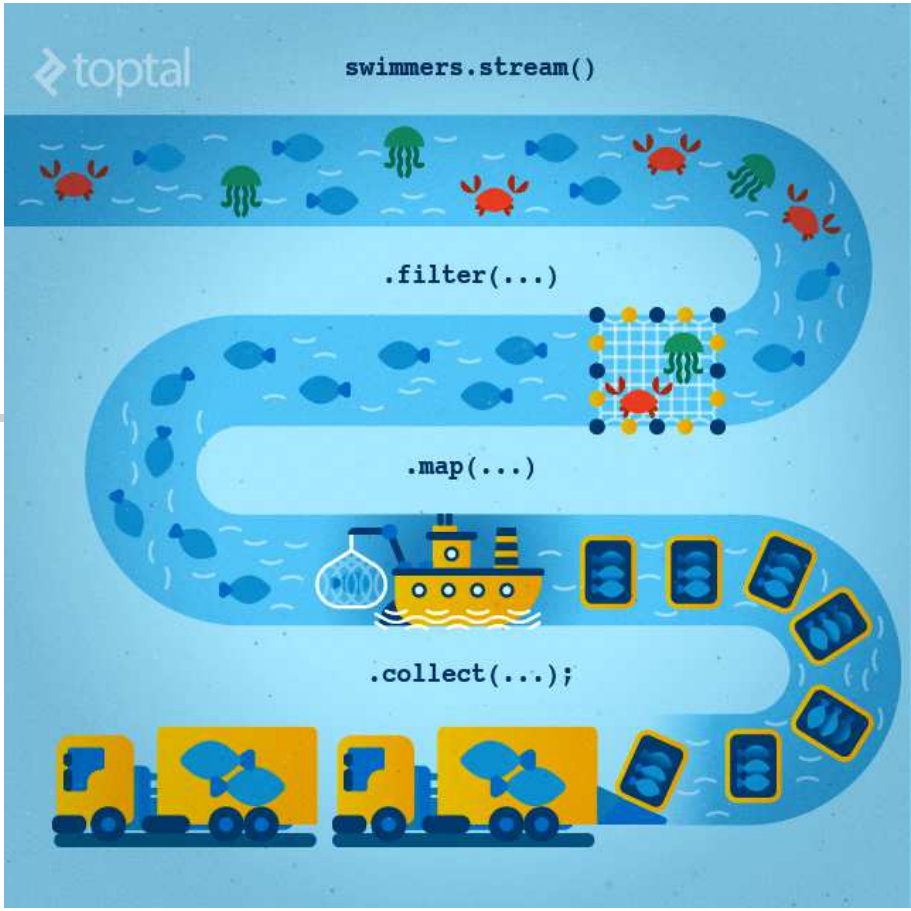
http://dai.fmph.uniba.sk/courses/JAVA/

Streams & λ's
API Java 8

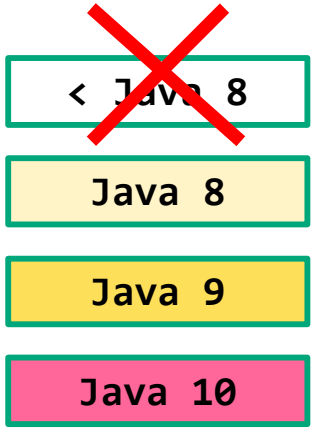


dnes bude:

- iný pohľad na prácu s kolekciami,
- ochutnávka tzv. *funkcionálneho programovania*,
- malý výlet do kombinatoriky, ako ju nepoznáte

Cvičenie:

- práca s kolekciami, Stream API

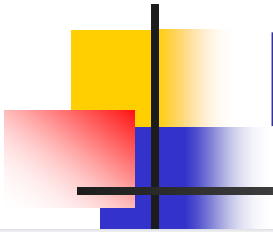


http://en.proft.me/2016/11/13/tutorial-lambda-expression-and-stream-api-java-8/

Kolekcie

(a práca s nimi – ako to poznáme)

```
List<Integer> lst = new ArrayList<Integer>();
List<Integer> lst = new ArrayList<>();
ArrayList<Integer> lst = new ArrayList<>();
for (int i = 0; i < 100; i++)
   lst.add(i);
// explicitná inicializácia
List<Integer> lst1 = Arrays.asList(0,1,2,3,4,5,6,7,8,9);
// Nová syntax Java 9
List<Integer> list = List.of(0, 1, 2, 3, 4, 5, 6, 7, 8, 9);
Set<Integer> set = Set.of(0, 1, 2, 3, 4, 5, 6, 7, 8, 9);
Map<String,Integer> map = Map.of("Jano",1, "Palo",3, "Igor",0);

for (Integer value : lst)              // foreach cyklus
   System.out.println(value);
lst.forEach(System.out::println);    // <Class name>::<method name>
lst.forEach(e -> System.out.println(e+e)); // foreach metóda
```



List interface – statický .of

`static <E> List<E>`	`of(E e1)`	Returns an immutable list containing one element.
`static <E> List<E>`	`of(E... elements)`	Returns an immutable list containing an arbitrary number of elements.
`static <E> List<E>`	`of(E e1, E e2)`	Returns an immutable list containing two elements.
`static <E> List<E>`	`of(E e1, E e2, E e3)`	Returns an immutable list containing three elements.
`static <E> List<E>`	`of(E e1, E e2, E e3, E e4)`	Returns an immutable list containing four elements.
`static <E> List<E>`	`of(E e1, E e2, E e3, E e4, E e5)`	Returns an immutable list containing five elements.
`static <E> List<E>`	`of(E e1, E e2, E e3, E e4, E e5, E e6)`	Returns an immutable list containing six elements.
`static <E> List<E>`	`of(E e1, E e2, E e3, E e4, E e5, E e6, E e7)`	Returns an immutable list containing seven elements.
`static <E> List<E>`	`of(E e1, E e2, E e3, E e4, E e5, E e6, E e7, E e8)`	Returns an immutable list containing eight elements.
`static <E> List<E>`	`of(E e1, E e2, E e3, E e4, E e5, E e6, E e7, E e8, E e9)`	Returns an immutable list containing nine elements.
`static <E> List<E>`	`of(E e1, E e2, E e3, E e4, E e5, E e6, E e7, E e8, E e9, E e10)`	Returns an immutable list containing ten elements.

```
of(E e1)

of(E... elements)
```

Otázka od Juraja

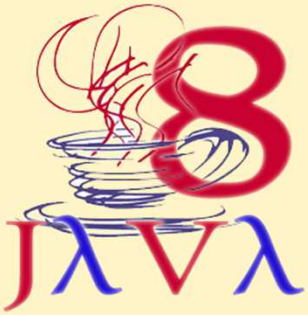
```
Set<Integer[]> set3 = Set.of(new Integer[] { 4 }, new Integer[] { 4 });
// Ideal, ale asi nie je mozne

// Workaround 1
Set<Integer[]> set5 = Set.of(new Integer[][]{{4}});
// Workaround 2
Integer[] value = {6}; Set<Integer[]> set6 = Set.of(value, value);
```

redundancia medzi `Set.of(E elements)` a `Set.of(E e1)`
takze preto toto ide (lebo tam sa `Set.of(E elements)` nechyta).

syntax **`.<typ>`**

```
Set<Integer[]> set = Set.<Integer[]>of(new Integer[] { 5 });
```

Anonymné funkcie v Jave
(lambdas)



Plná syntax pre zápis anonymnej funkcie:

```
(double a, double b) -> { return Math.sqrt(a*a+b*b); }
```

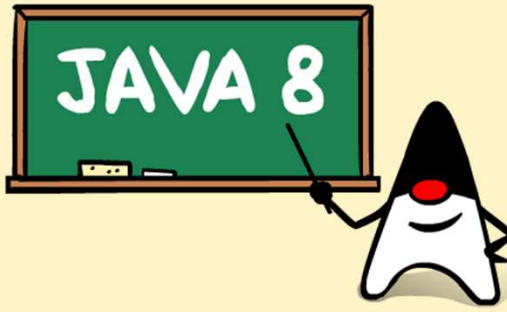
Typová inferencia parametrov
odvodenie typu bez nutnosti typ explicitne uviesť

```
(a, b) -> { return Math.sqrt(a*a+b*b); }
```

Syntax sugar, výsledkom je príjemná funkcionálna syntax:

```
(a, b) -> { Math.sqrt(a*a+b*b) }
(a, b) -> Math.sqrt(a*a+b*b)
n -> n*n
```

```
import math
fcia = lambda a,b: math.sqrt(a*a + b*b)
print(fcia(3,4))
5.0
```



Funkcionálny interface

Funkcionálnym interface je interface, ktorý má jedinú metódu

Nepovinná anotácia pre FI je @FunctionalInterface

```
@FunctionalInterface
interface BinOp { double operation(double a, double b);  }

BinOp plus = (a, b) -> a + b;
System.out.println("3 + 4 = " + plus.operation(3, 4));
```

```
3 + 4 = 7.0
```

```
BinOp vector = (double a, double b) -> {return Math.sqrt(a*a + b*b); };
BinOp vector = (a,b) -> Math.sqrt(a*a + b*b);
System.out.println("vector(3,4) = " + vector.operation(3,4));

System.out.println("vector(3,4) = "+
  ((BinOp)(a, b) -> Math.sqrt(a*a + b*b)).operation(3,4));
```

```
vector(3,4) = 5.0
```

Example.java

Jshell
(Java 9)

It's cool, just use it !

Java(TM) Platform SE binary

```
jshell>

jshell>

jshell> public class Example {
   ...>     interface BinOp { double operation(double a, double b);  }
   ...>
   ...>   public static void main(String args[]){
   ...>     BinOp plus = (a, b) -> a + b;
   ...>     BinOp vector =
   ...>  (double a, double b) -> {return Math.sqrt(a*a + b*b); };
   ...>     System.out.println("3 + 4 = " + plus.operation(3, 4));
   ...>     System.out.println("vector(3,4) = "+vector.operation(3,4));
   ...>   }
   ...> }
|  modified class Example

jshell> Example.main(null);
3 + 4 = 7.0
vector(3,4) = 5.0

jshell>
```

Funkcionálny interface

(interface a `void` metóda = procedúra)

```
@FunctionalInterface
interface FunkcionalnyInterface { // koncept funkcie v JDK8
   public void doit(String s);    // jediná "procedúra"
}

                              // metóda foo má procedúru ako argument
public static void foo(FunkcionalnyInterface fi) {
   fi.doit("hello");
}

                            // metóda goo vráti procedúru ako výsledok
public static FunkcionalnyInterface goo() {
   return (String s) -> System.out.println(s + s);
   resp.
   return s -> System.out.println(s + s);
}
```

```
foo(goo())
"hellohello"
```

Funkcie.java

Funkcionálny interface

(interface a NEvoid metóda = funkcia)


```
@FunctionalInterface
interface FunkcionalnyInterface { //String->String
   public String doit(String s);  // jediná "funkcia"
}

                                  // metóda foo má funkciu ako argument
public static String foo(FunkcionalnyInterface fi) {
   return fi.doit("hello");
}

                                  // metóda goo vráti funkciu ako výsledok
public static FunkcionalnyInterface goo() {
   return (String s)->(s+s);
   resp.
   return s->s+s;
}
```

foo(goo())
"hellohello"

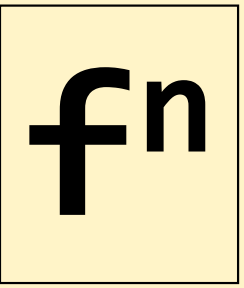
Funkcie.java

Funkcionálny interface

(interface a reálna funkcia)

$$f^n = \begin{cases} \text{identita}, & n=0 \\ f, & n=1 \\ f \circ f^{n-1} & \end{cases}$$

```
@FunctionalInterface
interface RealnaFunkcia {
   public double doit(double s);              // funkcia R->R
}
public static RealnaFunkcia iterate(int n, RealnaFunkcia f){
   if (n == 0)
        return d->d;                          // identita
   else {
        RealnaFunkcia rf = iterate(n-1, f);   // f^(n-1)
        return d->f.doit(rf.doit(d));         // d->f(rf(d))
        resp.
        return d->f.doit(iterate(n-1, f).doit(d));
   }
}
```




```
RealnaFunkcia rf = iterate(5, (double d)->d*2);
System.out.println(rf.doit(1));
```

Funkcie.java

Existujúce @FunctionalInterface

miesto doit() apply(), test()

`java.util.function.Function<T,R>` `<R> apply(<T>)` **// funkcia T -> R**

`java.util.function.Predicate<T>` `boolean test(<T>)` **// T ->boolean**

Príklady:

```
Function<Double,Double>
   celsius2Fahrenheit = x -> (x*9/5)+32,
   rad2Deg = r -> (r/Math.PI)*180;
Function<String, Integer>
   string2Int = x -> Integer.valueOf(x);
Function<Integer, String>
   int2String = x -> String.valueOf(x);
Predicate<Integer>
   odd = n -> n % 2 > 0;
Predicate<Integer>
   isSquare = n ->
            Math.pow(Math.floor(Math.sqrt(n)),2)==n;
```

```
celsius2Fahrenheit.apply(30.0) 86.0
rad2Deg.apply(Math.PI)          180

string2Int.apply("4")           4

int2String.apply(123))          "123"

odd.test(5));                   true
odd.test(4));                   false

isSquare.test(9));              true
isSquare.test(8));              false
```

Funkcie.java

Iné existujúce @FunctionalInterface

`java.lang.Runnable`	`void run()`
`java.util.concurrent.Callable<E>`	`E call() throws Exception`
`java.util.Comparator<T>`	`int compare(<T> o1, <T> o2)`

Príklady:

OLD STYLE < Java 8

```
Runnable r = new Runnable() {
    public void run() {
        // Run Forest, Run !
    };
};
ArrayList<String> l = new ArrayList<>(Arrays.asList(
  "Xenia", "Jan", "Peter", "Zora", "Pavel", "Jana"));
l.sort(new Comparator<String>() {
  @Override
  public int compare(String o1, String o2) {
    return Integer.compare(o1.length(), o2.length());
}});
```

NEW STYLE = Java 8

```
Runnable r1 = ()->{
  Run Forest, Run !
};

l.sort((o1, o2) ->
   Integer.compare(
      o1.length(),
      o2.length()));
```

Comparator

```
String[] pole = { "GULA", "cerven", "zelen", "ZALUD" };
Comparator<String> comp =
   (fst, snd)->Integer.compare(fst.length(), snd.length());
Arrays.sort(pole, comp);
```

```
GULA
zelen
ZALUD
cerven
```

```
Arrays.sort(pole,
   (fst,snd)-> fst.toUpperCase().compareTo(snd.toUpperCase()));
```

```
cerven
GULA
ZALUD
zelen
```

```
class Karta {
   int hodnota;
   String farba;   // konštruktor, gettery, settery...
   ... }
List<Karta> karty = List.of(
   new Karta(7,"Gula"), new Karta(8,"Zalud"),
   new Karta(9,"Cerven"), new Karta(10,"Zelen"));
```

```
[Gula/7, Zalud/8,
Cerven/9, Zelen/10]
```

MapFilter.java

forEach, map, filter

[Gula/7, Zalud/8, Cerven/9, Zelen/10]

```
karty.forEach(k -> k.setFarba("Cerven"));
```

[Cerven/7, Cerven/8, Cerven/9, Cerven/10]

```
Stream<Karta> vacsieKartyStream =
    karty.stream().filter(k -> k.getHodnota() > 8);
List<Karta> vacsieKarty = vacsieKartyStream.toList();
```

[Cerven/9, Cerven/10]

```
List<Karta> vacsieKarty2 = karty
    .stream()
    .filter(k -> k.getHodnota() > 8)
    .toList();
```

[Cerven/9, Cerven/10]

MapFilter.java

stream()-collect()

[Cerven/7, Cerven/8, Cerven/9, Cerven/10]

```
List<Karta> vacsieKarty3 = karty
    .stream()
    .map(k->new Karta(k.getHodnota()+1,k.getFarba()))
    .filter(k -> k.getHodnota() > 8)
    .toList();
```

[Cerven/9, Cerven/10, Cerven/11]

```
List<Karta> vacsieKarty4 = karty
    .stream()
    .parallel()
    .filter(k -> k.getHodnota() > 8)
    .sequential()
    .toList();
```

[Cerven/9, Cerven/10]

MapFilter.java

Sekvenčný a paralelný stream

IntStream je stream interface pre celočíselné hodnoty (Integer)

```
// vyrobí stream obsahujuci 0..99
Stream<Integer> stream = IntStream.range(0, 100).boxed();
```

Každá z týchto operácií prebehne `stream` a vyčerpá ho:

- `List<Integer> lst = stream.toList();`
- `System.out.println(stream.count());`
- `stream.forEach(e -> System.out.println(e+e));`
- `stream.forEach(System.out::println);`

```
100
```

preto, ak urobíte **dve** na tom istom streame, výsledná chyba je

```
Exception: stream has already been operated upon or closed
```

```
// toto už nedostaneme v poradí 0, 1, ...
stream.parallel().forEach(e -> System.out.println(e+e));
```

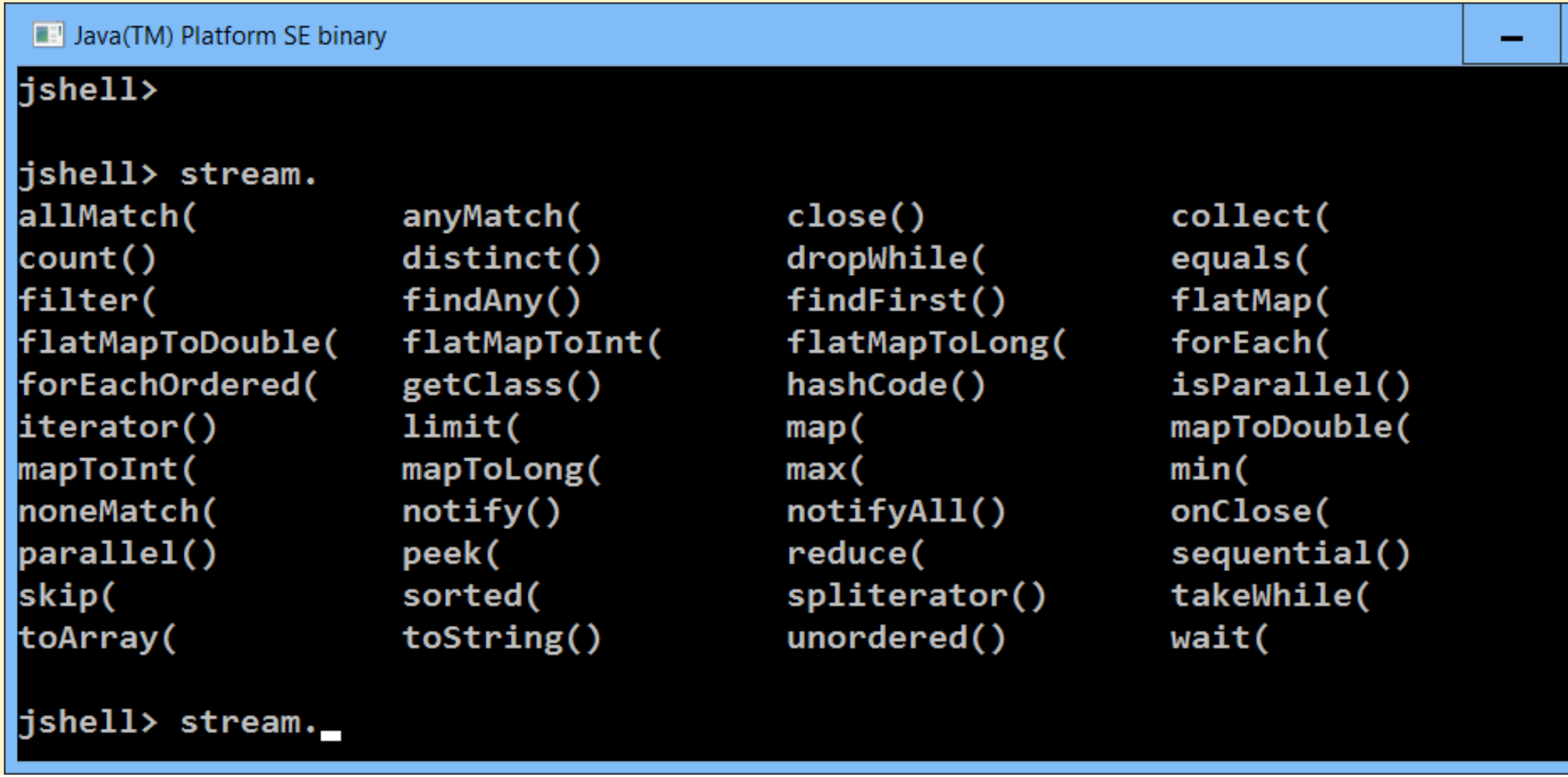
```
130
132
134
124
126
128
62
...
```

MapFilter.java

Aké metódy ma Stream

(Jshell pozná autocompletion)

- Kliknite na TAB



map/filter

(existuje/neexistuje/pre všetky)

z predošlého príkladu:
List<Integer> lst = 0, 1, … 99

```
lst.
   stream().
   filter(e -> (e % 2 == 0)).
   forEach(System.out::print);        // 024681012141618202222…
lst.
   stream().
   map(e -> e*e).
   forEach(System.out::print);        // 01491625364964 …
```

∃

```
lst.stream().anyMatch(e -> (e == 51))        // true
lst.stream().anyMatch(e -> (e * e == e))     // true
```

∄

```
lst.stream().noneMatch(e -> (e > 100))       // true
lst.stream().noneMatch(e -> (e + e == e))    // false
```

∀

```
lst.stream().allMatch(e -> e>0 )             // false
lst.stream().filter(e -> e>0 ).count()       // 99
```

MapFilter.java

Optional

(buď existuje alebo neexistuje)

```
z predošlého príkladu:
List<Integer> lst = 0, 1, … 99
```

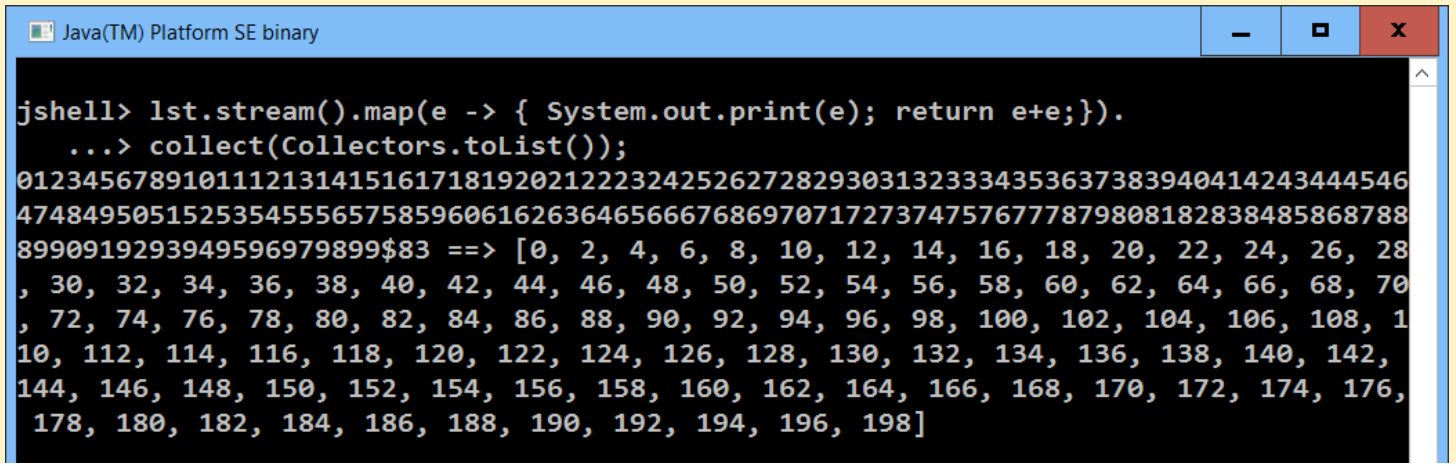
```
lst.stream().findFirst()             // Optional[0]
lst.stream().findFirst().isPresent() // true
lst.stream().findFirst().get()       // 0

lst.parallelStream().findAny().get() // 56,65,… nejednoznačné

lst.stream().min(Integer::compare).get()          // 0
lst.stream().min(Integer::compare).isPresent()    // true
lst.stream().max(Integer::compare).get()          // 99

lst.stream().map(i->i%10).sorted().forEach(System.out::print);
000000000011111111112222222223333333334444444445555555556666
666666777777777888888889999999999

lst.stream().map(i->i%10).distinct().forEach(System.out::print);
0123456789
```

MapFilter.java

Lenivosť
(laziness)

z predošlého príkladu:
List<Integer> lst = 0, 1, … 99

```
lst.stream().map(e -> { System.out.print(e); return e+e;});

lst.stream().filter(e -> {System.out.print(e);return true;});

lst.stream().map(e -> { System.out.print(e); return e+e;}).
       findFirst().get();                                    0

lst.stream().map(e -> { System.out.print(e); return e+e;}).
       toList();
```



MapFilter.java

ParallelStream
(komutatívnosť)

z predošlého príkladu:
List<Integer> lst = 0, 1, … 99

```
lst.parallelStream().
   map(e -> e+e).                          // zdvojí čísla
   filter(e -> (e % 3 > 0)).               // nedeliteľné 3
   forEach(e -> System.out.println(e))

lst.parallelStream().
   filter(e -> (e % 3 > 0)).               // nedeliteľné 3
   map(e -> e+e).                          // zdvojí čísla
   forEach(e -> System.out.println(e))

lst.parallelStream().
   map(e -> e+e).                          // zdvojí čísla
   filter(e -> (e % 3 > 0)).               // nedeliteľné 3
   collect(Collectors.toList()).size()  // koľko je výsledok
```

MapFilter.java

ParallelStream

(skladanie funkcií)

z predošlého príkladu:
List<Integer> lst = 0, 1, … 99

```
lst.parallelStream().
   map(e -> f1(e)).  // čo vieme povedať o kompozícii ?
   map(e -> f2(e)).
   toList()

lst.parallelStream().
   map(e -> f2(f1(e))).  // čo vieme povedať o kompozícii ?
   toList()

Integer f1(Integer e) { return e+e; }
Integer f2(Integer e) { return 5*e; }
```

MapFilter.java

ParallelStream

(funkcie so side-effect)

```
z predošlého príkladu:
List<Integer> lst = 0, 1, … 99
```

Funkcie poznáme *slušné* a iné:

Slušná funkcia (referenčne transparentná) vždy pre rovnaký vstup vráti rovnaký výsledok, t.j. nerobí žiaden side-effect, nepoužíva globálnu premennú, súbor, ...

Programovací jazyk je *slušný*, ak v ňom môžete písať len slušné funkcie.

Príklad (neslušný):

```
lst.parallelStream().
   map(e->funWithSideEffect(e)).
   filter(e -> (e % 3 > 0)).
   sorted().
   toList();

Integer globalVariable = 0;
Integer funWithSideEffect(Integer n) {
   return n+n + (++globalVariable);
}
```

MapFilter.java

Globálne premenné

(sú identifikovaná *smrť*)

V praxi: funkcia sa môže javiť ako slušná, a pri tom ňou nie je ... ☹

Java(TM) Platform SE binary

```
jshell> globalVariable = 0
globalVariable ==> 0

jshell> lst.parallelStream().
   ...> map(e->funWithSideEffect(e)).
   ...>    filter(e -> (e % 3 > 0)).
   ...> sorted().
   ...> collect(Collectors.toList());
$27 ==> [47, 73, 83, 112, 115, 115, 118, 118, 118, 121, 122, 122, 125, 125, 127, 127, 128, 130, 130,
5, 146, 149, 152, 166, 167, 169, 170, 172, 175, 175, 179, 179, 182, 185, 185, 194, 220, 224, 224, 232

jshell> globalVariable = 0
globalVariable ==> 0

jshell> lst.parallelStream().
   ...> map(e->funWithSideEffect(e)).
   ...>    filter(e -> (e % 3 > 0)).
   ...> sorted().
   ...> collect(Collectors.toList());
$29 ==> [34, 38, 41, 44, 46, 47, 47, 49, 50, 50, 53, 53, 100, 103, 107, 110, 113, 115, 118, 119, 119,
51, 152, 154, 154, 155, 157, 158, 158, 161, 161, 163, 163, 166, 166, 169, 169, 184, 187, 190, 202, 20
 241, 241, 242, 244]

jshell>
```

Trochu novej syntaxe
(pripomína Java collections syntax sugar JDK9)

- Stream obsahujúci pár hodnôt

```
Stream.of(0,1,2,3,4,5,6,7,9).toList()
[0, 1, 2, 3, 4, 5, 6, 7, 9]

Stream.of("Palo", "Peter", "Jano", "Jana").toList()
[Palo, Peter, Jano, Jana]
```

- Konverzia poľa na Stream

```
Arrays.stream(new Integer[]{0,1,2,3,4,5,6,7,8,9}).toList()
[0, 1, 2, 3, 4, 5, 6, 7, 9]
```

- IntStream a range

```
IntStream.range(0,100).forEach(e -> System.out.print(e));
0123456789101112131415161718192021222324…
```

MapFilter.java

mapToObj

```
IntStream.range(0,10).mapToObj(e -> (char)('@'+e)).
   forEach(System.out::print);
@ABCDEFGHI

IntStream.range(0,10).
   mapToObj(e -> IntStream.range(0, e)).
   forEach(row -> System.out.print(row.count()));
0123456789

IntStream.range(0,10).
   mapToObj(e -> IntStream.range(0, e)).
   forEach(row -> System.out.println(
                        row.boxed().toList());
```

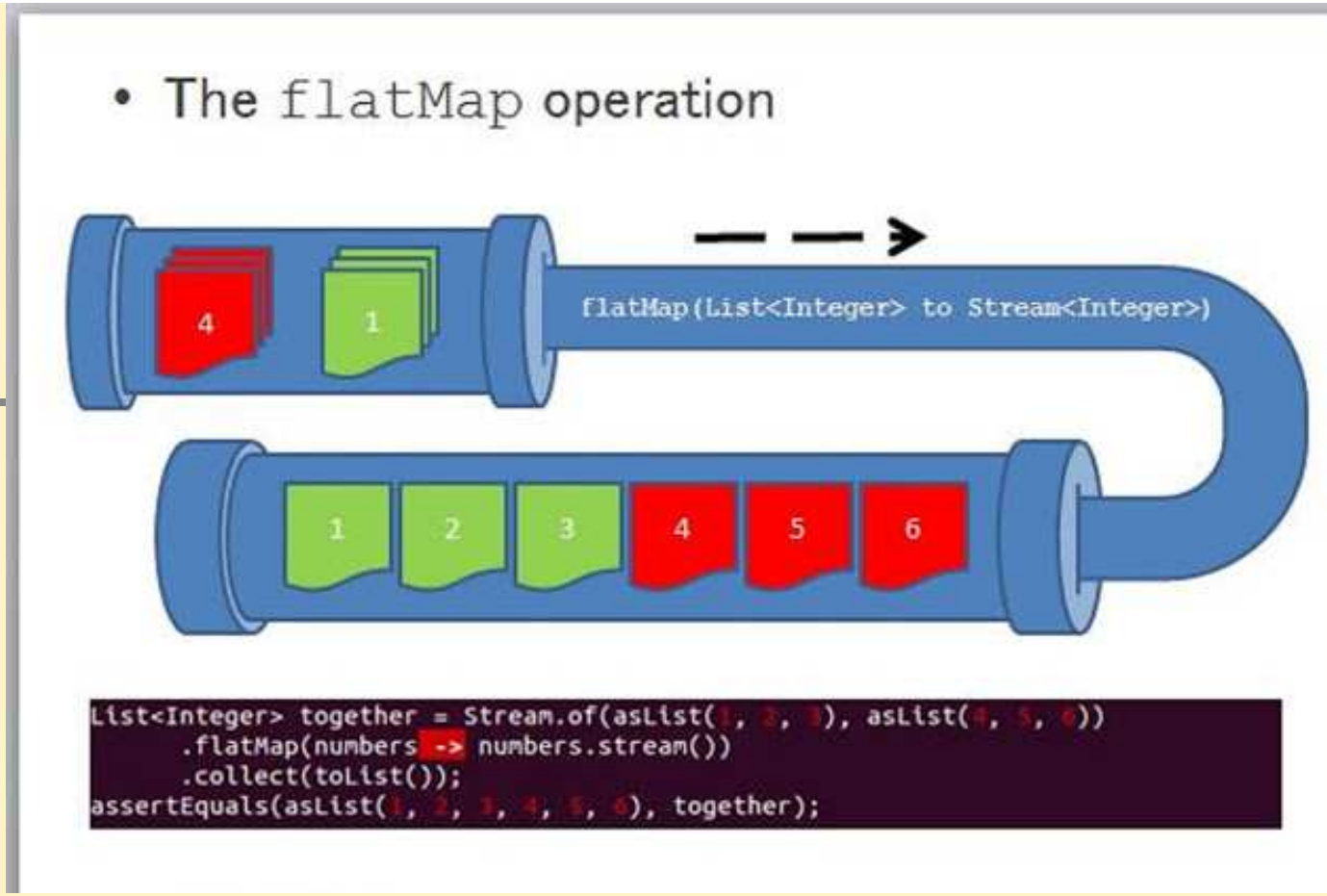
```
[]
[0]
[0, 1]
[0, 1, 2]
[0, 1, 2, 3]
[0, 1, 2, 3, 4]
[0, 1, 2, 3, 4, 5]
[0, 1, 2, 3, 4, 5, 6]
[0, 1, 2, 3, 4, 5, 6, 7]
[0, 1, 2, 3, 4, 5, 6, 7, 8]
```

Konverzie IntStream <-> Stream<Integer>

- Stream<Integer> intStream.boxed()
- IntStream stream.mapToInt(e-> …)

MapFilter.java

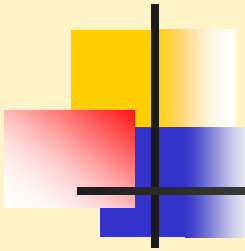
flatMap




```
List<List<String>> l2 = List.of(
                List.of("Palo", "Jana"),
                List.of("Peter", "Kamil", "Martina"));
```

```
[[Palo, Jana], [Peter, Kamil, Martina]]
l2.stream().flatMap(lst -> lst.stream()).
            toList();
[Palo, Jana, Peter, Kamil, Martina]
```

http://www.java67.com/2016/03/how-to-use-flatmap-in-java-8-stream.html



flatMap

```
IntStream.range(0,10).
   flatMap(e -> IntStream.range(0, e)).
   forEach(System.out::print);
```

```
0010120123012340123450123456012345670123456 78
```

```
IntStream.range(0,10).
   flatMap(e -> IntStream.range(0, e).
                        filter(i->i%2==0)).
   forEach(System.out::print);
```

```
000202024024024602460246 8
```

MapFilter.java

z predošlého príkladu:
List<Integer> lst = 0, 1, … 99

Collectors

(groupingBy, partitioningBy, reducing)

```
Map<Integer, List<Integer>>map = lst.parallelStream().collect(
   Collectors.groupingBy( e -> (String.valueOf(e).length()) ));
{1=[0, 1, 2, 3, 4, 5, 6, 7, 8, 9], 2=[10, 11, 12, ... , 94, 95, 96, 97, 98, 99]}

map.forEach((len, list) -> System.out.println(len + ", "+ list));
1, [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
2, [10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, …

Map<Boolean, List<Integer>>partitions = lst.parallelStream().
   collect(Collectors.partitioningBy( e-> e % 3 == 0) );
{false=[1, 2, 4, 5, 7, 8, 10, ...], true=[0, 3, 6, 9, 12, 15, 18, ...]}

Long count = lst.parallelStream().collect(
   Collectors.reducing(0L, e -> 1L, Long::sum));   // 100
Long sum = lst.parallelStream().collect(
   Collectors.reducing(0L, e -> new Long(e), Long::sum)); // 4950
int sumInt = lst.parallelStream().reduce(0, Integer::sum); //4950
```


```
z predošlého príkladu:
List<Integer> lst = 0, 1, … 99
```

Collectors

toSet, toMap

```
List<Integer> zoznam = lst.stream()
   .map(x -> x%10).collect(Collectors.toSet())
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
```

```
lst.stream().collect(Collectors.toMap(x -> x, x -> x))
{0=0, 1=1, 2=2, …, 98=98, 99=99}
```

```
lst.stream().collect(Collectors.toMap(
      x -> Integer.toBinaryString(x),    // Integer::toBinaryString,
      x -> Integer.toBinaryString(x).length()  ))
{1001111=7, 0=1, 1010001=7, 1=1, 1010000=7, 1101=4, 1100=4, …}
```

```
lst.stream().collect(Collectors.toMap( x -> x % 10, x -> x ))
Duplicate key 0 (attempted merging values 0 and 10)
```

z predošlého príkladu:
List<Integer> lst = 0, 1, … 99

Grouping

```
lst.stream().collect(Collectors.groupingBy(
                        e -> Integer.toString(e).length(),
                        Collectors.averagingInt(x->x))  )
```

```
{1=4.5, 2=54.5}
```

```
lst.stream().collect(Collectors.groupingBy(
                       e -> Integer.toString(e).length(),
                       //Collectors.maxBy((o1,o2)->Integer.compare(o1,o2)
                       Collectors.maxBy(Integer::compare)) )
```

```
{1=Optional[9], 2=Optional[99]}
```

```
lst.stream().collect(Collectors.groupingBy(
                       e -> e/10,
                       Collectors.counting()) )
```

```
{0=10, 1=10, 2=10, 3=10, 4=10, 5=10, 6=10, 7=10, 8=10, 9=10}
```

z predošlého príkladu:
List<Integer> lst = 0, 1, … 99

Reducing

```
lst.stream().reduce(0, Integer::sum)
lst.stream().reduce(0, (a,b) -> a+b)
lst.stream().mapToLong(e -> e).reduce(0L, (a, b) -> a + b)
4950

lst.stream().reduce( Integer::max)
Optional[99]

lst.stream()
        .map(x -> Integer.toString(x))
        .reduce( "vysledok",  (acc, x) -> acc+x)
vysledok0123456789101112..9899

lst.stream()
        .map(x -> Integer.toString(x))
        .reduce(  (acc, x) -> acc+x)
Optional[0123456789101112..9899]
```

Stream.iterate

```
Stream.iterate("", s -> "a"+s).limit(10).toList()
[, a, aa, aaa, aaaa, aaaaa, aaaaaa, aaaaaaa, aaaaaaaa, aaaaaaaaa]

Stream.iterate(1L, n -> 2*n).takeWhile(n -> n < 1_000_000).toList()
Stream.iterate(1L, n -> n < 1_000_000, n -> 2*n).toList()
[1, 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024, 2048, 4096, 8192, 16384, 32768, 65536, 131072, 262144, 524288]

Stream.iterate(918972645, n -> n > 0, n -> n/10).toList()
[918972645, 91897264, 9189726, 918972, 91897, 9189, 918, 91, 9]

Stream.iterate(918972645, n -> n > 0, n -> n/10).map(n -> n%10).toList()
[5, 4, 6, 2, 7, 9, 8, 1, 9]

Stream.iterate(918972645, n -> n > 0, n -> n/10)
        .map(n -> n%10)
        .reduce((a,y) -> 10*a+y)
                resp.
        .reduce(0,(a,y) -> 10*a+y)

Optional[546279819], resp. 546279819
```

z predošlého príkladu:
List<Integer> lst = 0, 1, … 99

Collectors

(rozdeliť stream na úseky, kde neplatí predikát)

```
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20
static boolean isPrime(Integer n) {
    return IntStream.range(2, 1+(int)Math.floor(Math.sqrt(n)))
                    .allMatch(i -> n % i != 0);
}
[[4], [6], [8, 9, 10], [12], [14, 15, 16], [18], [20, 21, 22], ...
int[] splitters = Stream.of(
        IntStream.of(-1),
        IntStream.range(0,lst.size()).filter(i->isPrime(lst.get(i))),
        IntStream.of(lst.size()))
     .flatMapToInt(s -> s).toArray();       //[-1, 0,1,2,3,5,7,11,13,17,19, 100]

List<List<Integer>> chunks =
  IntStream.range(0, splitters.length - 1)
    .mapToObj(i -> lst.subList(splitters[i]+1, splitters[i+1]))
    .filter(chunk -> chunk.size() > 0)
    .toList();    // [[4], [6], [8, 9, 10], [12], [14, 15, 16], [18], [20, 21, 22], ...
```

MapFilter.java

EntrySet

```
List<Student> db = List.of(
        new Student(1, "C1", 2),
        new Student(1, "C2", 1),
        new Student(1, "C3", 3),

        new Student(2, "C1", 1),
        new Student(2, "C2", 5),

        new Student(3, "C1", 1),
        new Student(3, "C2", 1),
        new Student(3, "C3", 1),

        new Student(4, "C1", 4),
        new Student(4, "C2", 3),
        new Student(4, "C3", 2)
        );
```

```
record Student(Integer studentID, String courseID, Integer grade) {}

db.stream().collect(Collectors.groupingBy(Student::studentID,
                                Collectors.averagingDouble(Student::grade)))
{1=2.0, 2=3.0, 3=1.0, 4=3.0}
-- priemery jednotlivých študentov

db.stream().collect(Collectors.groupingBy(Student::courseID,
                        Collectors.maxBy(Comparator.comparingInt(Student::grade))))
{C3=Optional[Student[studentID=1, courseID=C3, grade=3]],
 C1=Optional[Student[studentID=4, courseID=C1, grade=4]],
 C2=Optional[Student[studentID=2, courseID=C2, grade=5]]}
-- najhorší študent daného kurzu

db.stream().collect(Collectors.groupingBy(Student::courseID,
                                Collectors.averagingDouble(Student::grade)))
            .entrySet().stream()
            //.max((o1,o2) -> Double.compare(o1.getValue(), o2.getValue()))
            .max(Comparator.comparingDouble(Map.Entry::getValue))
            .get()
            .getKey()  // resp. getValue()
C2 // resp. 2.5
-- kurz s najhorším priemerom a jeho priemer
```

Binárne vektory {0,1}

(klasické riešenie)

Počet = 2^n

```
List<String> binaries(int n) {
   if (n == 0) {
        return Arrays.asList("");
   } else {
        List<String> result = new ArrayList<>();
        for (String s : binaries(n-1)) {
               result.add(s + "0");
               result.add(s + "1");
        }
        return result;
   }
}
binaries(4)
```

```
[0000, 0001, 0010, 0011, 0100, 0101, 0110, 0111, 1000, 1001, 1010, 1011, 1100, 1101, 1110, 1111]
```

Kombinatorika.java

Binárne vektory {0,1}

(streamové riešenie)

Počet = 2^n

```
Stream<String> binaries1(int n) {
   if (n == 0) {
        return Stream.of("");
   } else {
        return
               binaries1(n-1).
               flatMap(s -> Stream.of(s + "0", s + "1"));
   }
}
Stream<String> binaries1(int n) {
   return (n == 0)?Stream.of(""):
   binaries1(n-1).flatMap(s -> Stream.of(s + "0", s + "1"));
}
binaries1(4).toList()
```

```
[0000, 0001, 0010, 0011, 0100, 0101, 0110, 0111, 1000, 1001, 1010, 1011, 1100, 1101, 1110, 1111]
```

Kombinatorika.java

Permutácie

```
perms(4).toList()
[4321, 3421, 3241, 3214, 4231, 2431,
2341, 2314, 4213, 2413, 2143, 2134,
4312, 3412, 3142, 3124, 4132, 1432,
1342, 1324, 4123, 1423, 1243, 1234]
```

Počet = n!

```
Stream<String> perms(int n) {
   if (n <= 0) {
        return Stream.of("");
   } else {
        return
              perms(n-1).
              flatMap(s->IntStream.range(0, n).
                    mapToObj(i -> insert(i, n, s)) );
   }
}
String insert(int i, int n, String s) {
   return      s.substring(0,i) +
               String.valueOf(n) +
               s.substring(i, s.length());
}
```

Kombinatorika.java

Kombinácie bez opakovania

Počet = n nad k

```
Stream<String> kbo(int k, int n) {
   if (k > n) {
        return Stream.of();
   } else if (k == 0) {
        return Stream.of("");
   } else {
        return Stream.concat(          // zreťazenie dvoch streamov
               kbo(k, n-1),
               kbo(k-1, n-1).map(s -> s + String.valueOf(n-1)));
   }
}
kbo(3,6).toList()
```

```
[012, 013, 023, 123, 014, 024, 124, 034, 134, 234, 015, 025, 125, 035, 135, 235, 045, 145, 245, 345]
```

Kombinatorika.java

Kombinácie s opakovaním

Počet = (n+k-1) nad k

```
Stream<String> kso(int k, int n) {
   if (n == 0) {
        return Stream.of();
   } else if (k == 0) {
        return Stream.of("");
   } else {
        return Stream.concat(          // zreťazenie dvoch streamov
                kso(k, n-1),
                kso(k-1, n).map(s -> s + String.valueOf(n-1)));
   }
}
kso(2,6).toList()
[01, 11, 02, 12, 22, 03, 13, 23, 33, 04, 14, 24, 34, 44, 05, 15, 25, 35, 45, 55]
```

Kombinatorika.java

Variácie s opakovaním

Počet = k^n

```
static Stream<String> vso(int n, int k) {
   if (n == 0) {
      return Stream.of("");
   } else {
      return vso(n-1, k)
             .flatMap(s -> IntStream.range(0, k)
                    .mapToObj(i -> s + String.valueOf(i)) );
   }
}
```

Kombinatorika.java

Variácie bez opakovania

Počet = n(n-1)…(n-k+1)

```
Stream<String> vbo(int k, int n) {
    if (k > n) {
        return Stream.of();
    } else if (k == 0) {
        return Stream.of("");
    } else {
        return Stream.concat(
                vbo(k, n-1),
                vbo(k-1, n-1).
                flatMap(s -> IntStream.range(0, k).
                        mapToObj(i -> insert(i, n-1, s))));
    }
}
vbo(3,4).toList()
```

```
[210, 120, 102, 201, 021, 012, 310, 130, 103, 301, 031, 013, 320, 230, 203, 302, 032, 023, 321,
    231, 213, 312, 132, 123]
```

Kombinatorika.java

Bonmot

Ak by vám (v 1.semestri) neprezradili priradenie (=) a cyklus (for/while),

tak tu máme spústu šikovných funkcionálnych programátorov...