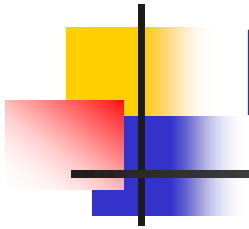
Streams & Lambdas

Peter Borovanský
KAI, I-18

borovan 'at' ii.fmph.uniba.sk
http://dai.fmph.uniba.sk/courses/JAVA/

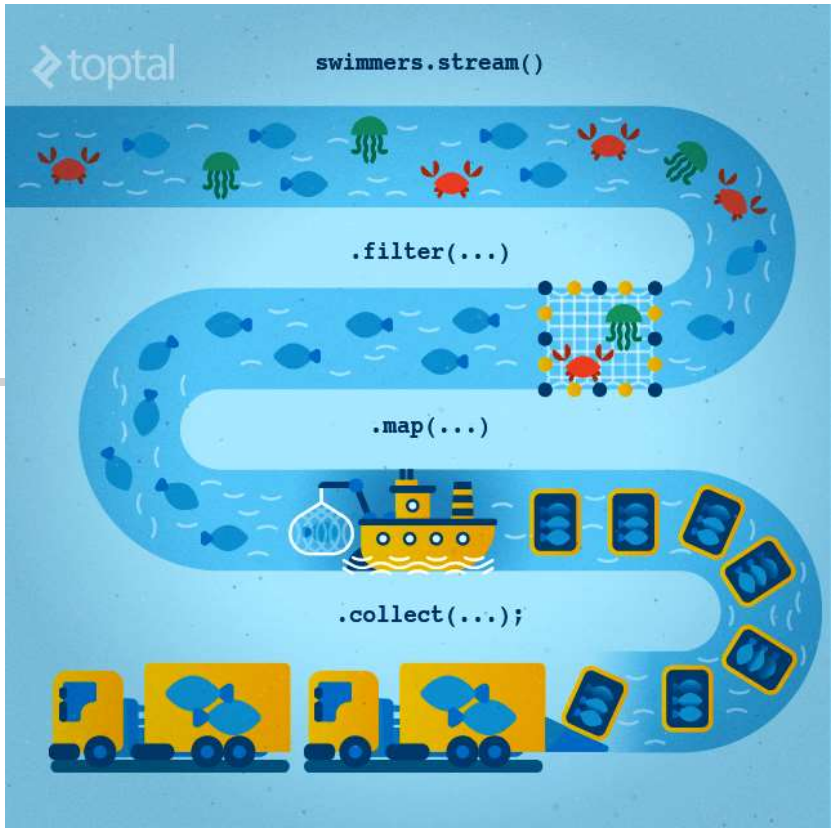


Harmonogram

- Zajtra, 1.4. Quadterm, 9:40-11:20
  - Príklady zverejním 9:30 a **čítajte** si zadania **skôr než** sa pustíte do **kódenia**. 10 min. na otázky, online/chat, rozmyslenie si, stratégie urobí divy ...
- DU7 – Lambdas tradične piatok 2.4.
- CV7 – Lambdas bude až o týždeň 8.4.
- 1.apríl ☺

Streams & λ's

API Java 8

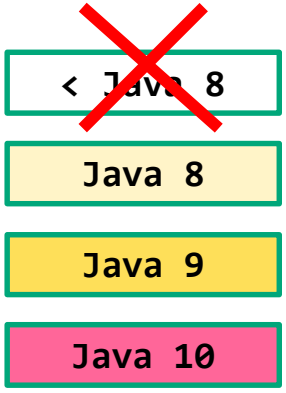


dnes bude:

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

Cvičenie:

- ~~práca s kolekciami~~ Quadterm



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.

Anonymné funkcie v Jave
(lambdas)

Plná syntax pre zápis anonymnej funkcie:

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

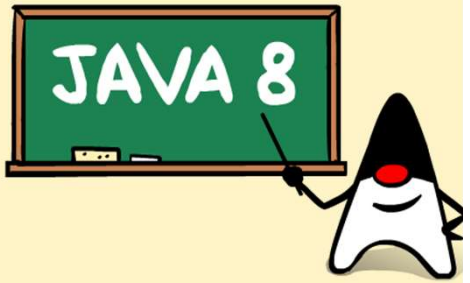
Typová inferencia parametrov
odvodenie typu bez nutnosti typ explicitne uviesť

```
(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"

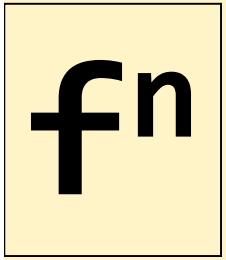
Funkcie.java

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**

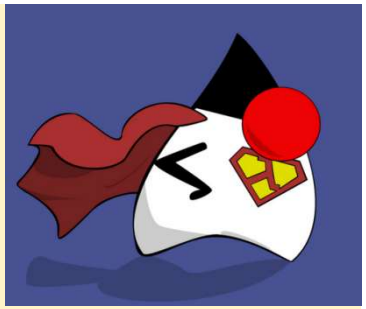
Príklady:

```
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()));
```

Funkcie.java

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.collect(Collectors.toList());
```

```
[Cerven/9, Cerven/10]
```

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

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

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

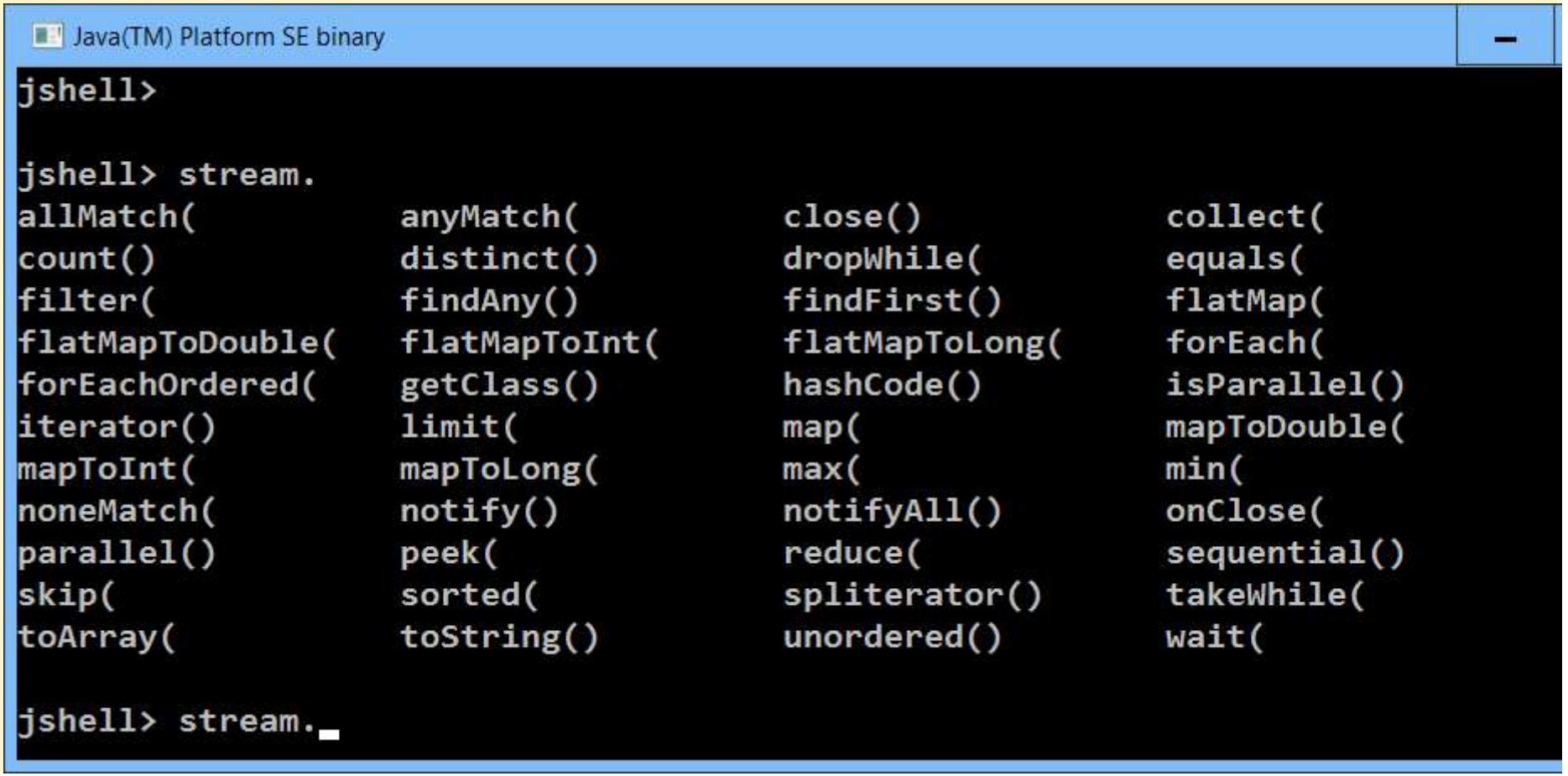
```
130
132
134
124
126
128
62
...
```

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
```

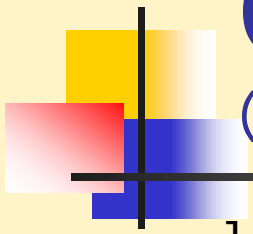
∄

```
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

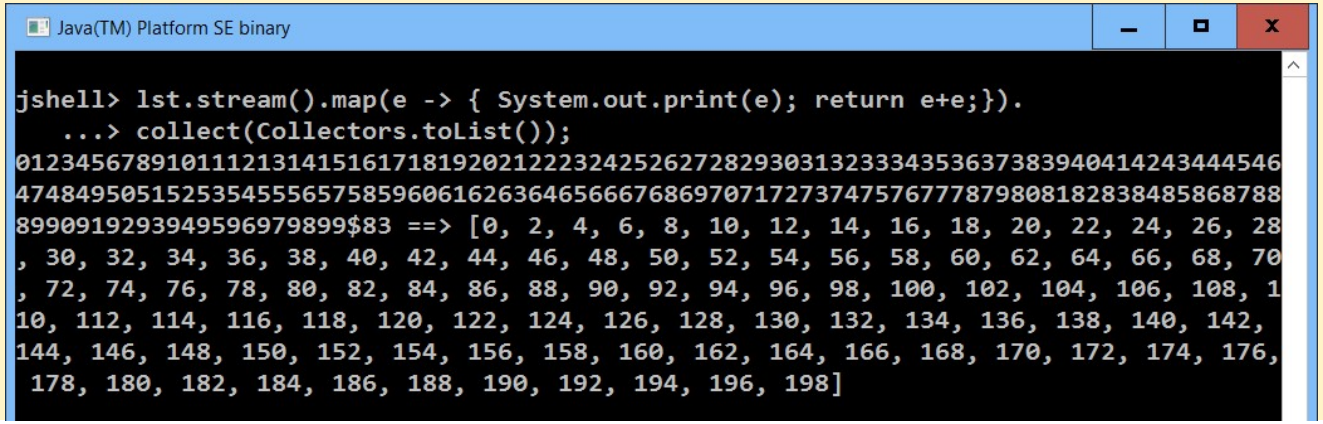
```
lst.stream().findFirst()              // Optional[0]
lst.stream().findFirst().isPresent() // true
lst.stream().findFirst().get()        // 0

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);
0000000001111111112222222223333333334444444445555555556666
6666677777777778888888889999999999

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;}).
       collect(Collectors.toList());
```



MapFilter.java

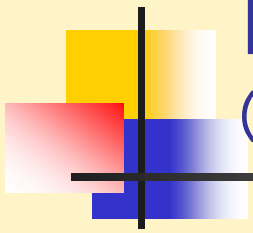
ParallelStream

(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



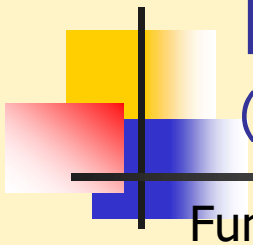
ParallelStream

(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)).
   collect(Collectors.toList())

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

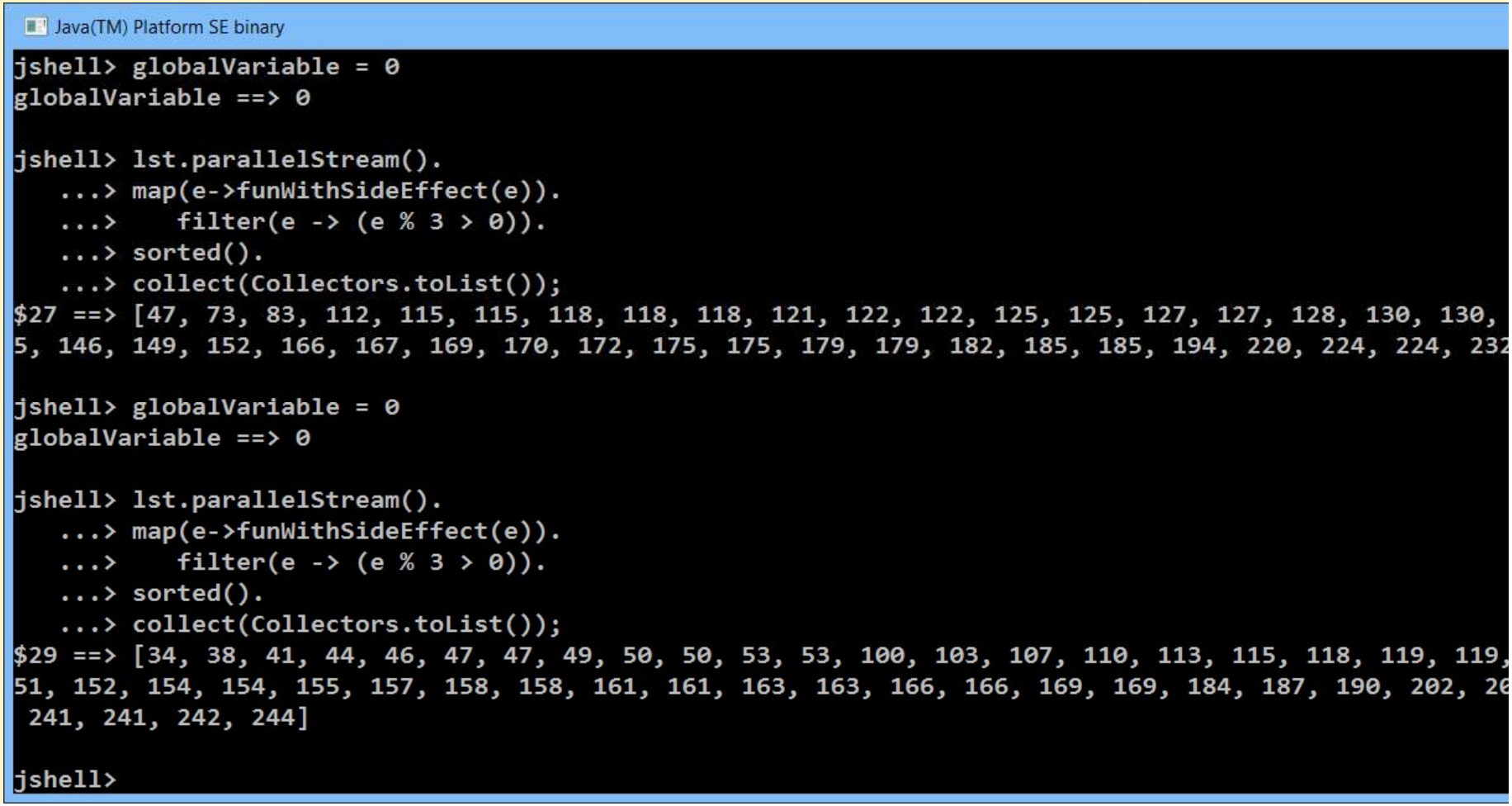
```
lst.parallelStream().
   map(e->funWithSideEffect(e)).
   filter(e -> (e % 3 > 0)).
   sorted().
   collect(Collectors.toList());

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

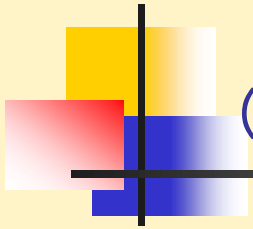
MapFilter.java

Globálne premenné

(sú identifikovaná *smrť*)

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





Trochu novej syntaxe

(pripomína Java collections syntax sugar JDK9)

- Stream obsahujúci pár hodnôť

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

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

- Konverzia poľa na Stream

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

- IntStream a range

```
IntStream.range(0,100).forEach(e -> System.out.print(e));
012345678910111213141516171819202122232 4…
```

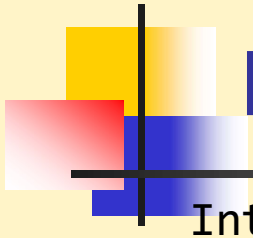
MapFilter.java

```
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
```



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().collect(Collectors.toList())));
```

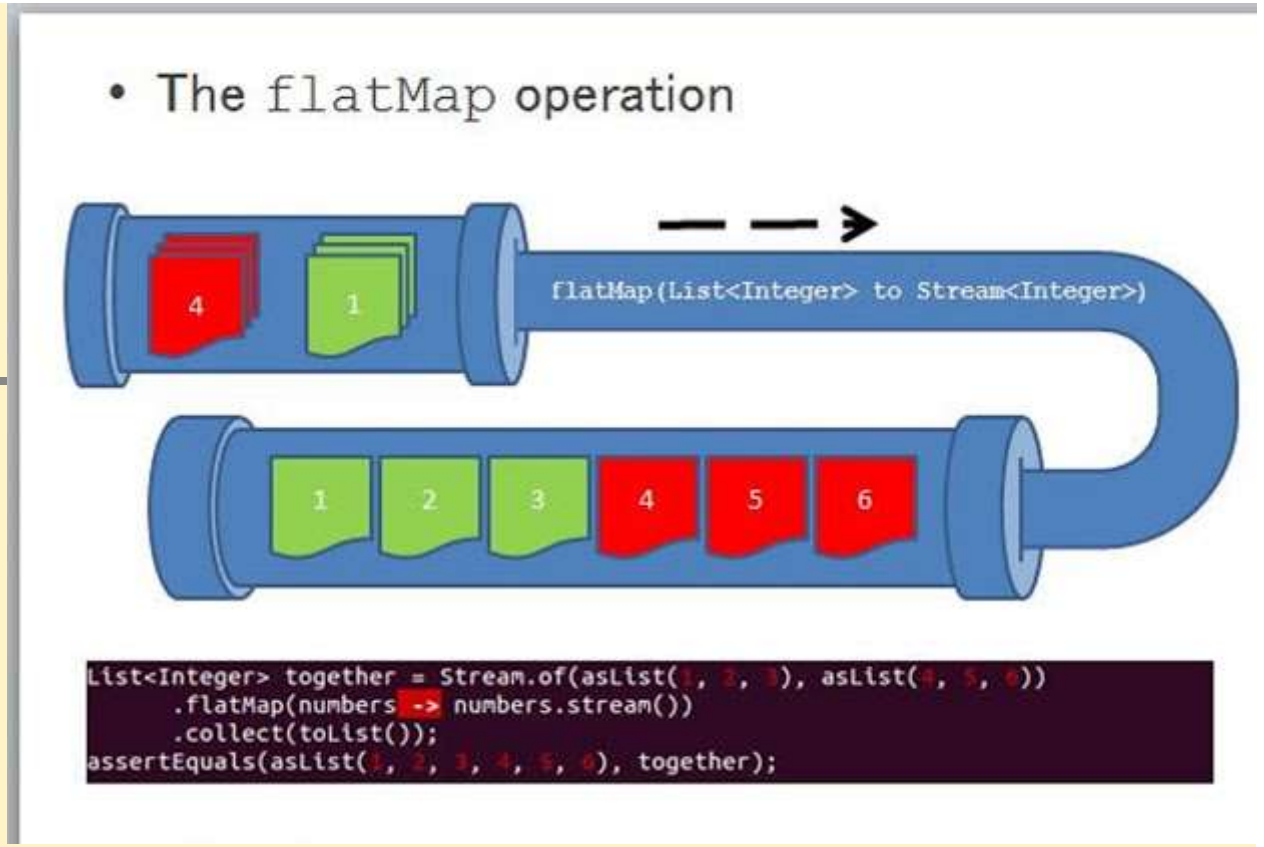
```
[]
[0]
[0, 1]
[0, 1, 2]
[0, 1, 2, 3]
[0, 1, 2, 3, 4]
[0, 1, 2, 3, 4, 5]
[0, 1, 2, 3, 4, 5, 6]
[0, 1, 2, 3, 4, 5, 6, 7]
[0, 1, 2, 3, 4, 5, 6, 7, 8]
```

Konverzie IntStream <-> Stream<Integer>

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

MapFilter.java

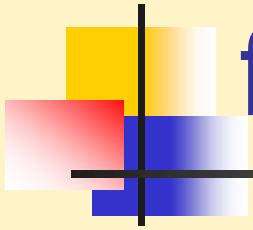
flatMap




```
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()).
            collect(Collectors.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

(rozdeliť stream na úseky, kde platí 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( //[-1, 0,1,2,3,5,7,11,13,17,19, 100]
    IntStream.of(-1),
    IntStream.range(0,lst.size()).filter(i->isPrime(lst.get(i))),
    IntStream.of(lst.size()))
  .flatMapToInt(s -> s).toArray();
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)
  .collect(Collectors.toList());
```

MapFilter.java

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).collect(Collectors.toList())
[0000, 0001, 0010, 0011, 0100, 0101, 0110, 0111, 1000, 1001, 1010, 1011, 1100, 1101, 1110, 1111]
```

Kombinatorika.java

Permutácie

```
perms(4).collect(Collectors.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).collect(Collectors.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).collect(Collectors.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 = n^k

```
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).collect(Collectors.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...